kaspersky

KasperskyOS Community Edition 1.2

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What's new

KasperskyOS Community Edition 1.2 has the following new capabilities and refinements:

> Due to modifications made to SDK components, you must make changes to application code that was developed using KasperskyOS Community Edition version 1.1.1 before using that code with KasperskyOS Community Edition version 1.2. For more details, refer to Migrating application code from version 1.1.1 to version 1.2.

- Updated system requirements: the Ubuntu GNU/Linux 22.04 "Jammy Jellyfish" operating system is required for SDK installation.
- Added capability to use dynamic libraries.
- Added capability to use a hardware watchdog on the Raspberry Pi 4 Model B.
- Added ExecutionManager component designed for creating, starting, and stopping processes.
- Added script for automatically setting environment variables used by SDK tools.
- Added data transmission to Kaspersky servers when starting a build of examples from the SDK. Data is transmitted to account for the number of users of KasperskyOS Community Edition and to obtain information about the distribution and use of KasperskyOS Community Edition. You can disable this functionality.
- Updated Developer's Guide, including:
  - Added section titled "Working with an IPC message arena".
  - Added section titled "Information about certain limits set in the system".
  - Added descriptions of scenarios for working with libkos library interfaces.
  - Updated instructions on building and running solution security policy tests.
  - Added glossary.
- Added the following third-party libraries and applications:
  - Guidelines Support Library (GSL) (2.1.0)
  - json_scheme_validator (2.1.0)
  - libpcap (1.10.4)
  - libunwind (1.6.2)
- Updated the following third-party libraries and applications:
  - libxml2
  - Mbedtls
  - Mosquitto

    - OpenSSL
    - spdlog
    - sqlite
    - fmt
    - zlib
    - flex
    - bison
    - QEMU
- Excluded the following third-party libraries and applications from the SDK:
    - ffmpeg
    - opencv
    - libjpeg-turbo
    - libpng
    - protobuf

KasperskyOS Community Edition 1.1.1 has the following new capabilities and refinements:

- Updated the following third-party libraries and applications:
    - FFmpeg
    - libxml2
    - Eclipse Mosquitto
    - opencv
    - OpenSSL
    - protobuf
    - sqlite
    - usb
- Added support for the Raspberry Pi 4 Model B hardware platform (Revision 1.5).

KasperskyOS Community Edition 1.1 has the following new capabilities and refinements:

- Added support for working with an I2C bus in master device mode.

- Added support for working with an SPI bus in master device mode.
- Added support for USB HID devices.
- Added support for Symmetric Multiprocessing (SMP).
- Expanded capabilities for device profiling: added iperf library and counters that track system parameters.
- Added PCRE library and usage example.
- Added SPDLOG library and usage example.
- Added MessageBus component and usage example.
- Added dynamic code analysis tools (ASAN, UBSAN).

KasperskyOS Community Edition 1.0 has the following new capabilities and refinements:

- Added support for the Raspberry Pi 4 Model B hardware platform.
- Added SD card support for the Raspberry Pi 4 Model B hardware platform.
- Added Ethernet support for the Raspberry Pi 4 Model B hardware platform.
- Added GPIO port support for the Raspberry Pi 4 Model B hardware platform.
- Added network services for DHCP, DNS, and NTP and usage examples.
- Added library for working with the MQTT protocol and usage examples.

About KasperskyOS Community Edition

KasperskyOS Community Edition (CE) is a publicly available version of KasperskyOS that is designed to help you master the main principles of application development under KasperskyOS. KasperskyOS Community Edition will let you see how the concepts rooted in KasperskyOS actually work in practical applications. KasperskyOS Community Edition includes sample applications with source code, detailed explanations, and instructions and tools for building applications.

KasperskyOS Community Edition will help you:

- Learn the principles and techniques of "secure by design" development based on practical examples.
- Explore KasperskyOS as a potential platform for implementing your own projects.
- Make prototypes of solutions (primarily Embedded/IoT) based on KasperskyOS.
- Port applications/components to KasperskyOS.
- Explore security issues in software development.

KasperskyOS Community Edition lets you develop applications in the C and C++ languages. For more details about setting up the development environment, see "Configuring the development environment".

You can download KasperskyOS Community Edition here.

In addition to this documentation, we also recommend that you explore the materials provided in the specific KasperskyOS website section for developers.

About this Guide

The KasperskyOS Community Edition Developer's Guide is intended for specialists involved in the development of secure solutions based on KasperskyOS.

The Guide is designed for specialists who know the C/C++ programming languages, have experience developing for POSIX-compatible systems, and are familiar with GNU Binary Utilities (binutils).

You can use the information in this Guide to:

- Install and remove KasperskyOS Community Edition.
- Use KasperskyOS Community Edition.

Distribution kit

The KasperskyOS SDK is a set of software tools for creating KasperskyOS-based solutions.

The distribution kit of KasperskyOS Community Edition includes the following:

- DEB package for installation of KasperskyOS Community Edition, including:
  - Image of the KasperskyOS kernel

    - Development tools (GCC compiler, LD linker, binutils toolset, QEMU emulator, and accompanying tools)
    - Utilities and scripts (for example, source code generators, `makekss` script for creating the Kaspersky Security Module, and `makeimg` script for creating the solution image)
    - A set of libraries that provide partial compatibility with the POSIX standard
    - Drivers
    - System programs (for example, virtual file system)
    - Usage examples for components of KasperskyOS Community Edition
    - End User License Agreement
    - Information about third-party code (Legal Notices)
- KasperskyOS Community Edition Developer's Guide (Online Help)
- Release Notes

The KasperskyOS SDK is installed to a computer running the Ubuntu GNU/Linux® operating system.

The following components included in the KasperskyOS Community Edition distribution kit are the Runtime Components as defined by the terms of the License Agreement:

- Image of the KasperskyOS kernel.

All the other components of the distribution kit are not the Runtime Components. Terms and conditions of the use of each component can be additionally defined in the section "Information about third-party code".

System requirements

To install KasperskyOS Community Edition and run examples on QEMU, the following is required:

1. **Operating system:** Ubuntu GNU/Linux 22.04 (Jammy Jellyfish). A Docker container can be used.
2. **Processor:** x86-64 architecture (support for hardware virtualization is required for higher performance).
3. **RAM**: it is recommended to have at least 4 GB of RAM for convenient use of the build tools.
4. **Disk space**: at least 3 GB of free space in the `/opt` folder (depending on the solution being developed).

To run examples on the Raspberry Pi hardware platform, the following is required:

- Raspberry Pi 4 Model B (Revision 1.1, 1.2, 1.4, 1.5) with 2, 4, or 8 GB of RAM
- MicroSD card with at least 2 GB
- USB-UART converter

Included third-party libraries and applications

To simplify the application development process, KasperskyOS Community Edition also includes the following third-party libraries and applications:

- **flex (v.2.6.2)** is a lexical analyzer generator.

  Documentation: https://github.com/westes/flex

- **pkg-config-lite (v.0.28)** is a tool that provides an interface for getting information about the libraries installed in the system (such as the version and parameters for the C/C ++ compiler and linker).

  Documentation: https://sourceforge.net/projects/pkgconfiglite

- **CMake (v.3.25.0)** is a cross-platform software tool that automatically builds software from source code.

  Documentation: https://cmake.org/documentation

- **autoconf-archive (v.2022.09.03)** is a set of macros for the Autoconf tool, which creates configuration scripts for automatically configuring and building software from source code.

  Documentation: https://www.gnu.org/software/autoconf-archive

- **Automake (v.1.13 and v.1.16.4)** is a tool that generates standard `Makefile.in` files for automatically configuring and building software from source code.

  Documentation: https://www.gnu.org/software/automake

- **Autoconf (v.2.69)** is a tool that generates `configure` scripts for automatically configuring and building software from source code.

  Documentation: https://www.gnu.org/software/autoconf

- **autotools-wrappers (v.am-10)** is a wrapper for the Autoconf and Automake tools that determines which installed version of a tool is suitable for automatically configuring and building software.

  Documentation: https://gitweb.gentoo.org/proj/autotools-wrappers.git/tree

- **Libtool (v.2.4.2)** is a generic library support script that conceals the complexity of using shared libraries behind a consistent, portable interface.

  Documentation: https://www.gnu.org/software/libtool

- **Binutils (v.2.38)** is a set of tools for working with binary files that includes an assembler, linker, archiver, and other tools.

  Documentation: https://www.gnu.org/software/binutils

- **Bison (v.3.5.4)** is a general-purpose syntax analyzer generator that converts an annotated context-free grammar into an LR or GLR parser employing LALR(1) parser tables.

  Documentation: https://www.gnu.org/software/bison

- **GNU Compiler Collection (GCC) (v.9.2.1)** is a set of compilers for various programming languages, including C and C ++.

  Documentation: https://gcc.gnu.org/onlinedocs

- **QEMU (v.8.1.3)** is a program that emulates hardware of various platforms.

  Documentation: https://www.qemu.org/docs/master

- **Automated Testing Framework (ATF) (v.0.20)** is a set of libraries for writing tests for programs in C, C++ and POSIX shell.

  Documentation: https://github.com/jmmv/atf

- **Boost (v.1.78.0)** is a set of class libraries that utilize C++ language functionality and provide a convenient cross-platform, high-level interface for concise coding of various everyday programming subtasks (such as working with data, algorithms, files, threads, and more).

  Documentation: https://www.boost.org/doc

- **nlohmann_json (v.3.9.1)** is the library for working with JSON format.

  Documentation: https://github.com/nlohmann/json

- **Civetweb (v.1.11)** is an easy-to-use, powerful, embeddable web server based on C/C++ with additional support for CGI, SSL and Lua.

  Documentation: http://civetweb.github.io/civetweb/UserManual.html

- **fmt (v.9.1.0)** is an open-source formatting library.

  Documentation: https://fmt.dev/latest/index.html

- **Guidelines Support Library (GSL) (v.2.1.0)** is a library containing functions and types that are suggested for use by the C++ Core Guidelines maintained by the Standard C++ Foundation.

  Documentation: https://github.com/microsoft/gsl

- **GoogleTest (v.1.10.0)** is a C++ code testing library.

  Documentation: https://google.github.io/googletest

- **iperf (v.3.10.1)** is a network performance testing library.

  Documentation: https://software.es.net/iperf

- **json-schema-validator (v.2.1.0)** is a library designed for validating data in JSON format according to defined JSON schemas.

  Documentation: https://github.com/pboettch/json-schema-validator

- **libffi (v.3.2.1)** is a library providing a C interface for calling previously compiled code.

  Documentation: https://github.com/libffi/libffi

- **jsoncpp (v.1.9.4)** is a library for working with JSON format.

  Documentation: https://github.com/open-source-parsers/jsoncpp

- **libpcap (v.1.10.4)** is a library for developing programs that can capture, filter, and analyze network traffic in UNIX-like systems.

  Documentation: https://www.tcpdump.org/index.html#documentation

- **libunwind (v.1.6.2)** is a library for handling exceptional situations and implementing a mechanism for backtracing the stack of function calls when a process crashes.

  Documentation: https://www.nongnu.org/libunwind/docs.html

- **libxml2 (v.2.10.4)** is a library for working with XML.

  Documentation: http://xmlsoft.org

- **Mbed TLS (v.3.3.0)** is a library that implements cryptographic protocols such as TLS/SSL and DTLS, and algorithms for encryption, hashing, and authentication.

  Documentation: https://mbed-tls.readthedocs.io/en/latest

- **Eclipse Mosquitto (v2.0.18)** is a message broker that implements the MQTT protocol.

  Documentation: https://mosquitto.org/documentation

- **jsoncpp (v.4.2.8P15)** is a library for working with the NTP time protocol.

  Documentation: http://www.ntp.org/documentation.html

- **OpenSSL (v.1.1.1t)** is a full-fledged open-source encryption library.

  Documentation: https://www.openssl.org/docs/

- **pcre (v.8.44)** is a library for working with regular expressions.

  Documentation: https://www.pcre.org/current/doc/html

- **spdlog (v.1.11.0)** is a logging library.

  Documentation: https://github.com/gabime/spdlog

- **sqlite (v.3.41.2)** is a library for working with databases.

  Documentation: https://www.sqlite.org/docs.html

- **Zlib (v.1.2.13)** is the data compression library.

  Documentation: https://zlib.net/manual.html

- **usb (v.13.0.0)** is a library for working with USB devices.

  Documentation: https://github.com/freebsd/freebsd-src/tree/release/13.0.0/sys/dev/usb

- **libevdev (v.1.6.0)** is a library for working with evdev peripheral devices.

  Documentation: https://www.freedesktop.org/software/libevdev/doc/latest

- **dhcpcd (v.9.4.1)** is a DHCP/DHCPv6 client intended for automatic configuration of network settings on the client side.

  Documentation: https://github.com/NetworkConfiguration/dhcpcd

- **Lwext4 (v.1.0.0)** is a library for working with the ext2/3/4 file systems.

  Documentation: https://github.com/gkostka/lwext4.git

See also Information about third-party code.

Limitations and known issues

Because the KasperskyOS Community Edition is intended for educational purposes only, it includes several limitations:

1. The maximum supported number of running programs is 32.
2. When a program is terminated through any method (for example, "return" from the main thread), the resources allocated by the program are not released, and the program goes to sleep. Programs cannot be started repeatedly.
3. You cannot start two or more programs that have the same EDL description.
4. The system stops if no running programs remain, or if one of the driver program threads has been terminated, whether normally or abnormally.
5. When running examples on the Raspberry Pi 4 Model B hardware platform, the maximum size of the solution image (kos-image file) must not exceed 248 MB.

Migrating application code from SDK version 1.1.1 to SDK version 1.2

Due to modifications made to SDK components in version 1.2, you must make changes to application code that was developed using KasperskyOS Community Edition version 1.1.1 before using that code with KasperskyOS Community Edition version 1.2.

Required changes:

1. The SDK now includes a driver for working with the VideoCore (VC6) coprocessor via mailbox technology: `kl.drivers.Bcm2711MboxArmToVc`. The `kl.drivers.DNetSrv` and `kl.drivers.USB` drivers require access to this new driver.

   - If the `init.yaml.in` template is used to create the solution init description (`init.yaml` file) and the `@INIT_ProgramName_ENTITY_CONNECTIONS+@` or `@INIT_ProgramName_ENTITY_CONNECTIONS@` macros were used for the `kl.drivers.DNetSrv` and `kl.drivers.USB` processes, no changes to the init description are required.

     Otherwise, if IPC channels for the `kl.drivers.DNetSrv` and `kl.drivers.USB` processes are manually specified, you must add the `kl.drivers.Bcm2711MboxArmToVc` process to the init description and define the IPC channels between it and the `kl.drivers.DNetSrv` and `kl.drivers.USB` processes:

```
- name: kl.drivers.Bcm2711MboxArmToVc
  path: bcm2711_mbox_arm2vc_h

- name: kl.drivers.USB
  path: usb
  connections:
  ...
  - target: kl.drivers.Bcm2711MboxArmToVc
    id: kl.drivers.Bcm2711MboxArmToVc

- name: kl.drivers.DNetSrv
  path: dnet_entity
  connections:
  ...
  - target: kl.drivers.Bcm2711MboxArmToVc
    id: kl.drivers.Bcm2711MboxArmToVc
```

   - You must add the `kl.drivers.Bcm2711MboxArmToVc` process to the `security.psl` file and allow the `kl.drivers.DNetSrv` and `kl.drivers.USB` processes and the kernel to interact with it:

```
...
use kl.drivers.Bcm2711MboxArmToVc._

...

execute src = Einit dst = kl.drivers.Bcm2711MboxArmToVc  { grant () }

request src = kl.drivers.Bcm2711MboxArmToVc dst = kl.core.Core  { grant () }
response src = kl.core.Core dst = kl.drivers.Bcm2711MboxArmToVc { grant () }

request src = kl.drivers.DNetSrv dst = kl.drivers.Bcm2711MboxArmToVc  { grant () }
response src = kl.drivers.Bcm2711MboxArmToVc dst = kl.drivers.DNetSrv { grant () }
```

```
request src = kl.drivers.USB dst = kl.drivers.Bcm2711MboxArmToVc  { grant () }
response src = kl.drivers.Bcm2711MboxArmToVc dst = kl.drivers.USB{ grant () }
```

2. All implementations of the VFS component now require access to the `kl.EntropyEntity` program.

   - If the `init.yaml.in` template is used to create the solution init description (`init.yaml` file) and the `@INIT_ProgramName_ENTITY_CONNECTIONS+@` or `@INIT_ProgramName_ENTITY_CONNECTIONS@` macros were used for processes that use the VFS component (the `kl.VfsNet`, `kl.VfsRamFs`, and `kl.VfsSdCardFs` processes as well as the processes that statically include VFS), no changes to the init description are required.

     Otherwise, if IPC channels for processes that use the VFS component are manually specified, you must add the `kl.EntropyEntity` process to the init description and define the IPC channels between it and the processes that use the VFS component:

```
- name: kl.VfsSdCardFs
  path: VfsSdCardFs
  connections:
  ...
  - target: kl.EntropyEntity
    id: kl.EntropyEntity

- name: kl.VfsNet
  path: VfsNet
  connections:
  ...
  - target: kl.EntropyEntity
    id: kl.EntropyEntity

- name: kl.ProgramWithEmbeddedVfs
  path: ProgramWithEmbedVfs
  connections:
  ...
  - target: kl.EntropyEntity
    id: kl.EntropyEntity

- name: kl.EntropyEntity
  path: Entropy
```

   - You must add the `kl.EntropyEntity` process to the `security.psl` file and allow the kernel and processes that use the VFS component to interact with it:

```
...
use kl.EntropyEntity._
...

execute src = Einit dst = kl.drivers.EntropyEntity { grant () }
...
request src = kl.EntropyEntity dst = kl.core.Core  { grant () }
response src = kl.core.Core dst = kl.EntropyEntity { grant () }

request src = kl.VfsNet dst = kl.EntropyEntity { grant () }
response src = kl.EntropyEntity  dst = kl.VfsNet { grant () }

request src = kl.VfsSdCardFs dst = kl.EntropyEntity { grant () }
response src = kl.EntropyEntity dst = kl.VfsSdCardFs { grant () }
```

```
request src = kl.ProgramWithEmbeddedVfs dst = kl.EntropyEntity   { grant () }
response src = kl.EntropyEntity  dst = kl.ProgramWithEmbeddedVfs { grant () }
```

3. The `kl.drivers.USB` driver now requires access to the `kl.core.NameServer` program.

   - If the `init.yaml.in` template is used to create the solution init description (`init.yaml` file) and the `@INIT_ProgramName_ENTITY_CONNECTIONS+@` or `@INIT_ProgramName_ENTITY_CONNECTIONS@` macros were used for the `kl.drivers.USB` process, no changes to the init description are required.

     Otherwise, if IPC channels for the `kl.drivers.USB` process are manually specified, you must add the `kl.core.NameServer` process to the init description and define the IPC channels between it and the `kl.drivers.USB` process:

```
- name: kl.core.NameServer
  path: ns

- name: kl.drivers.USB
  path: usb
  connections:
  ...
  - target: kl.core.NameServer
    id: kl.core.NameServer
```

   - You must add the `kl.core.NameServer` process to the `security.psl` file and allow the `kl.drivers.USB` process and the kernel to interact with it:

```
...
use kl.core.NameServer
...

execute src = Einit dst = kl.core.NameServer { grant () }
...
request src = kl.core.NameServer dst = kl.core.Core { grant () }
response src = kl.core.Core dst = kl.core.NameServer { grant () }

request src = kl.drivers.USB dst = kl.core.NameServer { grant () }
response src = core.NameServer dst = kl.drivers.USB { grant () }
```

4. The capability to use dynamic libraries has been added to the SDK. Now all solutions are built using dynamic linking by default. This may affect the build of solutions containing libraries that have both static and dynamic variants.

   - To include enforced static linking of executable files, replace `initialize_platform()` with `initialize_platform (FORCE_STATIC)` in the root CMakeLists.txt of the project.

   - To switch from static linking to dynamic linking, you must complete additional steps as described in the article titled Using dynamic libraries.

   - To use dynamic libraries, your solution must include the system program BlobContainer.

   - You must add the `kl.bc.BlobContainer` process to the `security.psl` file and allow processes that use dynamic libraries to interact with it:

```
...
use kl.bc.BlobContainer
...

execute src = Einit dst = kl.bc.BlobContainer  { grant () }

request
{
    /* Allows tasks with the kl.bc.BlobContainer class to send requests to
specified tasks. */
    match src = kl.bc.BlobContainer
    {
        match dst = kl.core.Core     { grant () }
        match dst = kl.VfsSdCardFs   { grant () }
    }
    /* Allows task with the kl.bc.BlobContainer class to recive request from any
task. */
    match dst = kl.bc.BlobContainer  { grant () }
}

response
{
    /* Allows tasks with the kl.bc.BlobContainer class to get responses from
specified tasks. */
    match dst = kl.bc.BlobContainer
    {
        match src = kl.core.Core     { grant () }
        match src = kl.VfsSdCardFs   { grant () }
    }
    /* Allows task with the kl.bc.BlobContainer class to send response to any task.
*/
    match src = kl.bc.BlobContainer  { grant () }
}
```

You can move the permissions for `kl.bc.BlobContainer` operations to a separate PSL file and include this file in the solution. (see the secure_logger example in the SDK).

5. The romfs file system can now be mounted only in read-only mode.

   - When mounting romfs in C/C++ code using the `mount()` function, you must pass the `MS_RDONLY` flag.
   - You must also make changes to the command-line arguments of the VFS program in the init description or in the CMakeLists.txt file for building the Einit program.

   Example of mounting the romfs file system in the init.yaml file:

```
- name: kl.VfsSdCardFs
  path: VfsSdCardFs
  connections:
  - target: kl.drivers.SDCard
    id: kl.drivers.SDCard
  - target: kl.EntropyEntity
    id: kl.EntropyEntity

  args:
        - -l
        - nodev /tmp ramfs 0
        - -l
```

```
        - romfs /etc romfs ro
  env:
        ROOTFS: mmc0,0 / fat32 0
        VFS_FILESYSTEM_BACKEND: server:kl.VfsSdCardFs
```

Example of mounting the romfs file system in the CMakeLists.txt file:

```
set (VFS_NET_ARGS "
    - -l
    - devfs /dev devfs 0
    - -l
    - romfs /etc romfs ro")

set_target_properties (${precompiled_vfsVfsNet} PROPERTIES
                       EXTRA_ARGS ${VFS_NET_ARGS})
```

Overview of KasperskyOS

KasperskyOS is a specialized operating system based on a separation microkernel and security monitor.

See also:

- What's new
- About KasperskyOS Community Edition
- System requirements
- Getting started

Overview

Microkernel

KasperskyOS is a microkernel operating system. The kernel provides minimal functionality, including scheduling of program execution, management of memory and input/output. The code of device drivers, file systems, network protocols and other system software is executed in user mode (outside of the kernel context).

Processes and endpoints

Software managed by KasperskyOS is executed as processes. A *process* is a running program that has the following distinguishing characteristics:

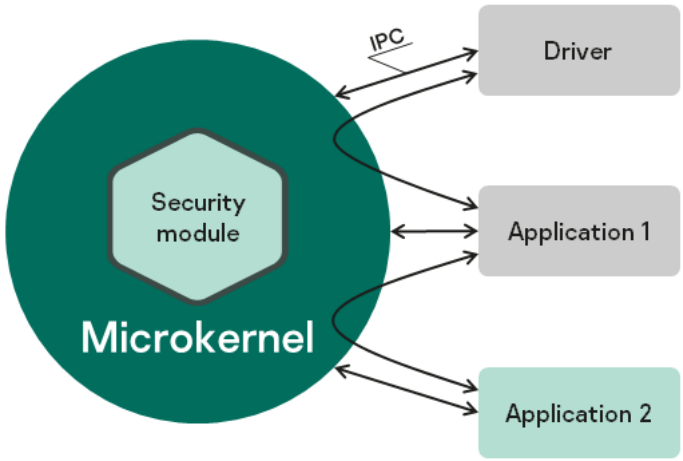
- It can provide endpoints to other processes and/or use the endpoints of other processes via the IPC mechanism.
- It uses core endpoints via the IPC mechanism.
- It is associated with security rules that regulate the interactions of the process with other processes and with the kernel.

An *endpoint* is a set of logically related methods available via the IPC mechanism (for example, an endpoint for receiving and transmitting data over the network, or an endpoint for handling interrupts).

Implementation of the MILS and FLASK architectural approaches

When developing a KasperskyOS-based system, software is designed as a set of components (programs) whose interactions are regulated by security mechanisms. In terms of security, the degree of trust in each component may be high or low. In other words, the system software includes trusted and untrusted components. Interactions between different components (and between components and the kernel) are controlled by the kernel (see the figure below), which has a high level of trust. This type of system design is based on the architectural approach known as MILS (Multiple Independent Levels of Security), which is employed when developing critical information systems.

A decision on whether to allow or deny a specific interaction is made by the Kaspersky Security Module. (This decision is referred to as the *security module decision*.) The security module is a kernel module whose trust level is high like the trust level of the kernel. The kernel executes the security module decision. This type of division of interaction management functions is based on the architectural approach known as FLASK (Flux Advanced Security Kernel), which is used in operating systems for flexible application of security policies.



Interaction between different processes and between processes and the kernel in KasperskyOS

KasperskyOS-based solution

A *KasperskyOS-based solution* (hereinafter also referred to as the *solution*) consists of system software (including the KasperskyOS kernel and Kaspersky Security Module) and applications integrated to work as part of the software/hardware system. The programs included in a KasperskyOS-based solution are considered to be *components of the KasperskyOS-based solution* (hereinafter referred to as *solution components*). Each instance of a solution component is executed in the context of a separate process.

Security policy for a KasperskyOS-based solution

Interactions between the various processes and between processes and the KasperskyOS kernel are allowed or denied according to the *KasperskyOS-based solution security policy* (hereinafter referred to as the *solution security policy* or simply the *policy*). The solution security policy is stored in the Kaspersky Security Module and is used by this module whenever it makes decisions on whether to allow or deny interactions.

The solution security policy can also define the logic for handling queries sent by a process to the security module via the *security interface*. A process can use the security interface to send some data to the security module (for example, to influence future decisions made by the security module) or to receive a security module decision that is needed by the process to determine its own further actions.

Kaspersky Security System technology

Kaspersky Security System technology lets you implement diverse security policies for solutions. You can also combine multiple security mechanisms and flexibly regulate the interactions between different processes and between processes and the KasperskyOS kernel. A Kaspersky Security Module to be used in a specific solution is created based on the solution security policy description.

Source code generators

Some of the source code of a KasperskyOS-based solution is created by source code generators. Specialized programs generate the source code in C from declarative descriptions. They generate source code of the Kaspersky Security Module, source code of the *initializing program* (which starts all other programs in the solution and statically defines the topology of interaction between them), and the source code of the methods and types for carrying out IPC (*transport code*).

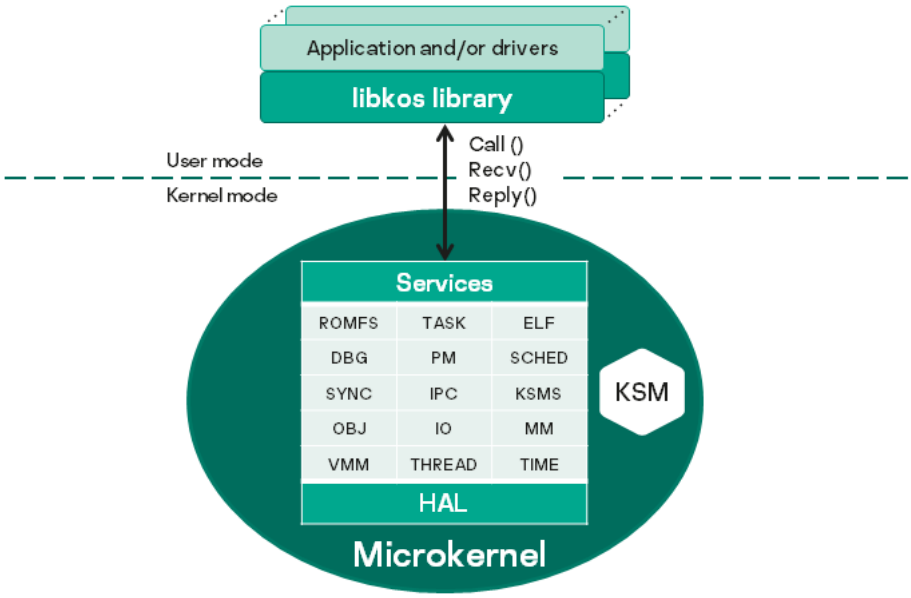
The transport code is generated by the `nk-gen-c` compiler based on the formal specifications of solution components.

The source code of the Kaspersky Security Module is generated by the `nk-psl-gen-c` compiler from the solution security policy description and formal specifications of solution components.

The source code of the initializing program is generated by the `einit` tool from the init description and formal specifications of solution components.

KasperskyOS architecture

The KasperskyOS architecture is presented in the figure below:



KasperskyOS architecture

In KasperskyOS, applications and drivers interact with each other and with the kernel by using the `libkos` library, which provides the interfaces for querying core endpoints. (In KasperskyOS, a driver generally operates with the same level of privileges as the application.) The `libkos` library queries the kernel by executing only three system calls: `Call()`, `Recv()` and `Reply()`. These calls are implemented by the IPC mechanism. Core endpoints are supported by kernel subsystems whose purposes are presented in the table below. Kernel subsystems interact with hardware through the hardware abstraction layer (HAL), which makes it easier to port KasperskyOS to various platforms.

Kernel subsystems and their purpose

Designation	Name	Purpose
HAL	Hardware abstraction subsystem	Basic hardware support: timers, interrupt controllers, memory management unit (MMU). This subsystem includes UART drivers and low-level means for power management.
IO	I/O manager	Registration and deallocation of hardware platform resources required for the operation of drivers, such as Interrupt ReQuest (IRQ), Memory-Mapped Input-Output (MMIO), I/O ports, and DMA buffers. If the hardware platform

		has an input–output memory management unit (IOMMU), this subsystem guarantees the allocation of memory used by devices.
MM	Physical memory manager	Allocation and deallocation of physical memory pages, distribution of physically contiguous page areas.
VMM	Virtual memory manager	Management of physical and virtual memory: reserving, committing, and releasing memory. Working with memory page tables for insulating the address spaces of processes.
THREAD	Thread manager	Management of threads: creating, terminating, locking, and resuming threads.
TIME	Real-time clock subsystem	Getting the time and setting the system clock. Using clocks provided by hardware.
SCHED	Scheduler	Scheduling of threads: standard threads, real-time threads, and idle threads.
SYNC	Synchronization primitive support subsystem	Implementation of basic synchronization primitives: spinlocks, mutexes, and events. The kernel supports only one primitive—futex. All other primitives are implemented based on a futex in the user space.
IPC	Interprocess communication subsystem	Implementation of a synchronous IPC mechanism based on the rendezvous principle.
KSMS	Security module interaction subsystem	This subsystem is used for working with the security module. It provides all messages relayed via IPC to the security module so that these messages can be checked.
OBJ	Object manager	Management of the general behavior of all KasperskyOS resources: tracking their life cycle and assigning unique security IDs (for details, see "Resource Access Control"). This subsystem is closely linked to the capability-based access control mechanism (OCap).
ROMFS	Immutable file system image startup subsystem	Operations with files from ROMFS: opening and closing, receiving a list of files and their descriptions, and receiving file characteristics (name, size).
TASK	Process management subsystem	Management of processes: creating, starting, and terminating processes. Receiving information about running processes (such as names and paths) and their exit codes.
ELF	Executable file loading subsystem	Loading executable ELF files from ROMFS into RAM, parsing headers of ELF files.
DBG	Debug support subsystem	Debugging mechanism based on GDB (GNU Debugger). The availability of this subsystem in the kernel is optional.
PM	Power manager	Power management: restart and shutdown.

IPC

IPC mechanism

Exchanging IPC messages

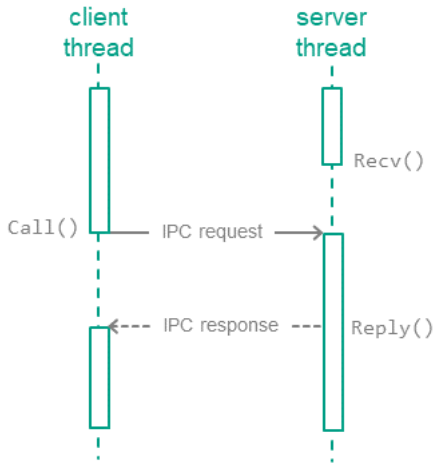
In KasperskyOS, processes interact with each other by exchanging IPC messages (*IPC request* and *IPC response*). In an interaction between processes, there are two separate roles: *client* (the process that initiates the interaction) and *server* (the process that handles the request). Additionally, a process that acts as a client in one interaction can act as a server in another.

To exchange IPC messages, the client and server use three system calls: `Call()`, `Recv()` and `Reply()` (see the figure below):

1. The client sends an IPC request to the server. To do so, one of the client's threads makes the `Call()` system call and is locked until an IPC response is received from the server.

2. The server thread that has made the `Recv()` system call waits for IPC requests. When an IPC request is received, this thread is unlocked and handles the request, then sends an IPC response by making the `Reply()` system call.

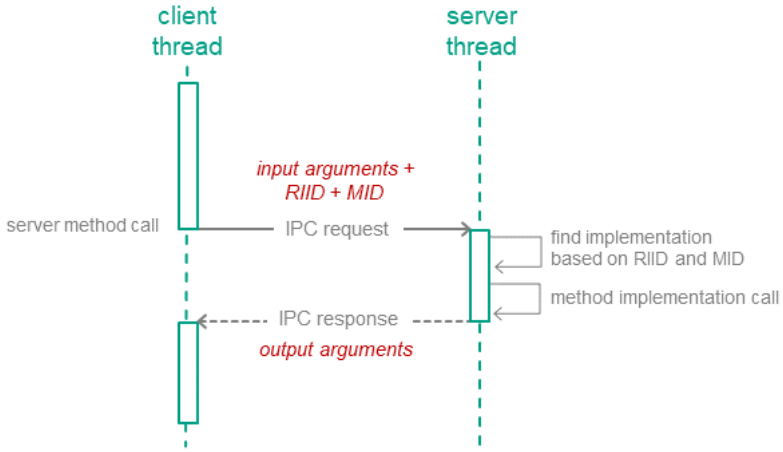
3. When an IPC response is received, the client thread is unlocked and continues execution.



Exchanging IPC messages between a client and a server

Calling methods of server endpoints

IPC requests are sent to the server when the client calls *endpoint methods* of the server (hereinafter also referred to as *interface methods*) (see the figure below). The IPC request contains input parameters for the called method, as well as the endpoint ID (RIID) and the called method ID (MID). Upon receiving a request, the server uses these identifiers to find the method's implementation. The server calls the method's implementation while passing in the input parameters from the IPC request. After handling the request, the server sends the client an IPC response that contains the output parameters of the method.



Calling a server endpoint method

IPC channels

To enable two processes to exchange IPC messages, an *IPC channel* must be established between them. An IPC channel has a client side and a server side. One process can use multiple IPC channels at the same time. A process may act as a server for some IPC channels while acting as a client for other IPC channels.

KasperskyOS has two mechanisms for creating IPC channels:

1. The static mechanism allows the parent process to create an IPC channel between child processes. Static creation of IPC channels is normally performed by the initializing program.

2. The dynamic mechanism allows already running processes to create IPC channels between each other.

IPC control

The Kaspersky Security Module is integrated into the IPC implementation mechanism. The security module is aware of the structure of IPC messages for all possible interactions because IDL, CDL and EDL descriptions are used to generate the source code of this module. This enables the security module to verify that the interactions between processes comply with the solution security policy.

The KasperskyOS kernel queries the security module each time a process sends an IPC message to another process. The security module operating scenario includes the following steps:

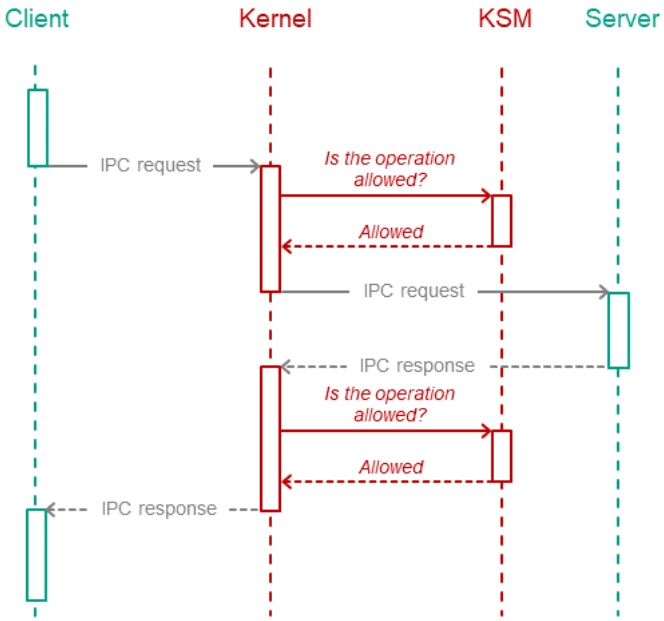
1. The security module verifies that the IPC message complies with the called method of the endpoint (the size of the IPC message is verified along with the size and location of certain structural elements).

2. If the IPC message is incorrect, the security module makes the "deny" decision and the next step of the scenario is not carried out. If the IPC message is correct, the next step of the scenario is carried out.

3. The security module checks whether the security rules allow the requested action. If allowed, the security module makes the "granted" decision. Otherwise it makes the "denied" decision.

The kernel executes the security module decision. In other words, it either delivers the IPC message to the recipient process or rejects its delivery. If delivery of an IPC message is rejected, the sender process receives an error code via the return code of the `Call()` or `Reply()` system call.

The security module checks IPC requests as well as IPC responses. The figure below depicts the controlled exchange of IPC messages between a client and a server.



Controlled exchange of IPC messages between a client and a server

Transport code for IPC

Implementation of interprocess interaction requires transport code, which is responsible for generating, sending, receiving, and processing IPC messages. However, developers of KasperskyOS-based solutions do not have to write their own transport code. Instead, you can use special tools and libraries included in the KasperskyOS SDK.

Transport code for developed components of a solution

A developer of a KasperskyOS-based solution component can generate transport code based on IDL, CDL and EDL descriptions related to this component. The KasperskyOS SDK includes the `nk-gen-c` compiler for this purpose. The `nk-gen-c` compiler generates transport methods and types for use by both a client and a server.

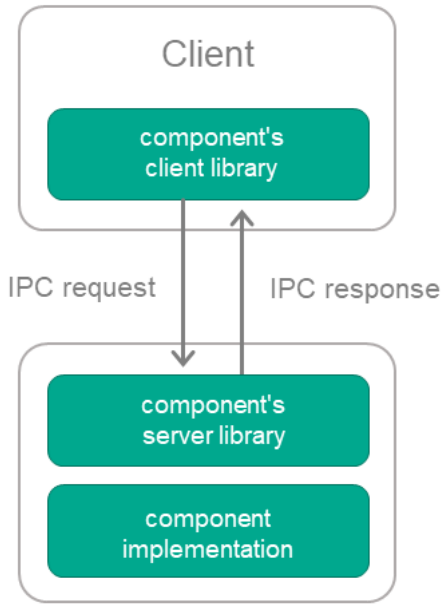
Transport code for supplied components of a solution

Most components included in the KasperskyOS SDK may be used in a solution both locally (through static linking with other components) as well as via IPC.

To use a supplied component via IPC, the KasperskyOS SDK provides the following *transport libraries*:

- *Solution component's client library*, which converts local calls into IPC requests.
- *Solution component's server library*, which converts IPC requests into local calls.

The client library is linked to the client code (the component code that will use the supplied component). The server library is linked to the implementation of the supplied component (see the figure below).



Using a supplied solution component via IPC

IPC between a process and the kernel

The IPC mechanism is used for interaction between processes and the KasperskyOS kernel. In other words, processes exchange IPC messages with the kernel. The kernel provides endpoints, and processes use those endpoints. Processes query core endpoints by calling functions of the `libkos` library (directly or via other libraries). The client transport code for interaction between a process and the kernel is included in this library.

A solution developer is not required to create IPC channels between processes and the kernel because these channels are created automatically when processes are created. (To set up interaction between processes, the solution developer has to create IPC channels between them.)

The Kaspersky Security Module makes decisions regarding interaction between processes and the kernel the same way it makes decisions regarding interaction between a process and other processes. (The KasperskyOS SDK has IDL, CDL and EDL descriptions for the kernel that are used to generate source code of the security module.)

Resource Access Control

Types of resources

KasperskyOS has two types of resources:

- *System resources*, which are managed by the kernel. Some examples of these include processes, memory regions, and interrupts.
- *User resources*, which are managed by processes. Examples of user resources: files, input-output devices, data storage.

Handles

Both system resources and user resources are identified by *handles*. Processes (and the KasperskyOS kernel) can transfer handles to other processes. By receiving a handle, a process obtains access to the resource that is identified by this handle. In other words, the process that receives a handle can request operations to be performed on a resource by specifying its received handle in the request. The same resource can be identified by multiple handles used by different processes.

Security identifiers (SID)

The KasperskyOS kernel assigns security identifiers to system resources and user resources. A *security identifier* (SID) is a global unique ID of a resource (in other words, a resource can have only one SID but can have multiple handles). The Kaspersky Security Module identifies resources based on their SID.

> When transmitting an IPC message containing handles, the kernel modifies the message so that it contains SID values instead of handles when the message is checked by the security module. When the IPC message is delivered to its recipient, it will contain the handles.
> The kernel also has an SID like other resources.

Security context

Kaspersky Security System technology lets you employ security mechanisms that receive SID values as inputs. When employing these mechanisms, the Kaspersky Security Module distinguishes resources (and the KasperskyOS kernel) and binds security contexts to them. A *security context* consists of data that is associated with an SID and used by the security module to make decisions.

The contents of a security context depend on the security mechanisms being used. For example, a security context may contain the state of a resource and the levels of integrity of access subjects and/or access objects. If a security context stores the state of a resource, this lets you allow certain operations to be performed on a resource only if the resource is in a specific state, for example.

The security module can modify a security context when it makes a decision. For example, it can modify information about the state of a resource (the security module used the security context to verify that a file is in the "not in use" state and allowed the file to be opened for write access and wrote a new state called "opened for write access" into the security context of this file).

Resource access control by the KasperskyOS kernel

The KasperskyOS kernel controls access to resources by using two mutually complementary methods at the same time: executing the decisions of the Kaspersky Security Module and implementing a security mechanism based on object capabilities (OCap).

Each handle is associated with access rights to the resource identified by this handle, which means it is a *capability* in OCap terms. By receiving a handle, a process obtains the access rights to the resource that is identified by this handle. For example, these access rights may consist of read permissions, write permissions, and/or permissions to allow another process to perform operations on the resource (handle transfer permission).

Processes that use the resources provided by the kernel or other processes are referred to as *resource consumers*. When a resource consumer opens a system resource, the kernel sends the consumer the handle associated with the access rights to this resource. These access rights are assigned by the kernel. Before an operation is performed on a system resource requested by a consumer, the kernel verifies that the consumer has sufficient rights. If the consumer does not have sufficient rights, the kernel rejects the request of the consumer.

In an IPC message, a handle is sent together with its permissions mask. The *handle permissions mask* is a value whose bits are interpreted as access rights to the resource identified by the handle. A resource consumer can find out their access rights to a system resource from the handle permissions mask of this resource. The kernel uses the handle permissions mask to verify that the consumer is allowed to request the operations to be performed on the system resource.

The security module can verify the permissions masks of handles and use these verifications to either allow or deny interactions between different processes and between processes and the kernel when such interactions are related to resource access.

The kernel prohibits the expansion of access rights when handles are transferred among processes (when a handle is transferred, access rights can only be restricted).

Resource access control by resource providers

Processes that control user resources and access to those resources for other processes are referred to as *resource providers*. For example, drivers are resource providers. Resource providers control access to resources by using two mutually complementary methods: executing the decisions of the Kaspersky Security Module and using the OCap mechanism that is provided by the KasperskyOS kernel.

If a resource is queried by its name (for example, to open it), the security module cannot be used to control access to the resource without the involvement of the resource provider. This is because the security module identifies a resource by its SID, not by its name. In such cases, the resource provider finds the resource handle based on the resource name and forwards this handle (together with other data, such as the required state of the resource) to the security module via the security interface (the security module receives the SID corresponding to the transferred handle). The security module makes a decision and returns it to the resource provider. The resource provider implements the decision of the security module.

When a resource consumer opens a user resource, the resource provider sends the consumer the handle associated with the access rights to this resource. In addition, the resource provider decides which specific rights for accessing the resource will be granted to the resource consumer. Before an operation is performed on a user resource as requested by a consumer, the resource provider verifies that the consumer has sufficient rights. If the consumer does not have sufficient rights, the resource provider rejects the request of the consumer.

A resource consumer can find out their access rights to a user resource from the permissions mask of the handle of this resource. The resource provider uses the handle permissions mask to verify that the consumer is allowed to request the operations to be performed on the user resource.

Structure and startup of a KasperskyOS-based solution

Structure of a solution

The image of the KasperskyOS-based solution loaded into hardware contains the following files:

- Image of the KasperskyOS kernel
- File containing the executable code of the Kaspersky Security Module
- Executable file of the initializing program
- Executable files of all other solution components (for example, applications and drivers)
- Files used by programs (for example, dynamic libraries, files containing settings, fonts, graphical and audio data)

The ROMFS file system is used to save files in the solution image.

Starting a solution

A KasperskyOS-based solution is started as follows:

1. The bootloader starts the KasperskyOS kernel.
2. The kernel finds and loads the security module (as a kernel module).
3. The kernel starts the initializing program.
4. The initializing program starts the programs included in the solution (one, several, or all).

Getting started

This section tells you what you need to know to start working with KasperskyOS Community Edition.

Using a Docker container

To install and use KasperskyOS Community Edition, you can use a Docker container in which an image of one of the supported operating systems is deployed.

To use a Docker container for installing KasperskyOS Community Edition:

1. Make sure that the Docker software is installed and running.
2. To download the official Docker image of the Ubuntu GNU/Linux 22.04 (Jammy Jellyfish) operating system from the public Docker Hub repository, run the following command:
   `docker pull ubuntu:22.04`
3. To run the image, run the following command:
   `docker run --net=host --user root --privileged -it --rm ubuntu:22.04 bash`
4. Copy the DEB package for installation of KasperskyOS Community Edition into the container.
5. Install KasperskyOS Community Edition.
6. To ensure correct operation of some examples, you must add the `/usr/sbin` directory to the `PATH` environment variable within the container by running the following command:
   `export PATH=/usr/sbin:$PATH`

Installation and removal

Installation

KasperskyOS Community Edition is distributed as a DEB package. It is recommended to use the `apt` package installer to install KasperskyOS Community Edition.

To deploy the package using `apt`, run the following command:

```
$ sudo apt update && sudo apt install <path-to-deb-package>
```

The package will be installed in `/opt/KasperskyOS-Community-Edition-<version>`.

To conveniently work with tools provided in the KasperskyOS Community Edition SDK, the path to the executable files of these tools in `/opt/KasperskyOS-Community-Edition-<version>/toolchain/bin` must be added to the `PATH` environment variable. To avoid having to do this each time you log in to a user session, run the script `/opt/KasperskyOS-Community-Edition-<version>/set_env.sh`, log out and log in to a session again.

Syntax of the command for calling the `set_env.sh` script:

```
$ sudo ./set_env.sh [-h] [-d]
```

Parameters:

- `-d`
  Cancels the action of the script.
- `-h`, `--help`
  Displays the Help text.

In addition to changing the `PATH` environment variable, the script defines the `KOSCEVER` and `KOSCEDIR` environment variables that contain the version and absolute path to the KasperskyOS Community Edition SDK, respectively. Use of these environment variables allows the build system to determine the SDK installation path at startup, and to verify that the solution version matches the SDK version.

Removal

Prior to removing KasperskyOS Community Edition, cancel the action of the `set_env.sh` script if you ran this script after installing the SDK.

To remove KasperskyOS Community Edition, run the following command:

```
$ sudo apt remove --purge kasperskyos-community-edition
```

After running this command, all installed files in the `/opt/KasperskyOS-Community-Edition-<version>` directory will be deleted.

Configuring the development environment

This section provides brief instructions on configuring the development environment and adding the header files included in KasperskyOS Community Edition to a development project.

Configuring the code editor

Before getting started, you should do the following to simplify your development of solutions based on KasperskyOS:

- Install code editor extensions and plugins for your programming language (C and/or C++).
- Add the header files included in KasperskyOS Community Edition to the development project.
  The header files are located in the directory: `/opt/KasperskyOS-Community-Edition-<version>/sysroot-aarch64-kos/include`.

Example of how to configure Visual Studio Code

For example, during KasperskyOS development, you can work with source code in Visual Studio Code.

To more conveniently navigate the project code, including the system API:

1. Create a new workspace or open an existing workspace in Visual Studio Code.
   A workspace can be opened implicitly by using the `File` > `Open folder` menu options.
2. Make sure the C/C++ for Visual Studio Code extension is installed.
3. In the `View` menu, select the `Command Palette` item.
4. Select the `C/C++: Edit Configurations (UI)` item.
5. In the `Include path` field, enter `/opt/KasperskyOS-Community-Edition-<version>/sysroot-aarch64-kos/include`.
6. Close the `C/C++ Configurations` window.

Building and running examples

Building the examples

The examples are built using the `CMake` build system that is included in KasperskyOS Community Edition.

The code of the examples and build scripts are available at the following path:

`/opt/KasperskyOS-Community-Edition-<version>/examples`

> You need to build the examples in a directory in which you have write access, such as the home directory.

Building the examples to run on QEMU

To build an example, go to the directory with the example and run this command:

```
$ ./cross-build.sh
```

Running the `cross-build.sh` script creates a KasperskyOS-based solution image that includes the example, and initiates startup of the example in QEMU. The `kos-qemu-image` solution image is located in the `<name of example>/build/einit` directory.

Building the examples to run on Raspberry Pi 4 B

To build an example, go to the directory with the example and run this command:

```
$ ./cross-build.sh --target {kos-image|sd-image}
```

The type of image that is created by the `cross-build.sh` script depends on the value that you choose for the `target` parameter:

- `kos-image`

  This creates a KasperskyOS-based solution image that includes the example. The `kos-image` solution image is located in the `<name of example>/build/einit` directory.

- `sd-image`

  This creates a file system image for a bootable SD card. The following is loaded into the file system image: `kos-image`, U-Boot bootloader that starts the example, and the firmware for Raspberry Pi 4 B. The source code for the U-Boot bootloader and firmware can be downloaded from the website https://github.com. The file system image file `rpi4kos.img` is saved in the directory `<example name>/build`.

Running examples on QEMU

Running examples on QEMU on Linux with a graphical shell

An example is run on QEMU on Linux with a graphical shell using the `cross-build.sh` script, which also builds the example. To run the script, go to the folder with the example and run the command:

```
$ sudo ./cross-build.sh
```

Running examples on QEMU on Linux without a graphical shell

To run an example on QEMU on Linux without a graphical shell, go to the directory with the example, build the example and run the following commands:

```
$ cd build/einit
# Before running the following command, be sure that the path to
# the directory with the qemu-system-aarch64 executable file is saved in
# the PATH environment variable. If it is not there,
# add it to the PATH variable.
$ qemu-system-aarch64 -m 2048 -machine vexpress-a15,secure=on -cpu cortex-a72 -
nographic -monitor none -smp 4 -nic user -serial stdio -kernel kos-qemu-image
```

Preparing Raspberry Pi 4 B to run examples

Connecting a computer and Raspberry Pi 4 B

To see the output from Raspberry Pi 4 B on a computer, do the following:

1. Connect the pins of the FT232 USB-UART converter to the corresponding GPIO pins of the Raspberry Pi 4 B (see the figure below).

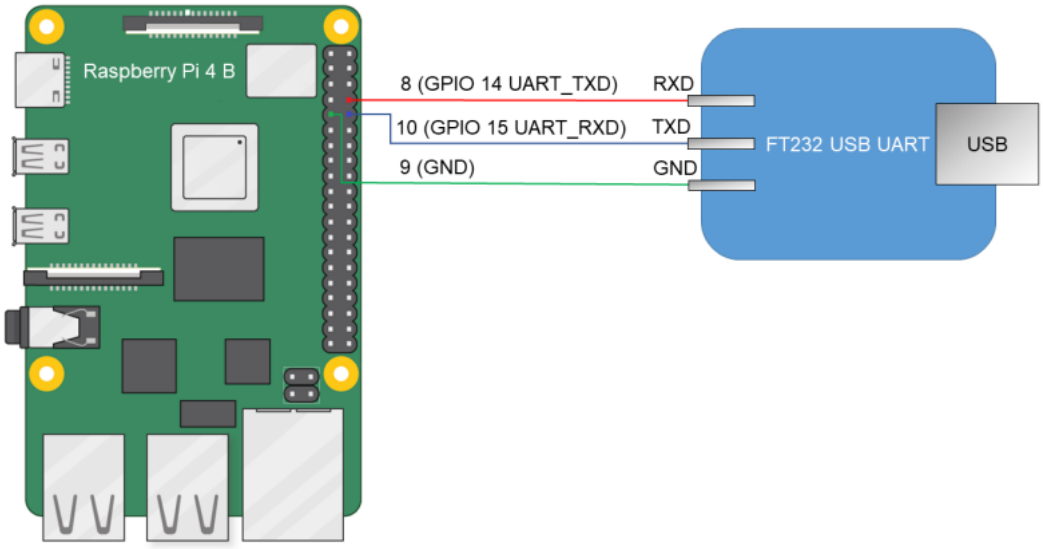


Diagram for connecting the USB-UART converter and Raspberry Pi 4 B

2. Connect the computer's USB port to the USB-UART converter.

3. Install PuTTY or another equivalent program. Configure the settings as follows: `bps = 115200`, `data bits = 8`, `stop bits = 1`, `parity = none`, `flow control = none`. Define the USB port connected to the USB-UART converter used for receiving output from Raspberry Pi 4 B.

To allow a computer and Raspberry Pi 4 B to interact through Ethernet:

1. Connect the network cards of the computer and Raspberry Pi 4 B to a switch or to each other.

2. Configure the computer's network card so that its IP address is in the same subnet as the IP address of the Raspberry Pi 4 B network card (the settings of the Raspberry Pi 4 B network card are defined in the `dhcpcd.conf` file, which is found at the path `<example name>/resources/...`).

Preparing a bootable SD card for Raspberry Pi 4 B

If the `rpi4kos.img` image was created when building the example, all you have to do is write the resulting image to the SD card. To do this, connect the SD card to the computer and run the following command:

```
# In the following command, path_to_img is the path to the image file
# [X] is the final character in the name of the SD card block device.
$ sudo pv -L 32M path_to_img | sudo dd bs=64k of=/dev/sd[X] conv=fsync
```

If `kos-image` was created when building the example, the SD card requires additional preparations before you can write the image to it. A bootable SD card for Raspberry Pi 4 B can be prepared automatically or manually.

To automatically prepare the bootable SD card, connect the SD card to the computer and run the following commands:

```
# To create a bootable drive image file (*.img),
# run the script:
$ sudo /opt/KasperskyOS-Community-Edition-
<version>/common/rpi4_prepare_sdcard_image.sh
```

```
# In the following command, path_to_img is the path to the image file
# of the bootable drive (this path is displayed upon completion
# of the previous command), [X] is the final character
# in the name of the SD card block device.
$ sudo pv -L 32M path_to_img | sudo dd bs=64k of=/dev/sd[X] conv=fsync
```

To manually prepare the bootable SD card:

1. Build the U-Boot bootloader for ARMv8, which will automatically run the example. To do this, run the following commands:

```
$ sudo apt install git build-essential libssl-dev bison flex unzip parted gcc-
aarch64-linux-gnu pv -y
$ git clone --depth 1 --branch v2022.01 https://github.com/u-boot/u-boot.git u-
boot-armv8
$ cd u-boot-armv8
$ make ARCH=arm CROSS_COMPILE=aarch64-linux-gnu- rpi_4_defconfig
$ echo 'CONFIG_SERIAL_PROBE_ALL=y' > ./.custom_config
$ echo 'CONFIG_BOOTCOMMAND="fatload mmc 0 ${loadaddr} kos-image; bootelf
${loadaddr} ${fdt_addr}"' >> ./.custom_config
$ echo 'CONFIG_PREBOOT="pci enum;"' >> ./.custom_config
$ ./scripts/kconfig/merge_config.sh '.config' '.custom_config'
$ make ARCH=arm CROSS_COMPILE=aarch64-linux-gnu- u-boot.bin
```

2. Prepare the image containing the file system for the SD card.

```
# Image will contain a boot partition of 1 GB in fat32 and three partitions of
350 MB each in ext2, ext3 and ext4, respectively.
$ fs_image_name=sdcard.img
$ dd if=/dev/zero of=${fs_image_name} bs=1024k count=2048
$ sudo parted ${fs_image_name} mklabel msdos
$ loop_device=$(sudo losetup --find --show --partscan ${fs_image_name})
$ sudo parted ${loop_device} mkpart primary fat32 8192s 50%
$ sudo parted ${loop_device} mkpart extended 50% 100%
$ sudo parted ${loop_device} mkpart logical ext2 50% 67%
$ sudo parted ${loop_device} mkpart logical ext3 67% 84%
$ sudo parted ${loop_device} mkpart logical ext4 84% 100%
$ sudo parted ${loop_device} set 1 boot on
$ sudo mkfs.vfat ${loop_device}p1
$ sudo mkfs.ext2 ${loop_device}p5
$ sudo mkfs.ext3 ${loop_device}p6
$ sudo mkfs.ext4 -O ^64bit,^extent ${loop_device}p7
```

3. Copy the U-Boot bootloader and embedded software (firmware) for Raspberry Pi 4 B to the received file system image by running the following commands:

```
# In the following commands, the path ~/mnt/fat32 is just an example.
# You can use a different path.
$ mount_temp_dir=~/mnt/fat32
$ mkdir -p ${mount_temp_dir}
$ sudo mount ${loop_device}p1 ${mount_temp_dir}
$ git clone --depth 1 --branch 1.20220331
https://github.com/raspberrypi/firmware.git firmware
$ sudo cp u-boot.bin ${mount_temp_dir}/u-boot.bin
$ sudo cp -r firmware/boot/. ${mount_temp_dir}
```

4. Fill in the configuration file for the U-Boot bootloader in the image by using the following commands:

```
$ sudo sh -c "echo '[all]' > ${mount_temp_dir}/config.txt"
$ sudo sh -c "echo 'arm_64bit=1' >> ${mount_temp_dir}/config.txt"
$ sudo sh -c "echo 'enable_uart=1' >> ${mount_temp_dir}/config.txt"
$ sudo sh -c "echo 'kernel=u-boot.bin' >> ${mount_temp_dir}/config.txt"
$ sudo sh -c "echo 'dtparam=i2c_arm=on' >> ${mount_temp_dir}/config.txt"
$ sudo sh -c "echo 'dtparam=i2c=on' >> ${mount_temp_dir}/config.txt"
$ sudo sh -c "echo 'dtparam=spi=on' >> ${mount_temp_dir}/config.txt"
$ sudo sh -c "echo 'device_tree_address=0x2eff5b00' >>
${mount_temp_dir}/config.txt"
$ sudo sh -c "echo 'device_tree_end=0x2f0f5b00' >> ${mount_temp_dir}/config.txt"
$ sudo sh -c "echo 'dtoverlay=uart5' >> ${mount_temp_dir}/config.txt"
$ sudo umount ${mount_temp_dir}
$ sudo losetup -d ${loop_device}
```

5. Write the resulting image to an SD card. To do this, connect the SD card to the computer and run the following command:

```
# In the following command, [X] is the last symbol in the name of the block device
for the SD card.
$ sudo pv -L 32M ${fs_image_name} | sudo dd bs=64k of=/dev/sd[X] conv=fsync
```

Running examples on Raspberry Pi 4 B

To run an example on a Raspberry Pi 4 B:

1. Go to the directory with the example and build the example.
2. Make sure that Raspberry Pi 4 B and the bootable SD card are prepared to run examples.
3. Connect the bootable SD card to the Raspberry Pi 4 B.
4. Supply power to the Raspberry Pi 4 B and wait for the example to run.

   The output displayed on the computer connected to Raspberry Pi 4 B indicates that the example started.

Starting processes

Overview: Einit and init.yaml

Einit initializing program

When a solution is started, the KasperskyOS kernel finds the executable file named `Einit` (initializing program) in the solution image and runs this executable file. The initializing program performs the following operations:

- Creates and starts processes when a solution is started.
- Creates IPC channels between processes when a solution is started (statically creates IPC channels).

A process of the initializing program belongs to the `Einit` class.

Generating the source code of the initializing program

The KasperskyOS SDK includes the `einit` tool, which generates the C-language source code of the initializing program. The standard way to use the `einit` tool is to integrate an einit call into one of the steps of the build script, which generates the `einit.c` file containing the source code of the initializing program. In one of the following steps of the build script, you must compile the `einit.c` file into the executable file of `Einit` and include it into the solution image.

> You are not required to create formal specification files for the initializing program. These files are provided in the KasperskyOS SDK and are automatically applied during a solution build. However, the `Einit` process class must be specified in the `security.psl` file.

The `einit` tool generates the source code of the initializing program based on the *init description*, which consists of a text file that is usually named `init.yaml`.

Syntax of init.yaml

An init description contains data in YAML format. This data identifies the following:

- Processes that are started when the solution starts.
- IPC channels that are created when the solution starts and are used by processes to interact with each other (not with the kernel).

This data consists of a dictionary with the `entities` key containing a list of dictionaries of processes. Process dictionary keys are presented in the table below.

Process dictionary keys in an init description

Key	Required	Value
`name`	Yes	Process class name (from the EDL description).
`task`	No	Process name. If this name is not specified, the process class name will be used. Each process must have a unique name. You can start multiple processes of the same class if they have different names.
`path`	No	Name of the executable file in ROMFS (in the solution image). If this name is not specified, the process class name (without prefixes and dots) will be used. For example, processes of the `Client` and `net.Client` classes for which an executable file name is not specified will be started from the `Client` file. You can start multiple processes from the same executable file.
`connections`	No	Process IPC channel dictionaries list. This list defines the statically created IPC channels whose client IPC handles will be owned by the process. The list is empty by default. (In addition to statically created IPC channels, processes can also use dynamically created IPC channels.)
`args`	No	List of program startup parameters (`main()` function parameters). The maximum size of one item on the list is 1024 bytes.
`env`	No	Dictionary of program environment variables. The keys in this dictionary are the names of environment variables. The maximum size of an environment variable value is 1024 bytes.

Process IPC channel dictionary keys are presented in the table below.

IPC channel dictionary keys in an init description

Key	Required	Value
`id`	Yes	IPC channel name, which can be defined as a specific value or as a link such as `{var: <constant name>, include: <path to header file>}`.
`target`	Yes	Name of the process that will own the server handle of the IPC channel.

Example init descriptions

This section provides examples of init descriptions that demonstrate various aspects of starting processes.

> The build system can automatically create an init description based on the `init.yaml.in` template.

Starting a client and server and creating an IPC channel between them

In this example, a process of the `Client` class and a process of the `Server` class are started. The names of the processes are not specified, so they will match the names of their respective process classes. The names of the executable files are not specified, so they will also match the names of their respective process classes. The processes will be connected by an IPC channel named `server_connection`.

init.yaml

```
entities:
- name: Client
  connections:
```

```
    - target: Server
      id: server_connection
  - name: Server
```

Starting processes from defined executable files

This example will start a `Client`-class process from the executable file named `cl`, a `ClientServer`-class process from the executable file named `csr`, and a `MainServer`-class process from the executable file named `msr`. The names of the processes are not specified, so they will match the names of their respective process classes.

init.yaml

```
entities:
- name: Client
  path: cl
- name: ClientServer
  path: csr
- name: MainServer
  path: msr
```

Starting two processes from the same executable file

This example will start a `Client`-class process from the executable file named `Client`, and two processes of the `MainServer` and `BkServer` classes from the executable file named `srv`. The names of the processes are not specified, so they will match the names of their respective process classes.

init.yaml

```
entities:
- name: Client
- name: MainServer
  path: srv
- name: BkServer
  path: srv
```

Starting two servers of the same class and a client, and creating IPC channels between the client and servers

This example will start a `Client`-class process (named `Client`) and two `Server`-class processes named `UserServer` and `PrivilegedServer`. The client will be connected to the servers via IPC channels named `server_connection_us` and `server_connection_ps`. The names of the executable files are not specified, so they will match the names of their respective process classes.

init.yaml

```
entities:
- name: Client
  connections:
  - id: server_connection_us
    target: UserServer
  - id: server_connection_ps
```

```
    target: PrivilegedServer
- task: UserServer
  name: Server
- task: PrivilegedServer
  name: Server
```

Setting the startup parameters and environment variables of programs

This example will start a `VfsFirst`-class process (named `VfsFirst`) and a `VfsSecond`-class process (named `VfsSecond`). The program that will run in the context of the `VfsFirst` process will be started with the parameter `-f /etc/fstab`, and will receive the `ROOTFS` environment variable with the value `ramdisk0,0 / ext2 0` and the `UNMAP_ROMFS` environment variable with the value `1`. The program that will run in the context of the `VfsSecond` process will be started with the `-l devfs /dev devfs 0` parameter. The names of the executable files are not specified, so they will match the names of their respective process classes.

init.yaml

```
entities:
- name: VfsFirst
  args:
  - -f
  - /etc/fstab
  env:
    ROOTFS: ramdisk0,0 / ext2 0
    UNMAP_ROMFS: 1
- name: VfsSecond
  args:
  - -l
  - devfs /dev devfs 0
```

Starting processes using the system program ExecutionManager

The ExecutionManager component provides a C++ interface for creating, starting and stopping processes in solutions that are based on KasperskyOS.

> The interface of the ExecutionManager component is not suitable for use in code that is written in C. To manage processes in the C language, use the task.h interface of the libkos library.

The ExecutionManager component API is an add-on over IPC that helps simplify the program development process. ExecutionManager is a separate system program that is accessed through IPC. However, developers are provided with a client library that eliminates the necessity of directly using IPC calls.

The programming interface of the ExecutionManager component is described in the article titled "ExecutionManager component".

ExecutionManager component usage scenario

Hereinafter "the client" refers to the application that uses the ExecutionManager component API to manage other applications.

The typical usage scenario for the ExecutionManager component includes the following steps:

1. Add the ExecutionManager program to a solution. To add ExecutionManager to a solution:

   - Add the following commands to the CMakeLists.txt root file:

```
find_package (execution_manager REQUIRED)
include_directories (${execution_manager_INCLUDE})
add_subdirectory (execution_manager)
```

> The `BlobContainer` program is required for the ExecutionManager program to work properly. This program is automatically added to a solution when adding ExecutionManager.

   - The ExecutionManager component is provided in the SDK as a set of static libraries and header files, and is built for a specific solution by using the CMake command `create_execution_manager_entity()` from the CMake library `execution_manager`.

     To build the ExecutionManager program, create a directory named `execution_manager` in the root directory of the project. In the new directory, create a `CMakeLists.txt` file containing the `create_execution_manager_entity()` command.

     The CMake command `create_execution_manager_entity()` takes the following parameters:

     Mandatory `ENTITY` parameter that specifies the name of the executable file for the ExecutionManager program.

     Optional parameters:

     - `DEPENDS` – additional dependencies for building the ExecutionManager program.
     - `MAIN_CONN_NAME` – name of the IPC channel for connecting to the ExecutionManager process. It must match the value of the `mainConnection` variable when calling the ExecutionManager API in the client code.
     - `ROOT_PATH` – path to the root directory for service files of the ExecutionManager program. The default root path is `"/ROOT"`.
     - `VFS_CLIENT_LIB` – name of the client transport library used to connect the ExecutionManager program to the `VFS` program.

```
include (execution_manager/create_execution_manager_entity)
create_execution_manager_entity(
    ENTITY ExecMgrEntity
    MAIN_CONN_NAME ${ENTITY_NAME}
    ROOT_PATH "/root"
    VFS_CLIENT_LIB ${vfs_CLIENT_LIB})
```

   - When building a solution (CMakeLists.txt file for the Einit program), add the following executable files to the solution image:

     - Executable file of the ExecutionManager program
     - Executable file of the `BlobContainer` program

2. Link the client executable file to the client proxy library of ExecutionManager by adding the following command to the `CMakeLists.txt` file for building the client:

```
target_link_libraries (<name of the CMake target for building the client>
${execution_manager_EXECMGR_PROXY})
```

3. Add permissions for the necessary events to the solution security policy description:

   a. To enable the ExecutionManager program to run other processes, the solution security policy must allow the following interactions for the `execution_manager.ExecMgrEntity` process class:

   - Security events of the `execute` type for all classes of processes that will be run.
   - Access to all endpoints of the `VFS` program.
   - Access to all endpoints of the `BlobContainer` program.
   - Access to the core endpoints `Sync`, `Task`, `VMM`, `Thread`, `HAL`, `Handle`, `FS`, `Notice`, `CM` and `Profiler` (their descriptions are located in the directory `sysroot-*-kos/include/kl/core` from the SDK).

   b. To enable a client to call the ExecutionManager program, the solution security policy must allow the following interactions for the client process class:

   - Access to the appropriate endpoints of the ExecutionManager program (their descriptions are located in the directory `sysroot-*-kos/include/kl/execution_manager` from the SDK).

4. Use of the ExecutionManager program API in the client code.

   Use the header file `component/package_manager/kos_ipc/package_manager_proxy.h` for this. For more details, refer to "ExecutionManager component".

Overview: Env program

The system program `Env` is intended for setting startup parameters and environment variables of programs. If the `Env` program is included in a solution, the processes connected via IPC channel to the `Env` process will automatically send IPC requests to this program and receive startup parameters and environment variables when these processes are started.

> Use of the `Env` system program is an outdated way of setting startup parameters and environment variables of programs. Instead, you must set the startup parameters and environment variables of programs via the `init.yaml.in` or `init.yaml` file.
> If the value of a startup parameter or environment variable of a program is defined through the `Env` program and via the `init.yaml.in` or `init.yaml` file, the value defined through the `Env` program will be applied.

To use the `Env` program in a solution, you need to do the following:

1. Develop the code of the `Env` program using the macros and functions from the header file `sysroot-*-kos/include/env/env.h` from the KasperskyOS SDK.
2. Build the executable file of the `Env` program by linking it to the `env_server` library from the KasperskyOS SDK.

3. In the init description, indicate that the `Env` process must be started and connected to other processes (`Env` acts as a server in this case). The name of the IPC channel is assigned by the `ENV_SERVICE_NAME` macro defined in the header file `env.h`.

4. Include the `Env` executable file in the solution image.

Source code of the Env program

The source code of the `Env` program utilizes the following macros and functions from the header file `env.h`:

- `ENV_REGISTER_ARGS(name,argarr)` sets the `argarr` startup parameters for the program that will run in the context of the `name` process.
- `ENV_REGISTER_VARS(name,envarr)` sets the `envarr` environment variables for the program that will run in the context of the `name` process.
- `ENV_REGISTER_PROGRAM_ENVIRONMENT(name,argarr,envarr)` sets the `argarr` startup parameters and `envarr` environment variables for the program that will run in the context of the `name` process.
- `envServerRun()` initializes the server part of the `Env` program so that it can respond to IPC requests.

Env program usage examples

Examples of using Env to set the startup parameters and environment variables of programs

> Use of the `Env` system program is an outdated way of setting startup parameters and environment variables of programs. Instead, you must set the startup parameters and environment variables of programs via the `init.yaml.in` or `init.yaml` file.
> If the value of a startup parameter or environment variable of a program is defined through the `Env` program and via the `init.yaml.in` or `init.yaml` file, the value defined through the `Env` program will be applied.

Example of setting startup parameters of a program

Source code of the `Env` program is presented below. When the process named `NetVfs` starts, the program passes the following two program startup parameters to this process: `-l devfs /dev devfs 0` and `-l romfs /etc romfs ro`:

env.c

```
#include <env/env.h>
#include <stdlib.h>

int main(int argc, char** argv)
{
    const char* NetVfsArgs[] = {
        "-l", "devfs /dev devfs 0",
        "-l", "romfs /etc romfs ro"
    };
    ENV_REGISTER_ARGS("NetVfs", NetVfsArgs);

    envServerRun();
```

```
    return EXIT_SUCCESS;
}
```

Example of setting environment variables of a program

Source code of the `Env` program is presented below. When the process named `Vfs3` starts, the program passes the following two program environment variables to this process: `ROOTFS=ramdisk0,0 / ext2 0` and `UNMAP_ROMFS=1`:

env.c

```
#include <env/env.h>
#include <stdlib.h>

int main(int argc, char** argv)
{
    const char* Vfs3Envs[] = {
        "ROOTFS=ramdisk0,0 / ext2 0",
        "UNMAP_ROMFS=1"
    };

    ENV_REGISTER_VARS("Vfs3", Vfs3Envs);

    envServerRun();
    return EXIT_SUCCESS;
}
```

File systems and network

In KasperskyOS, operations with file systems and the network are executed via a separate system program that implements a virtual file system (VFS).

In the SDK, the VFS component consists of a set of executable files, libraries, formal specification files, and header files. For more details, see the Contents of the VFS component section.

The main scenario of interaction with the VFS system program includes the following:

1. An application connects via IPC channel to the VFS system program and then links to the client library of the VFS component during the build.
2. In the application code, POSIX calls for working with file systems and the network are converted into client library function calls.

   > Input and output to file handles for standard I/O streams (stdin, stdout and stderr) are also converted into queries to the VFS. If the application *is not linked* to the client library of the VFS component, printing to stdout is not possible. If this is the case, you can only print to the standard error stream (stderr), which in this case is performed via special methods of the KasperskyOS kernel without using VFS.

3. The client library makes IPC requests to the VFS system program.

4. The VFS system program receives an IPC requests and calls the corresponding file system implementations (which, in turn, may make IPC requests to device drivers) or network drivers.

5. After the request is handled, the VFS system program responds to the IPC requests of the application.

Using multiple VFS programs

Multiple copies of the VFS system program can be added to a solution for the purpose of separating the data streams of different system programs and applications. You can also separate the data streams within one application. For more details, refer to Using VFS backends to separate data streams.

Adding VFS functionality to an application

The complete functionality of the VFS component can be included in an application, thereby avoiding the need to pass each request via IPC. For more details, refer to Including VFS functionality in a program.

However, use of VFS functionality via IPC enables the solution developer to do the following:

- Use a solution security policy to control method calls for working with the network and file systems.
- Connect multiple client programs to one VFS program.
- Connect one client program to two VFS programs to separately work with the network and file systems.

Contents of the VFS component

The VFS component implements the virtual file system. In the KasperskyOS SDK, the VFS component consists of a set of executable files, libraries, formal specification files and header files that enable the use of file systems and/or a network stack.

VFS libraries

The `vfs` CMake package contains the following libraries:

- `vfs_fs` contains implementations of the devfs, ramfs and ROMFS file systems, and adds implementations of other file systems to VFS.
- `vfs_net` contains the implementation of the devfs file system and the network stack.
- `vfs_imp` contains the `vfs_fs` and `vfs_net` libraries.
- `vfs_remote` is the client transport library that converts local calls into IPC requests to VFS and receives IPC responses.
- `vfs_server` is the VFS server transport library that receives IPC requests, converts them into local calls, and sends IPC responses.
- `vfs_local` is used to include VFS functionality in a program.

VFS executable files

The `precompiled_vfs` CMake package contains the following executable files:

- `VfsRamFs`
- `VfsSdCardFs`
- `VfsNet`

The `VfsRamFs` and `VfsSdCardFs` executable files include the `vfs_server`, `vfs_fs`, `vfat` and `lwext4` libraries. The `VfsNet` executable file includes the `vfs_server`, `vfs_imp` libraries.

Each of these executable files has its own default values for startup parameters and environment variables.

Formal specification files and header files of VFS

The `sysroot-*-kos/include/kl` directory from the KasperskyOS SDK contains the following VFS files:

- Formal specification files `VfsRamFs.edl`, `VfsSdCardFs.edl`, `VfsNet.edl` and `VfsEntity.edl`, and the header files generated from them.
- Formal specification file `Vfs.cdl` and the header file `Vfs.cdl.h` generated from it.
- Formal specification files `Vfs*.idl` and the header files generated from them.

Libc library API supported by VFS

VFS functionality is available to programs through the API provided by the `libc` library.

The functions implemented by the `vfs_fs` and `vfs_net` libraries are presented in the table below. The `*` character denotes the functions that are optionally included in the `vfs_fs` library (depending on the library build parameters).

Functions implemented by the vfs_fs library

`mount()`	`unlink()`	`ftruncate()`	`lsetxattr()*`
`umount()`	`rmdir()`	`chdir()`	`fsetxattr()*`
`open()`	`mkdir()`	`fchdir()`	`getxattr()*`
`openat()`	`mkdirat()`	`chmod()`	`lgetxattr()*`
`read()`	`fcntl()`	`fchmod()`	`fgetxattr()*`
`readv()`	`statvfs()`	`fchmodat()`	`listxattr()*`
`write()`	`fstatvfs()`	`chroot()`	`llistxattr()*`
`writev()`	`getvfsstat()`	`fsync()`	`flistxattr()*`
`stat()`	`pipe()`	`fdatasync()`	`removexattr()*`
`lstat()`	`futimens()`	`pread()`	`lremovexattr()*`
`fstat()`	`utimensat()`	`pwrite()`	`fremovexattr()*`

fstatat()	link()	sendfile()	acl_set_file()*
lseek()	linkat()	getdents()	acl_get_file()*
close()	symlink()	sync()	acl_delete_def_file()*
rename()	symlinkat()	ioctl()	
renameat()	unlinkat()	setxattr()*	

Functions implemented by the vfs_net library

read()	bind()	getsockname()	recvfrom()
readv()	listen()	gethostbyname()	recvmsg()
write()	connect()	getnetbyaddr()	send()
writev()	accept()	getnetbyname()	sendto()
fstat()	poll()	getnetent()	sendmsg()
close()	shutdown()	setnetent()	ioctl()
fcntl()	getnameinfo()	endnetent()	sysctl()
fstatvfs()	getaddrinfo()	getprotobyname()	
pipe()	freeaddrinfo()	getprotobynumber()	
futimens()	getifaddrs()	getsockopt()	
socket()	freeifaddrs()	setsockopt()	
socketpair()	getpeername()	recv()	

> If there is no implementation of a called function in VFS, the `EIO` error code is returned.

Creating an IPC channel to VFS

In this example, the `Client` process uses the file systems and network stack, and the `VfsFsnet` process handles the IPC requests of the `Client` process related to the use of file systems and the network stack. This approach is utilized when there is no need to separate data streams related to file systems and the network stack.

The IPC channel name must be assigned by the `_VFS_CONNECTION_ID` macro defined in the header file `sysroot-*-kos/include/vfs/defs.h` from the KasperskyOS SDK.

Init description of the example:

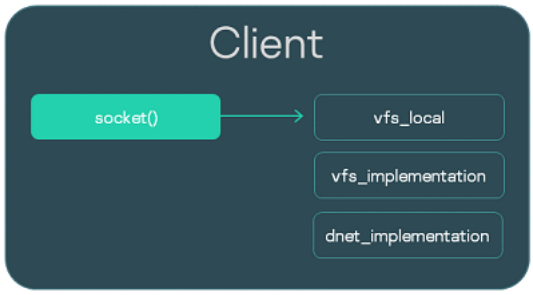
`init.yaml`

```
- name: Client
  connections:
  - target: VfsFsnet
    id: {var: _VFS_CONNECTION_ID, include: vfs/defs.h}

- name: VfsFsnet
```

Including VFS functionality in a program

In this example, the `Client` program includes the VFS program functionality for working with the network stack (see the figure below).



VFS component libraries in a program

The `client.c` implementation file is compiled and the `vfs_local`, `vfs_implementation` and `dnet_implementation` libraries are linked:

CMakeLists.txt

```
project (client)

include (platform/nk)

# Set compile flags
project_header_default ("STANDARD_GNU_11:YES" "STRICT_WARNINGS:NO")

# Generates the Client.edl.h file
nk_build_edl_files (client_edl_files NK_MODULE "client" EDL
"${CMAKE_SOURCE_DIR}/resources/edl/Client.edl")

add_executable (Client "src/client.c")
add_dependencies (Client client_edl_files)

# Linking with VFS libraries
target_link_libraries (Client ${vfs_LOCAL_LIB} ${vfs_IMPLEMENTATION_LIB}
${dnet_IMPLEMENTATION_LIB}
```

In case the `Client` program uses file systems, you must link the `vfs_local` and `vfs_fs` libraries, and the libraries for implementing these file systems. In this case, you must also add a block device driver to the solution.

Overview: startup parameters and environment variables of VFS

VFS program startup parameters

- `-l <entry in fstab format>`

  The startup parameter `-l` mounts the defined file system.

- `-f <path to fstab file>`

  The parameter `-f` mounts the file systems specified in the `fstab` file. If the `UNMAP_ROMFS` environment variable is not defined, the `fstab` file will be sought in the ROMFS image. If the `UNMAP_ROMFS` environment variable is defined, the `fstab` file will be sought in the file system defined through the `ROOTFS` environment variable.

Examples of using VFS program startup parameters

Environment variables of the VFS program

- `UNMAP_ROMFS`

  If the `UNMAP_ROMFS` environment variable is defined, the ROMFS image will be deleted from memory. This helps conserve memory. When using the startup parameter `-f`, it also provides the capability to search for the `fstab` file in the file system defined through the `ROOTFS` environment variable instead of searching the ROMFS image.

  Example of using the UNMAP_ROMFS environment variable

- `ROOTFS = <entry in fstab format>`

  The `ROOTFS` environment variable mounts the defined file system to the root directory. When using the startup parameter `-f`, a combination of the `ROOTFS` and `UNMAP_ROMFS` environment variables provides the capability to search for the `fstab` file in the file system defined through the `ROOTFS` environment variable instead of searching the ROMFS image.

  Example of using the ROOTFS environment variable

- `VFS_CLIENT_MAX_THREADS`

  The `VFS_CLIENT_MAX_THREADS` environment variable redefines the SDK configuration parameter `VFS_CLIENT_MAX_THREADS`.

- `_VFS_NETWORK_BACKEND=<VFS backend name>:<name of the IPC channel to the VFS process>`

  The `_VFS_NETWORK_BACKEND` environment variable defines the VFS backend for working with the network stack. You can specify the name of the standard VFS backend: `client` (for a program that runs in the context of a client process), `server` (for a VFS program that runs in the context of a server process) or `local`, and the name of a custom VFS backend. If the `local` VFS backend is used, the name of the IPC channel is not specified (`_VFS_NETWORK_BACKEND=local:`). You can specify more than one IPC channel by separating them with a comma.

- `_VFS_FILESYSTEM_BACKEND=<VFS backend name>:<name of the IPC channel to the VFS process>`

  The `_VFS_FILESYSTEM_BACKEND` environment variable defines the VFS backend for working with file systems. The name of the VFS backend and the name of the IPC channel to the VFS process are defined the same way as they are defined in the `_VFS_NETWORK_BACKEND` environment variable.

Default values for startup parameters and environment variables of VFS

For the `VfsRamFs` executable file:

```
ROOTFS = ramdisk0,0 / ext4 0
VFS_FILESYSTEM_BACKEND = server:kl.VfsRamFs
```

For the `VfsSdCardFs` executable file:

```
ROOTFS = mmc0,0 / fat32 0
VFS_FILESYSTEM_BACKEND = server:kl.VfsSdCardFs
-l nodev /tmp ramfs 0
-l nodev /var ramfs 0
```

For the `VfsNet` executable file:

```
VFS_NETWORK_BACKEND = server:kl.VfsNet
VFS_FILESYSTEM_BACKEND = server:kl.VfsNet
-l devfs /dev devfs 0
```

Mounting file systems when VFS starts

When the VFS program starts, only the RAMFS file system is mounted to the root directory by default. If you need to mount other file systems, this can be done not only by calling the `mount()` function but also by setting the startup parameters and environment variables of the VFS program.

> The `ROMFS` and `squashfs` file systems are intended for read-only operations. For this reason, you must specify the `ro` parameter to mount these file systems.

Using the startup parameter -l

One way to mount a file system is to set the startup parameter `-l <entry in fstab format>` for the VFS program.

In these examples, the devfs and ROMFS file systems will be mounted when the VFS program is started:

init.yaml.(in)

```
...
- name: VfsFirst
  args:
  - -l
  - devfs /dev devfs 0
  - -l
  - romfs /etc romfs ro
...
```

CMakeLists.txt

```
...
set_target_properties (${vfs_ENTITY} PROPERTIES
EXTRA_ARGS
"  - -l
  - devfs /dev devfs 0
  - -l
  - romfs /etc romfs ro")
...
```

Using the fstab file from the ROMFS image

When building a solution, you can add the `fstab` file to the ROMFS image. This file can be used to mount file systems by setting the startup parameter `-f <path to the fstab file>` for the VFS program.

In these examples, the file systems defined via the `fstab` file that was added to the ROMFS image during the solution build will be mounted when the VFS program is started:

`init.yaml.(in)`

```
...
- name: VfsSecond
  args:
  - -f
  - fstab
...
```

`CMakeLists.txt`

```
...
set_target_properties (${vfs_ENTITY} PROPERTIES
EXTRA_ARGS
"  - -f
  - fstab")
...
```

Using an "external" fstab file

If the `fstab` file resides in another file system instead of in the ROMFS image, you must set the following startup parameters and environment variables for the VFS program to enable use of this file:

1. `ROOTFS`. This environment variable mounts the file system containing the `fstab` file to the root directory.
2. `UNMAP_ROMFS`. If this environment variable is defined, the `fstab` file will be sought in the file system defined through the `ROOTFS` environment variable.
3. `-f`. This startup parameter is used to mount the file systems specified in the `fstab` file.

In these examples, the ext2 file system that should contain the `fstab` file at the path `/etc/fstab` will be mounted to the root directory when the VFS program starts:

`init.yaml.(in)`

```
...
- name: VfsThird
  args:
  - -f
  - /etc/fstab
  env:
    ROOTFS: ramdisk0,0 / ext2 0
    UNMAP_ROMFS: 1
...
```

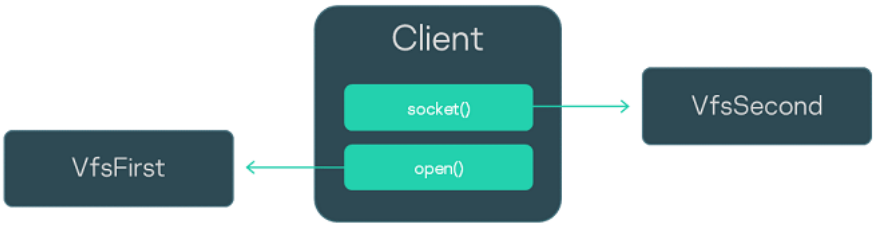
`CMakeLists.txt`

```
...
set_target_properties (${vfs_ENTITY} PROPERTIES
EXTRA_ARGS
"  - -f
  - /etc/fstab"
EXTRA_ENV
"  ROOTFS: ramdisk0,0 / ext2 0
  UNMAP_ROMFS: 1")
...
```

Using VFS backends to separate data streams

This example employs a secure development pattern that separates data streams related to file system use from data streams related to the use of a network stack.

The `Client` process uses file systems and the network stack. The `VfsFirst` process works with file systems, and the `VfsSecond` process provides the capability to work with the network stack. The environment variables of programs that run in the contexts of the `Client`, `VfsFirst` and `VfsSecond` processes are used to define the VFS backends that ensure the segregated use of file systems and the network stack. As a result, IPC requests of the `Client` process that are related to the use of file systems are handled by the `VfsFirst` process, and IPC requests of the `Client` process that are related to network stack use are handled by the `VfsSecond` process (see the figure below).



Process interaction scenario

Init description of the example:

init.yaml

```
entities:

- name: Client
  connections:
  - target: VfsFirst
    id: VFS1
  - target: VfsSecond
    id: VFS2
  env:
    _VFS_FILESYSTEM_BACKEND: client:VFS1
    _VFS_NETWORK_BACKEND: client:VFS2

- name: VfsFirst
  env:
    _VFS_FILESYSTEM_BACKEND: server:VFS1
```

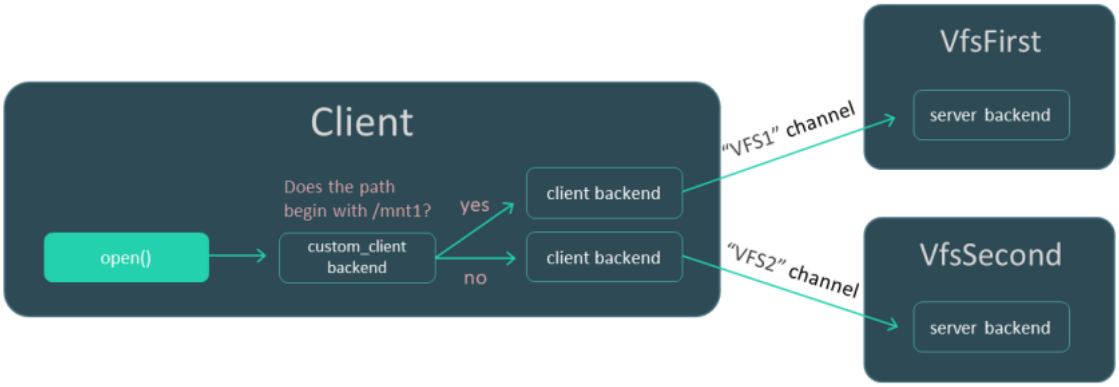
```
- name: VfsSecond
  env:
    _VFS_NETWORK_BACKEND: server:VFS2
```

Creating a VFS backend

This example demonstrates how to create and use a custom VFS backend.

The `Client` process uses the fat32 and ext4 file systems. The `VfsFirst` process works with the fat32 file system, and the `VfsSecond` process provides the capability to work with the ext4 file system. The environment variables of programs that run in the contexts of the `Client`, `VfsFirst` and `VfsSecond` processes are used to define the VFS backends ensuring that IPC requests of the `Client` process are handled by the `VfsFirst` or `VfsSecond` process depending on the specific file system being used by the `Client` process. As a result, IPC requests of the `Client` process related to use of the fat32 file system are handled by the `VfsFirst` process, and IPC requests of the `Client` process related to use of the ext4 file system are handled by the `VfsSecond` process (see the figure below).

On the `VfsFirst` process side, the fat32 file system is mounted to the directory `/mnt1`. On the `VfsSecond` process side, the ext4 file system is mounted to the directory `/mnt2`. The custom VFS backend `custom_client` used on the `Client` process side sends IPC requests over the IPC channel `VFS1` or `VFS2` depending on whether or not the file path begins with `/mnt1`. The custom VFS backend uses the standard VFS backend `client` as an intermediary.



Process interaction scenario

Source code of the VFS backend

This implementation file contains the source code of the VFS backend `custom_client`, which uses the standard `client` VFS backends:

backend.c

```
#include <vfs/vfs.h>

#include <stdio.h>
#include <stdlib.h>

#include <platform/compiler.h>
#include <pthread.h>
```

```
#include <errno.h>
#include <string.h>
#include <getopt.h>
#include <assert.h>

/* Code for managing file handles */
#define MAX_FDS 50

struct entry
{
    Handle handle;
    bool is_vfat;
};

struct fd_array
{
    struct entry entries[MAX_FDS];
    int pos;
    pthread_rwlock_t lock;
};

struct fd_array fds = { .pos = 0, .lock = PTHREAD_RWLOCK_INITIALIZER };

int insert_entry(Handle fd, bool is_vfat)
{
    pthread_rwlock_wrlock(&fds.lock);
    if (fds.pos == MAX_FDS)
    {
        pthread_rwlock_unlock(&fds.lock);
        return -1;
    }

    fds.entries[fds.pos].handle = fd;
    fds.entries[fds.pos].is_vfat = is_vfat;
    fds.pos++;

    pthread_rwlock_unlock(&fds.lock);
    return 0;
}

struct entry *find_entry(Handle fd)
{
    pthread_rwlock_rdlock(&fds.lock);
    for (int i = 0; i < fds.pos; i++)
    {
        if (fds.entries[i].handle == fd)
        {
            pthread_rwlock_unlock(&fds.lock);
            return &fds.entries[i];
        }
    }

    pthread_rwlock_unlock(&fds.lock);
    return NULL;
}

/* Custom VFS backend structure */
struct context
{
    struct vfs wrapper;
    pthread_rwlock_t lock;
```

```
    struct vfs *vfs_vfat;
    struct vfs *vfs_ext4;
};

struct context ctx =
{
    .wrapper =
    {
        .dtor = _vfs_backend_dtor,

        .disconnect_all_clients = _disconnect_all_clients,
        .getstdin = _getstdin,
        .getstdout = _getstdout,
        .getstderr = _getstderr,

        .open = _open,
        .read = _read,
        .write = _write,
        .close = _close,
    }
};

/* Implementation of custom VFS backend methods */
static bool is_vfs_vfat_path(const char *path)
{
    char vfat_path[5] = "/mnt1";
    if (memcmp(vfat_path, path, sizeof(vfat_path)) != 0)
        return false;

    return true;
}

static void _vfs_backend_dtor(struct vfs *vfs)
{
    ctx.vfs_vfat->dtor(ctx.vfs_vfat);
    ctx.vfs_ext4->dtor(ctx.vfs_ext4);
}

static void _disconnect_all_clients(struct vfs *self, int *error)
{
    (void)self;
    (void)error;

    ctx.vfs_vfat->disconnect_all_clients(ctx.vfs_vfat, error);
    ctx.vfs_ext4->disconnect_all_clients(ctx.vfs_ext4, error);
}

static Handle _getstdin(struct vfs *self, int *error)
{
    (void)self;

    Handle handle = ctx.vfs_vfat->getstdin(ctx.vfs_vfat, error);
    if (handle != INVALID_HANDLE)
    {
        if (insert_entry(handle, true))
        {
            *error = ENOMEM;
            return INVALID_HANDLE;
        }
    }

    return handle;
```

```
}

static Handle _getstdout(struct vfs *self, int *error)
{
    (void)self;

    Handle handle = ctx.vfs_vfat->getstdout(ctx.vfs_vfat, error);
    if (handle != INVALID_HANDLE)
    {
        if (insert_entry(handle, true))
        {
            *error = ENOMEM;
            return INVALID_HANDLE;
        }
    }

    return handle;
}

static Handle _getstderr(struct vfs *self, int *error)
{
    (void)self;

    Handle handle = ctx.vfs_vfat->getstderr(ctx.vfs_vfat, error);
    if (handle != INVALID_HANDLE)
    {
        if (insert_entry(handle, true))
        {
            *error = ENOMEM;
            return INVALID_HANDLE;
        }
    }

    return handle;
}

static Handle _open(struct vfs *self, const char *path, int oflag, mode_t mode, int
*error)
{
    (void)self;

    Handle handle;
    bool is_vfat = false;

    if (is_vfs_vfat_path(path))
    {
        handle = ctx.vfs_vfat->open(ctx.vfs_vfat, path, oflag, mode, error);
        is_vfat = true;
    }
    else
        handle = ctx.vfs_ext4->open(ctx.vfs_ext4, path, oflag, mode, error);

    if (handle == INVALID_HANDLE)
        return INVALID_HANDLE;

    if (insert_entry(handle, is_vfat))
    {
        if (is_vfat)
            ctx.vfs_vfat->close(ctx.vfs_vfat, handle, error);
        *error = ENOMEM;
        return INVALID_HANDLE;
    }
```

```
    return handle;
}

static ssize_t _read(struct vfs *self, Handle fd, void *buf, size_t count, bool
*nodata, int *error)
{
    (void)self;

    struct entry *found_entry = find_entry(fd);

    if (found_entry != NULL && found_entry->is_vfat)
        return ctx.vfs_vfat->read(ctx.vfs_vfat, fd, buf, count, nodata, error);

    return ctx.vfs_ext4->read(ctx.vfs_ext4, fd, buf, count, nodata, error);
}

static ssize_t _write(struct vfs *self, Handle fd, const void *buf, size_t count, int
*error)
{
    (void)self;

    struct entry *found_entry = find_entry(fd);

    if (found_entry != NULL && found_entry->is_vfat)
        return ctx.vfs_vfat->write(ctx.vfs_vfat, fd, buf, count, error);

    return ctx.vfs_ext4->write(ctx.vfs_ext4, fd, buf, count, error);
}

static int _close(struct vfs *self, Handle fd, int *error)
{
    (void)self;

    struct entry *found_entry = find_entry(fd);

    if (found_entry != NULL && found_entry->is_vfat)
        return ctx.vfs_vfat->close(ctx.vfs_vfat, fd, error);

    return ctx.vfs_ext4->close(ctx.vfs_ext4, fd, error);
}

/* Custom VFS backend builder. ctx.vfs_vfat and ctx.vfs_ext4 are initialized
 * as standard backends named "client". */
static struct vfs *_vfs_backend_create(Handle client_id, const char *config, int
*error)
{
    (void)config;

    ctx.vfs_vfat = _vfs_init("client", client_id, "VFS1", error);
    assert(ctx.vfs_vfat != NULL && "Can't initialize client backend!");
    assert(ctx.vfs_vfat->dtor != NULL && "VFS FS backend has not set the
destructor!");

    ctx.vfs_ext4 = _vfs_init("client", client_id, "VFS2", error);
    assert(ctx.vfs_ext4 != NULL && "Can't initialize client backend!");
    assert(ctx.vfs_ext4->dtor != NULL && "VFS FS backend has not set the
destructor!");

    return &ctx.wrapper;
}
```

```
/* Registration of the custom VFS backend under the name custom_client */
static void _vfs_backend(create_vfs_backend_t *ctor, const char **name)
{
    *ctor = &_vfs_backend_create;
    *name = "custom_client";
}

REGISTER_VFS_BACKEND(_vfs_backend)
```

Linking the Client program

Creating a static VFS backend library:

CMakeLists.txt

```
...
add_library (backend_client STATIC "src/backend.c")
...
```

Linking the `Client` program to the static VFS backend library:

CMakeLists.txt

```
...
add_dependencies (Client vfs_backend_client backend_client)

target_link_libraries (Client
    pthread
    ${vfs_CLIENT_LIB}
    "-Wl,--whole-archive" backend_client "-Wl,--no-whole-archive" backend_client
)
...
```

Setting the startup parameters and environment variables of programs

Init description of the example:

init.yaml

```
entities:

- name: vfs_backend.Client
  connections:
  - target: vfs_backend.VfsFirst
    id: VFS1
  - target: vfs_backend.VfsSecond
    id: VFS2
  env:
    _VFS_FILESYSTEM_BACKEND: custom_client:VFS1,VFS2

- name: vfs_backend.VfsFirst
  args:
  - -l
  - ahci0 /mnt1 fat32 0
```

```
  env:
    _VFS_FILESYSTEM_BACKEND: server:VFS1

- name: vfs_backend.VfsSecond
  - -l
  - ahci1 /mnt2 ext4 0
  env:
    _VFS_FILESYSTEM_BACKEND: server:VFS2
```

Dynamically configuring the network stack

To change the default network stack parameters, use the `sysctl()` function or `sysctlbyname()` function that are declared in the header file `sysroot-*-kos/include/sys/sysctl.h` from the KasperskyOS SDK. The parameters that can be changed are presented in the table below.

Configurable network stack parameters

Parameter name	Parameter description
`net.inet.ip.ttl`	Maximum time to live (TTL) of sent IP packets. It does not affect the ICMP protocol.
`net.inet.ip.mtudisc`	If its value is set to `1`, "Path MTU Discovery" (RFC 1191) mode is enabled. This mode affects the maximum size of a TCP segment (Maximum Segment Size, or MSS). In this mode, the MSS value is determined by the limitations of network nodes. If "Path MTU Discovery" mode is not enabled, the MSS value does not exceed the value defined by the `net.inet.tcp.mssdflt` parameter.
`net.inet.tcp.mssdflt`	MSS value (in bytes) that is applied if only the communicating side failed to provide this value when opening the TCP connection, or if "Path MTU Discovery" mode (RFC 1191) is not enabled. This MSS value is also forwarded to the communicating side when opening a TCP connection.
`net.inet.tcp.minmss`	Minimum MSS value, in bytes.
`net.inet.tcp.mss_ifmtu`	If its value is set to `1`, the MSS value is calculated for an opened TCP connection based on the maximum size of a transmitted data block (Maximum Transmission Unit, or MTU) of the employed network interface. If its value is set to `0`, the MSS value for an opened TCP connection is calculated based on the MTU of the network interface that has the highest value for this parameter among all available network interfaces (except the loopback interface).
`net.inet.tcp.keepcnt`	Number of times to send test messages (Keep-Alive Probes, or KA) without receiving a response before the TCP connection will be considered closed. If its value is set to `0`, the number of sent keep-alive probes is unlimited.
`net.inet.tcp.keepidle`	TCP connection idle period, after which keep-alive probes begin. This is defined in conditional units, which can be converted into seconds via division by the `net.inet.tcp.slowhz` parameter value.
`net.inet.tcp.keepintvl`	Time interval between recurring keep-alive probes when no response is received. This is defined in conditional units, which can be converted into seconds via division by the `net.inet.tcp.slowhz` parameter value.
`net.inet.tcp.recvspace`	Size of the buffer (in bytes) for data received over the TCP protocol.
`net.inet.tcp.sendspace`	Size of the buffer (in bytes) for data sent over the TCP protocol.

`net.inet.udp.recvspace`	Size of the buffer (in bytes) for data received over the UDP protocol.
`net.inet.udp.sendspace`	Size of the buffer (in bytes) for data sent over the UDP protocol.

MSS configuration example:

```
static const int mss_max = 1460;
static const int mss_min = 100;
static const char* mss_max_opt_name = "net.inet.tcp.mssdflt";
static const char* mss_min_opt_name = "net.inet.tcp.minmss";
int main(void)
{
...
    if ((sysctlbyname(mss_max_opt_name, NULL, NULL, &mss_max, sizeof(mss_max)) != 0)
||
       (sysctlbyname(mss_min_opt_name, NULL, NULL, &mss_min, sizeof(mss_min)) != 0))
    {
        ERROR(START, "Can't set tcp default maximum/minimum MSS value.");
        return EXIT_FAILURE;
    }
}
```

IPC and transport

Creating IPC channels

There are two methods for creating IPC channels: static and dynamic.

Static creation of IPC channels is simpler to implement because you can use the init description for this purpose.

Dynamic creation of IPC channels lets you change the topology of interaction between processes on the fly. This is necessary if it is unknown which specific server provides the endpoint required by the client. For example, you may not know which specific drive you will need to write data to.

Statically creating an IPC channel

Static creation of IPC channels has the following characteristics:

- The client and server are not yet running when the IPC channel is created.
- Creation of an IPC channel is performed by the parent process that starts the client and server (this is normally Einit).
- A deleted IPC channel cannot be restored.
- To get the IPC handle and the endpoint ID (riid) after an IPC channel is created, the client and server must use the API defined in the header file `sysroot-*-kos/include/coresrv/sl/sl_api.h` from the KasperskyOS SDK.

The IPC channels defined in the init description are statically created.

Dynamically creating an IPC channel

Dynamic creation of IPC channels has the following characteristics:

- The client and server are already running when the IPC channel is created.
- The IPC channel is jointly created by the client and server.
- A new IPC channel may be created in place of a deleted one.
- The client and server get the IPC handle and endpoint ID (riid) immediately after the IPC channel is successfully created.

Adding an endpoint from KasperskyOS Community Edition to a solution

To ensure that a `Client` program can use some specific functionality via the IPC mechanism, the following is required:

1. In KasperskyOS Community Edition, find the executable file (we'll call it `Server`) that implements the necessary functionality. (The term "functionality" used here refers to one or more endpoints that have their own IPC interfaces.)
2. Include the CMake package containing the `Server` file and its client library.
3. Add the `Server` executable file to the solution image.
4. Edit the init description so that when the solution starts, the `Einit` program starts a new server process from the `Server` executable file and connects it, using an IPC channel, to the process started from the `Client` file.

   > You must indicate the correct name of the IPC channel so that the transport libraries can identify this channel and find its IPC handles. The correct name of the IPC channel normally matches the name of the server process class. VFS is an exception in this case.

5. Edit the PSL description to allow startup of the server process and IPC interaction between the client and the server.
6. In the source code of the `Client` program, include the server methods header file.
7. Link the `Client` program with the client library.

Example of adding a GPIO driver to a solution

KasperskyOS Community Edition includes a `gpio_hw` file that implements GPIO driver functionality.

The following commands connect the gpio CMake package:

```
.\CMakeLists.txt
```

```
...
find_package (gpio REQUIRED COMPONENTS CLIENT_LIB ENTITY)
```

```
include_directories (${gpio_INCLUDE})
...
```

The `gpio_hw` executable file is added to a solution image by using the `gpio_HW_ENTITY` variable, whose name can be found in the configuration file of the package at `/opt/KasperskyOS-Community-Edition-<version>/sysroot-aarch64-kos/lib/cmake/gpio/gpio-config.cmake`:

einit\CMakeLists.txt

```
...
set (ENTITIES Client ${gpio_HW_ENTITY})
...
```

The following strings need to be added to the init description:

init.yaml.in

```
...
- name: client.Client
  connections:
  - target: kl.drivers.GPIO
    id: kl.drivers.GPIO

- name: kl.drivers.GPIO
  path: gpio_hw
```

The following strings need to be added to the PSL description:

security.psl.in

```
...
execute src=Einit, dst=kl.drivers.GPIO
{
    grant()
}

request src=client.Client, dst=kl.drivers.GPIO
{
    grant()
}

response src=kl.drivers.GPIO, dst=client.Client
{
    grant()
}
...
```

In the code of the `Client` program, you need to include the header file in which the GPIO driver methods are declared:

client.c

```
...
#include <gpio/gpio.h>
...
```

Finally, you need to link the `Client` program with the GPIO client library:

client\CMakeLists.txt

```
...
target_link_libraries (Client ${gpio_CLIENT_LIB})
...
```

> To ensure correct operation of the GPIO driver, you may need to add the BSP component to the solution. To avoid overcomplicating this example, BSP is not examined here. For more details, see the gpio_output example: `/opt/KasperskyOS-Community-Edition-<version>/examples/gpio_output`

Creating and using your own endpoints

Overview: IPC message structure

In KasperskyOS, all interactions between processes have statically defined types. The permissible structures of an IPC message are defined by the IDL descriptions of servers.

An IPC message (request and response) contains a constant part and an (optional) arena.

Constant part of an IPC message

The *constant part of an IPC message* contains the RIID, MID, and (optionally) fixed-size parameters of interface methods.

Fixed-size parameters are parameters that have IDL types of a fixed size.

The RIID and MID identify the interface and method being called:

- The RIID (Runtime Implementation ID) is the sequence number of the utilized endpoint within the set of server endpoints (starting at zero).
- The MID (Method ID) is the sequence number of the called method within the set of methods of the utilized endpoint (starting at zero).

The type of the constant part of the IPC message is generated by the NK compiler based on the IDL description of the interface. A separate structure is generated for each interface method. `Union` types are also generated for storing any request to a process, component or interface. For more details, refer to Example generation of transport methods and types.

IPC message arena

An *IPC message arena* (hereinafter also referred to as an *arena*) contains variable-size parameters of interface methods (and/or elements of these parameters).

Variable-size parameters are parameters that have IDL types of a variable size.

For more details, refer to "Working with an IPC message arena".

Maximum IPC message size

The maximum size of an IPC message is determined by the KasperskyOS kernel parameters. On most hardware platforms supported by KasperskyOS, the cumulative size of the constant part and arena of an IPC message cannot exceed 4, 8, or 16 MB.

IPC message structure verification by the security module

Prior to querying IPC message-related rules, the Kaspersky Security Module verifies that the sent IPC message is correct. Requests and responses are both validated. If the IPC message has an incorrect structure, it will be rejected without calling the security model methods associated with it.

Implementation of IPC interaction

To make it easier for a developer to implement IPC interaction, KasperskyOS Community Edition provides the following:

- NK compiler that generates transport methods and types.
- `Libkos` library that provides the API for working with IPC transport.

Implementation of simple IPC interaction is demonstrated in the echo and ping examples (`/opt/KasperskyOS-Community-Edition-<version>/examples/`).

Getting an IPC handle

The client and server IPC handles must be obtained if there are no ready-to-use transport libraries for the utilized endpoint (for example, if you wrote your own endpoint). To independently work with IPC transport, you need to first initialize it by using the `NkKosTransport_Init()` method and pass the IPC handle of the utilized channel as the second argument.

For more details, see the echo and ping examples (`/opt/KasperskyOS-Community-Edition-<version>/examples/`).

> You do not need to get an IPC handle to utilize endpoints that are implemented in executable files provided in KasperskyOS Community Edition. The provided transport libraries are used to perform all transport operations, including obtaining IPC handles.
> See the gpio_*, net_*, net2_* and multi_vfs_* examples (`/opt/KasperskyOS-Community-Edition-<version>/examples/`).

Getting an IPC handle when statically creating a channel

When statically creating an IPC channel, both the client and server can obtain their IPC handles immediately after startup by using the `ServiceLocatorRegister()` and `ServiceLocatorConnect()` methods and specifying the name of the created IPC channel.

For example, if the IPC channel is named `server_connection`, the following must be called on the client side:

```
#include <coresrv/sl/sl_api.h>
…
Handle handle = ServiceLocatorConnect("server_connection");
```

The following must be called on the server side:

```
#include <coresrv/sl/sl_api.h>
…
ServiceId id;
Handle handle = ServiceLocatorRegister("server_connection", NULL, 0, &id);
```

For more details, see the echo and ping examples (`/opt/KasperskyOS-Community-Edition-<version>/examples/`), and the header file `/opt/KasperskyOS-Community-Edition-<version>/sysroot-aarch64-kos/include/coresrv/sl/sl_api.h`.

> Closing an obtained IPC handle will cause the IPC channel to become unavailable. After an IPC handle is closed, it is impossible to obtain it again or restore access to the IPC channel.

Getting an IPC handle when dynamically creating a channel

Both the client and server receive their own IPC handles immediately after dynamic creation of an IPC channel is successful.

The client IPC handle is one of the output (`out`) arguments of the `KnCmConnect()` method. The server IPC handle is an output argument of the `KnCmAccept()` method. For more details, see the header file `/opt/KasperskyOS-Community-Edition-<version>/sysroot-aarch64-kos/include/coresrv/cm/cm_api.h`.

If the dynamically created IPC channel is no longer required, its client and server handles should be closed. The IPC channel can be created again if necessary.

Getting an endpoint ID (riid)

The endpoint ID (riid) must be obtained on the client side if there are no ready-to-use transport libraries for the utilized endpoint (for example, if you wrote your own endpoint). To call methods of the server, you must first call the proxy object initialization method on the client side and pass the endpoint ID as the third parameter. For example, for the `Filesystem` interface:

```
Filesystem_proxy_init(&proxy, &transport.base, riid);
```

For more details, see the echo and ping examples (`/opt/KasperskyOS-Community-Edition-<version>/examples/`).

> You do not need to get the endpoint ID to utilize endpoints that are implemented in executable files provided in KasperskyOS Community Edition. The provided transport libraries are used to perform all transport operations. See the gpio_*, net_*, net2_* and multi_vfs_* examples (`/opt/KasperskyOS-Community-Edition-<version>/examples/`).

Getting an endpoint ID when statically creating a channel

When statically creating an IPC channel, the client can obtain the ID of the necessary endpoint by using the `ServiceLocatorGetRiid()` method and specifying the IPC channel handle and the qualified name of the endpoint. For example, if the `OpsComp` component instance provides the `FS` endpoint, the following must be called on the client side:

```
#include <coresrv/sl/sl_api.h>
…
nk_iid_t riid = ServiceLocatorGetRiid(handle, "OpsComp.FS");
```

For more details, see the echo and ping examples (`/opt/KasperskyOS-Community-Edition-<version>/examples/`), and the header file `/opt/KasperskyOS-Community-Edition-<version>/sysroot-aarch64-kos/include/coresrv/sl/sl_api.h`.

Getting an endpoint ID when dynamically creating a channel

The client receives the endpoint ID immediately after dynamic creation of an IPC channel is successful. The client IPC handle is one of the output (`out`) arguments of the `KnCmConnect()` method. For more details, see the header file `/opt/KasperskyOS-Community-Edition-<version>/sysroot-aarch64-kos/include/coresrv/cm/cm_api.h`.

Example generation of transport methods and types

When building a solution, the NK compiler uses the EDL, CDL and IDL descriptions to generate a set of special methods and types that simplify the creation, forwarding, receipt and processing of IPC messages.

As an example, we will examine the `Server` process class that provides the `FS` endpoint, which contains a single `Open()` method:

`Server.edl`

```
entity Server

/* OpsComp is the named instance of the Operations component */
components {
    OpsComp: Operations
}
```

`Operations.cdl`

```
component Operations

/* FS is the local name of the endpoint implementing the Filesystem interface */
endpoints {
    FS: Filesystem
}
```

`Filesystem.idl`

```
package Filesystem

interface {
    Open(in string<256> name, out UInt32 h);
}
```

These descriptions will be used to generate the files named `Server.edl.h`, `Operations.cdl.h`, and `Filesystem.idl.h`, which contain the following methods and types:

Methods and types that are common to the client and server

- **Abstract interfaces containing the pointers to the implementations of the methods included in them.**

  In our example, one abstract interface (`Filesystem`) will be generated:

```
typedef struct Filesystem {
            const struct Filesystem_ops *ops;
        } Filesystem;

typedef nk_err_t
Filesystem_Open_fn(struct Filesystem *, const
                   struct Filesystem_Open_req *,
                   const struct nk_arena *,
                   struct Filesystem_Open_res *,
                   struct nk_arena *);

typedef struct Filesystem_ops {
            Filesystem_Open_fn *Open;
        } Filesystem_ops;
```

- **Set of interface methods.**

  When calling an interface method, the corresponding values of the RIID and MID are automatically inserted into the request.

  In our example, a single `Filesystem_Open` interface method will be generated:

```
nk_err_t Filesystem_Open(struct Filesystem *self,
                         struct Filesystem_Open_req *req,
                         const
                         struct nk_arena *req_arena,
                         struct Filesystem_Open_res *res,
                         struct nk_arena *res_arena)
```

Methods and types used only on the client

- **Types of proxy objects.**

  A proxy object is used as an argument in an interface method. In our example, a single `Filesystem_proxy` proxy object type will be generated:

```
typedef struct Filesystem_proxy {
            struct Filesystem base;
```

```
            struct nk_transport *transport;
            nk_iid_t iid;
        } Filesystem_proxy;
```

- **Functions for initializing proxy objects.**

  In our example, the single initializing function `Filesystem_proxy_init` will be generated:

```
void Filesystem_proxy_init(struct Filesystem_proxy *self,
                           struct nk_transport *transport,
                           nk_iid_t iid)
```

- **Types that define the structure of the constant part of a message for each specific method.**

  In our example, two such types will be generated: `Filesystem_Open_req` (for a request) and `Filesystem_Open_res` (for a response).

```
typedef struct __nk_packed Filesystem_Open_req {
            __nk_alignas(8)
            struct nk_message base_;
            __nk_alignas(4) nk_ptr_t name;
        } Filesystem_Open_req;

typedef struct Filesystem_Open_res {
            union {
                struct {
                    __nk_alignas(8)
                    struct nk_message base_;
                    __nk_alignas(4) nk_uint32_t h;
                };
                struct {
                    __nk_alignas(8)
                    struct nk_message base_;
                    __nk_alignas(4) nk_uint32_t h;
                } res_;
                struct Filesystem_Open_err err_;
            };
        } Filesystem_Open_res;
```

Methods and types used only on the server

- **Type containing all endpoints of a component, and the initializing function. (For each server component.)**

> If there are embedded components, this type also contains their instances, and the initializing function takes their corresponding initialized structures. Therefore, if embedded components are present, their initialization must begin with the most deeply embedded component.

In our example, the `Operations_component` structure and `Operations_component_init` function will be generated:

```
typedef struct Operations_component {
     struct Filesystem *FS;
};
```

```
void Operations_component_init(struct Operations_component *self,
                               struct Filesystem *FS)
```

- **Type containing all endpoints provided directly by the server; all instances of components included in the server; and the initializing function.**

  In our example, the `Server_entity` structure and `Server_entity_init` function will be generated:

```
#define Server_entity Server_component

typedef struct Server_component {
            struct : Operations_component *OpsComp;
        } Server_component;

void Server_entity_init(struct Server_entity *self,
                        struct Operations_component *OpsComp)
```

- **Types that define the structure of the constant part of a message for any method of a specific interface.**

  In our example, two such types will be generated: `Filesystem_req` (for a request) and `Filesystem_res` (for a response).

```
typedef union Filesystem_req {
    struct nk_message base_;
    struct Filesystem_Open_req Open;
};

typedef union Filesystem_res {
    struct nk_message base_;
    struct Filesystem_Open_res Open;
};
```

- **Types that define the structure of the constant part of a message for any method of any endpoint of a specific component.**

  > If embedded components are present, these types also contain structures of the constant part of a message for any method of any endpoint included in all embedded components.

  In our example, two such types will be generated: `Operations_component_req` (for a request) and `Operations_component_res` (for a response).

```
typedef union Operations_component_req {
            struct nk_message base_;
            Filesystem_req FS;
        } Operations_component_req;

typedef union Operations_component_res {
            struct nk_message base_;
            Filesystem_res FS;
        } Operations_component_res;
```

- **Types that define the structure of the constant part of a message for any method of any endpoint of a specific component whose instance is included in the server.**

> If embedded components are present, these types also contain structures of the constant part of a message for any method of any endpoint included in all embedded components.

In our example, two such types will be generated: `Server_entity_req` (for a request) and `Server_entity_res` (for a response).

```
#define Server_entity_req Server_component_req

typedef union Server_component_req {
            struct nk_message base_;
            Filesystem_req OpsComp_FS;
        } Server_component_req;

#define Server_entity_res Server_component_res

typedef union Server_component_res {
            struct nk_message base_;
            Filesystem_res OpsComp_FS;
        } Server_component_res;
```

- **Dispatch methods (dispatchers) for a separate interface, component, or process class.**

  Dispatchers analyze the received query (the RIID and MID values), call the implementation of the corresponding method, and then save the response in the buffer. In our example, three dispatchers will be generated: `Filesystem_interface_dispatch`, `Operations_component_dispatch`, and `Server_entity_dispatch`.

  The process class dispatcher handles the request and calls the methods implemented by this class. If the request contains an incorrect RIID (for example, an RIID for a different endpoint that this process class does not have) or an incorrect MID, the dispatcher returns `NK_EOK` or `NK_ENOENT`.

```
nk_err_t Server_entity_dispatch(struct Server_entity *self,
                                const
                                struct nk_message *req,
                                const
                                struct nk_arena *req_arena,
                                struct nk_message *res,
                                struct nk_arena *res_arena)
```

In special cases, you can use dispatchers of the interface and the component. They take an additional argument: interface implementation ID (`nk_iid_t`). The request will be handled only if the passed argument and RIID from the request match, and if the MID is correct. Otherwise, the dispatchers return `NK_EOK` or `NK_ENOENT`.

```
nk_err_t Operations_component_dispatch(struct Operations_component *self,
                                       nk_iid_t iidOffset,
                                       const
                                       struct nk_message *req,
                                       const
                                       struct nk_arena *req_arena,
                                       struct nk_message *res,
                                       struct nk_arena *res_arena)

nk_err_t Filesystem_interface_dispatch(struct Filesystem *impl,
                                       nk_iid_t iid,
                                       const
                                       struct nk_message *req,
```

```
                                        const
                                        struct nk_arena *req_arena,
                                        struct nk_message *res,
                                        struct nk_arena *res_arena)
```

Working with an IPC message arena

Arena overview

From the perspective of a developer of KasperskyOS-based solutions, an IPC message arena is a byte buffer in the memory of a process intended for storing variable-size data transmitted over IPC. This variable-size data includes input parameters, output parameters, and error parameters of interface methods (and/or elements of these parameters) that have variable-size IDL types. An arena is also used when querying the Kaspersky Security Module to store input parameters of security interface methods (and/or elements of these parameters) that have variable-size IDL types. (Parameters of fixed-size interface methods are stored in the constant part of an IPC message.) Arenas are used on the client side and on the server side. One arena is intended either for transmitting or for receiving variable-size data through IPC, but not for both transmitting and receiving this data at the same time. In other words, arenas can be divided into IPC request arenas (containing input parameters of interface methods) and IPC response arenas (containing output parameters and error parameters of interface methods).

Only the utilized part of an arena that is occupied by data is transmitted over IPC. (If it has no data, the arena is not transmitted.) The utilized part of an arena includes one or more segments. One segment of an arena stores an array of same-type objects, such as an array of single-byte objects or an array of structures. Arrays of different types of objects may be stored in different segments of an arena. The starting address of an arena must be equal to the boundary of a *2^N*-byte sequence, where *2^N* is a value that is greater than or equal to the size of the largest primitive type in the arena (for example, the largest field of a primitive type in a structure). The address of an arena chunk must also be equal to the boundary of a *2^N*-byte sequence, where *2^N* is a value that is greater than or equal to the size of the largest primitive type in the arena chunk.

An arena must have multiple segments if the interface method has multiple variable-size input, output, or error parameters, or if multiple elements of input, output, or error parameters of the interface method have a variable size. For example, if an interface method has an input parameter of the `sequence` IDL type and an input parameter of the `bytes` IDL type, the IPC request arena will have at least two segments. In this case, it may even require additional segments if a parameter of the `sequence` IDL type consists of elements of a variable-size IDL type (for example, if elements of a sequence are `string` buffers). As another example, if an interface method has one output parameter of the `struct` IDL type that contains two fields of the `bytes` and `string` type, the IPC response arena will have two segments.

Due to the alignment of arena chunk addresses, there may be unused intervals between these chunks. Therefore, the size of the utilized part of an arena may exceed the size of the data it contains.

API for working with an arena

The set of functions and macros for working with an arena is defined in the header file `sysroot-*-kos/include/nk/arena.h` from the KasperskyOS SDK. In addition, the function for copying a string to an arena is declared in the header file `sysroot-*-kos/include/coresrv/nk/transport-kos.h` from the KasperskyOS SDK.

Information on the functions and macros defined in the header file `sysroot-*-kos/include/nk/arena.h` is provided in the table below. In these functions and macros, an arena and arena chunk are identified by an arena descriptor (the `nk_arena` type) and an arena chunk descriptor (the `nk_ptr_t` type), respectively. An *arena descriptor* is a structure containing three pointers: one pointer to the start of the arena, one pointer to the start of the unused part of the arena, and one pointer to the end of the arena. An *arena chunk descriptor* is a structure containing the offset of the arena chunk in bytes (relative to the start of the arena) and the size of the arena chunk in bytes. (The arena chunk descriptor type is defined in the header file `sysroot-*-kos/include/nk/types.h` from the KasperskyOS SDK.)

Creating an arena

To pass variable-size parameters of interface methods over IPC, you must create arenas on the client side and on the server side. (When IPC requests are handled on the server side using the `NkKosDoDispatch()` function defined in the header file `sysroot-*-kos/include/coresrv/nk/transport-kos-dispatch.h` from the KasperskyOS SDK, the IPC request arena and IPC response arena are created automatically.)

To create an arena, you must create a buffer (in the stack or heap) and initialize the arena descriptor.

The address of the buffer must be aligned to comply with the maximum size of a primitive type that can be put into this buffer. The address of a dynamically created buffer usually has adequate alignment to hold the maximum amount of data of the primitive type. To ensure the required alignment of the address of a statically created buffer, you can use the `alignas` specifier.

To initialize an arena descriptor using the pointer to an already created buffer, you must use an API function or macro:

- `NK_ARENA_INITIALIZER()` macro
- `nk_arena_init()` function
- `nk_arena_create()` function
- `NK_ARENA_FINAL()` macro
- `nk_arena_init_final()` macro

The type of pointer makes no difference because this pointer is converted into a pointer to a single-byte object in the code of API functions and macros.

The `NK_ARENA_INITIALIZER()` macro and the `nk_arena_init()` and `nk_arena_create()` functions initialize arena descriptor that may contain one or more segments. The `NK_ARENA_FINAL()` and `nk_arena_init_final()` macros initialize arena descriptor that contains only one segment spanning the entire arena throughout its entire life cycle.

To create a buffer in the stack and initialize the handle in one step, use the `NK_ARENA_AUTO()` macro. This macro creates an arena that may contain one or more segments, and the address of the buffer created by this macro has adequate alignment to hold the maximum amount of data of the primitive type.

The size of an arena must be sufficient to hold variable-size parameters for IPC requests or IPC responses of one interface method or a set of interface methods corresponding to one interface, component, or process class while accounting for the alignment of segment addresses. Automatically generated transport code (the header files `*.idl.h`, `*.cdl.h`, and `*.edl.h`) contain `*_arena_size` constants whose values are guaranteed to comply with sufficient sizes of arenas in bytes.

The header files `*.idl.h`, `*.cdl.h`, and `*.edl.h` contain the following `*_arena_size` constants:

- `<interface name>_<interface method name>_req_arena_size` – size of an IPC request arena for the specified interface method of the specified interface
- `<interface name>_<interface method name>_res_arena_size` – size of an IPC response arena for the specified interface method of the specified interface
- `<interface name>_req_arena_size` – size of an IPC request arena for any interface method of the specified interface
- `<interface name>_res_arena_size` – size of an IPC response arena for any interface method of the specified interface

The header files `*.cdl.h` and `*.edl.h` also contain the following `*_arena_size` constants:

- `<component name>_component_req_arena_size` – size of an IPC request arena for any interface method of the specified component
- `<component name>_component_res_arena_size` – size of an IPC response arena for any interface method of the specified component

The `*.edl.h` header files also contain the following `*_arena_size` constants:

- `<process class name>_entity_req_arena_size` – size of an IPC request arena for any interface method of the specified process class
- `<process class name>_entity_res_arena_size` – size of an IPC response arena for any interface method of the specified process class

Constants containing the size of an IPC request arena or IPC response arena for one interface method (`<interface name>_<interface method name>_req_arena_size` and `<interface name>_<interface method name>_res_arena_size`) are intended for use on the client side. All other constants can be used on the client side and on the server side.

Examples of creating an arena:

```
/* Example 1 */
alignas(8) char reqBuffer[Write_WriteInLog_req_arena_size];
struct nk_arena reqArena = NK_ARENA_INITIALIZER(
                            reqBuffer, reqBuffer + sizeof(reqBuffer));

/* Example 2 */
struct nk_arena res_arena;
char res_buf[kl_rump_DhcpcdConfig_GetOptionNtpServers_res_arena_size];
nk_arena_init(&res_arena, res_buf, res_buf + sizeof(res_buf));

/* Example 3 */
char req_buffer[kl_CliApplication_Run_req_arena_size];
struct nk_arena req_arena = nk_arena_create(req_buffer, sizeof(req_buffer));

/* Example 4 */
nk_ptr_t ptr;
const char *cstr = "example";
nk_arena arena = NK_ARENA_FINAL(&ptr, cstr, strlen(cstr));

/* Example 5 */
const char *path = "path_to_file";
size_t len = strlen(path);
/* Structure for saving the constant part of an IPC request */
```

```
struct kl_VfsFilesystem_Rmdir_req req;
struct nk_arena req_arena;
nk_arena_init_final(&req_arena, &req.path, path, len);

/* Example 6 */
struct nk_arena res_arena = NK_ARENA_AUTO(kl_Klog_component_res_arena_size);
```

Adding data to an arena before transmission over IPC

Before transmitting an IPC request on the client side or an IPC response on the server side, data must be added to the arena. If the `NK_ARENA_FINAL()` macro or the `nk_arena_init_final()` macro is used to create an arena, you do not need to reserve an arena chunk. Instead, you only need to add data to this chunk. If the `NK_ARENA_INITIALIZER()` or `NK_ARENA_AUTO()` macro, or the `nk_arena_init()` or `nk_arena_create()` function is used to create an arena, one or multiple segments in the arena must be reserved to hold data. To reserve an arena chunk, you must use an API function or macro:

- `__nk_arena_alloc()` function
- `nk_arena_store()` macro
- `__nk_arena_store()` function
- `nk_arena_alloc()` macro
- `NkKosCopyStringToArena()` function

The arena chunk descriptor, which is passed through the output parameter of these functions and macros and through the output parameter of the `NK_ARENA_FINAL()` and `nk_arena_init_final()` macros, must be put into the constant part or into the arena of an IPC message. If an interface method has a variable-size parameter, the constant part of IPC messages contains arena chunk descriptor containing the parameter instead of the actual parameter. If an interface method has a fixed-size parameter with variable-size elements, the constant part of IPC messages contains arena chunk descriptors containing the parameter elements instead of the actual parameter elements. If an interface method has a variable-size parameter containing variable-size elements, the constant part of IPC messages contains arena chunk descriptor containing the descriptors of other arena chunks that contain these parameter elements.

The `nk_arena_store()` macro and the `__nk_arena_store()` and `NkKosCopyStringToArena()` functions not only reserve an arena chunk, but also copy data to this chunk.

The `nk_arena_alloc()` macro gets the address of a reserved arena chunk. An arena chunk address can also be received by using the `__nk_arena_get()` function or the `nk_arena_get()` macro, which additionally pass the arena size through the output parameter.

A reserved arena chunk can be reduced. To do so, use the `nk_arena_shrink()` macro or the `_nk_arena_shrink()` function.

To undo a current reservation of arena chunks so that new chunks can be reserved for other data (after sending an IPC message), call the `nk_arena_reset()` function. If the `NK_ARENA_FINAL()` macro or `nk_arena_init_final()` macro is used to create an arena, you do not need to undo a segment reservation because the arena contains one segment spanning the entire arena throughout its entire life cycle.

Examples of adding data to an arena:

```
/* Example 1 */
char req_buffer[kl_rump_NpfctlFilter_TableAdd_req_arena_size];
```

```
struct nk_arena req_arena = NK_ARENA_INITIALIZER(req_buffer, req_buffer +
sizeof(req_buffer));
/* Structure for saving the constant part of an IPC request */
struct kl_rump_NpfctlFilter_TableAdd_req req;
if (nk_arena_store(char, &req_arena, &req.tid, tid, tidlen))
    return ENOMEM;
if (nk_arena_store(char, &req_arena, &req.cidrAddr, cidr_addr, cidr_addrlen))
    return ENOMEM;

/* Example 2 */
char req_arena_buf[StringMaxSize];
struct nk_arena req_arena = NK_ARENA_INITIALIZER(req_arena_buf,
                                        req_arena_buf + sizeof(req_arena_buf));
/* Structure for saving the constant part of an IPC request */
kl_drivers_FBConsole_SetFont_req req;
size_t buf_size = strlen(fileName) + 1;
char *buf = nk_arena_alloc(char, &req_arena, &req.fileName, buf_size);
memcpy(buf, fileName, buf_size);

/* Example 3 */
char reqArenaBuf[kl_core_DCM_req_arena_size];
struct nk_arena reqArena
    = NK_ARENA_INITIALIZER(reqArenaBuf,
                           reqArenaBuf + sizeof(reqArenaBuf));
/* Structure for saving the constant part of an IPC request */
kl_core_DCM_Subscribe_req req;
rc = NkKosCopyStringToArena(&reqArena, &req.endpointType, endpointType);
if (rc != rcOk)
    return rc;
rc = NkKosCopyStringToArena(&reqArena, &req.endpointName, endpointName);
if (rc != rcOk)
    return rc;
rc = NkKosCopyStringToArena(&reqArena, &req.serverName, serverName);
if (rc != rcOk)
    return rc;

/* Example 4 */
unsigned counter = 0;
nk_ptr_t *paths;
/* Reserve an arena chunk for descriptors of other arena chunks */
paths = nk_arena_alloc(nk_ptr_t, resArena, &res->logRes, msgCount);
while(...)
{
    ...
    /* Reserve arena chunks and save their descriptors in
     * a previously reserved arena chunk with the paths address */
    char *str = nk_arena_alloc(
                                        char,
                                        resArena,
                                        &paths[counter],
                                        stringLength + 1);
    if (str == NK_NULL)
        return NK_ENOMEM;
    snprintf(str, (stringLength + 1), "%s", buffer);
    ...
    counter++;
}
```

Retrieving data from an arena after receipt over IPC

Prior to receiving an IPC request on the server side or an IPC response on the client side for an arena that will store the data received over IPC, you must undo the current reservation of segments by calling the `nk_arena_reset()` function. This must be done even if the `NK_ARENA_FINAL()` macro or the `nk_arena_init_final()` macro is used to create the arena. (The `NK_ARENA_INITIALIZER()` and `NK_ARENA_AUTO()` macros, and the `nk_arena_init()` and `nk_arena_create()` functions create an arena without reserved segments. You do not need to call the `nk_arena_reset()` function if this arena will only be used once to save data received over IPC.)

To receive pointers to arena chunks and the sizes of these chunks, you must use the `__nk_arena_get()` function or the `nk_arena_get()` macro while using the input parameter to pass the corresponding arena chunk descriptors received from the constant part and arena of the IPC message.

Example of receiving data from an arena:

```
struct nk_arena res_arena;
char res_buf[kl_rump_DhcpcdConfig_Version_res_ver_size];
nk_arena_init(&res_arena, res_buf, res_buf + sizeof(res_buf));
/* Structure for saving an IPC request */
struct kl_rump_DhcpcdConfig_Version_req req;
req.buflen = buflen;
/* Structure for saving an IPC response */
struct kl_rump_DhcpcdConfig_Version_res res;
/* Call the interface method */
if (kl_rump_DhcpcdConfig_Version(dhcpcd.proxy, &req, NULL, &res, &res_arena) !=
NK_EOK)
    return -1;
size_t ptrlen;
char *ptr = nk_arena_get(char, &res_arena, &res.ver, &ptrlen);
memcpy(buf, ptr, ptrlen);
```

Additional capabilities of the API

To get the arena size, call the `nk_arena_capacity()` function.

To get the size of the utilized part of the arena, call the `nk_arena_allocated_size()` function.

To verify that the arena chunk descriptor is correct, use the `nk_arena_validate()` macro or the `__nk_arena_validate()` function.

Information about API functions and macros

Functions and macros of arena.h

Function/Macro	Information about the function/macro
`NK_ARENA_INITIALIZER()`	Purpose Initializes the arena descriptor. Parameters • [in] `_start` – pointer to the start of the arena. • [in] `_end` – pointer to the end of the arena. Macro values

	Arena descriptor initialization code.
`nk_arena_init()`	Purpose Initializes the arena descriptor. Parameters • [out] `self` – pointer to the arena descriptor. • [in] `start` – pointer to the start of the arena. • [in] `end` – pointer to the end of the arena. Returned values N/A
`nk_arena_create()`	Purpose Creates and initializes the arena descriptor. Parameters • [in] `start` – pointer to the start of the arena. • [in] `size` – arena size in bytes. Returned values Arena descriptor.
`NK_ARENA_AUTO()`	Purpose Creates a buffer in the stack, and creates and initializes the arena descriptor. Parameters • [in] `size` – arena size in bytes. It must be defined as a constant. Macro values Arena descriptor.
`NK_ARENA_FINAL()`	Purpose Initializes the arena descriptor containing only one segment. Parameters • [out] `ptr` – pointer to the arena chunk descriptor. • [in] `start` – pointer to the start of the arena. • [in] `count` – number of objects in the arena chunk.

	Macro values Arena descriptor.
`nk_arena_reset()`	Purpose Resets the reservation of arena chunks. Parameters • [in,out] `self` – pointer to the arena descriptor. Returned values N/A
`__nk_arena_alloc()`	Purpose Reserves an arena chunk with a specific size and a specific alignment. Parameters • [in,out] `self` – pointer to the arena descriptor. • [out] `ptr` – pointer to the arena chunk descriptor. • [in] `size` – arena chunk size in bytes. • [in] `align` – value defining the arena chunk alignment. The arena chunk address can be unaligned (*align=1*) or aligned (*align=2,4,...,2^N*) to the boundary of a *2^N*-byte sequence (for example, two-byte or four-byte). Returned values If successful, the function returns `NK_EOK`, otherwise it returns an error code.
`nk_arena_capacity()`	Purpose Gets the size of an arena. Parameters • [in] `self` – pointer to the arena descriptor. Returned values Size of the arena in bytes. Additional information If the parameter has the `NK_NULL` value, it returns `0`.
`nk_arena_validate()`	Purpose Verifies that the arena chunk descriptor is correct.

	Parameters • [in] `type` – type of objects for which the arena chunk is intended. • [in] `arena` – pointer to the arena descriptor. • [in] `ptr` – pointer to the arena chunk descriptor. Macro values It has a value of `0` when the arena size is not zero if all of the following conditions are fulfilled: 1. The offset specified in the arena chunk descriptor does not exceed the arena size. 2. The size specified in the arena chunk descriptor does not exceed the arena size reduced by the offset specified in the arena chunk descriptor. 3. The size specified in the arena chunk descriptor is a multiple of the size of the type of objects for which this arena chunk is intended. It has a value of `0` when the arena size is zero if all of the following conditions are fulfilled: 1. The offset specified in the arena chunk descriptor is equal to zero. 2. The size specified in the arena chunk descriptor is equal to zero. It has a value of `-1` if even one of the conditions is not fulfilled (regardless of whether the arena size is zero or non-zero), or if the `ptr` parameter has the `NK_NULL` value.
`__nk_arena_validate()`	Purpose Verifies that the arena chunk descriptor is correct. Parameters • [in] `self` – pointer to the arena descriptor. • [in] `ptr` – pointer to the arena chunk descriptor. Returned values Returns `0` when the arena size is not zero if all of the following conditions are fulfilled: 1. The offset specified in the arena chunk descriptor does not exceed the arena size. 2. The size specified in the arena chunk descriptor does not exceed the arena size reduced by the offset specified in the arena chunk descriptor.

	Returns `0` when the arena size is zero if all of the following conditions are fulfilled: 1. The offset specified in the arena chunk descriptor is equal to zero. 2. The size specified in the arena chunk descriptor is equal to zero. Returns `-1` if even one of the conditions is not fulfilled (regardless of whether the arena size is zero or non-zero), or if the `ptr` parameter has the `NK_NULL` value.
`__nk_arena_get()`	Purpose Gets the pointer to the arena chunk and the size of this chunk. Parameters • [in] `self` – pointer to the arena descriptor. • [in] `ptr` – pointer to the arena chunk descriptor. • [out] `size` – arena chunk size in bytes. Returned values Pointer to the arena chunk or `NK_NULL` if even one parameter has the `NK_NULL` value.
`nk_arena_allocated_size()`	Purpose Gets the size of the utilized part of the arena. Parameters • [in] `self` – pointer to the arena descriptor. Returned values Size of the utilized part of the arena, in bytes. Additional information If the parameter has the `NK_NULL` value, it returns `0`.
`nk_arena_store()`	Purpose Reserves an arena chunk for the specified number of objects of the defined type and copies these objects to the reserved chunk. Parameters • [in] `type` – type of objects that need to be copied to the arena chunk. • [in,out] `arena` – pointer to the arena descriptor. • [out] `ptr` – pointer to the arena chunk descriptor.

	• [in] `src` – pointer to the buffer containing the objects that need to be copied to the arena chunk. • [in] `count` – number of objects that need to be copied to the arena chunk. Macro values It has a value of `0` if successful, otherwise it has a value of `-1`.
`__nk_arena_store()`	Purpose Reserves an arena chunk with a defined alignment for data of a specific size and copies this data to the reserved segment. Parameters • [in,out] `self` – pointer to the arena descriptor. • [out] `ptr` – pointer to the arena chunk descriptor. • [in] `src` – pointer to the buffer containing the data that needs to be copied to the arena chunk. • [in] `size` – size of the data that needs to be copied to the arena chunk, in bytes. • [in] `align` – value defining the arena chunk alignment. The arena chunk address can be unaligned (*align=1*) or aligned (*align=2,4,...,2^N*) to the boundary of a *2^N*-byte sequence (for example, two-byte or four-byte). Returned values Returns `0` if successful, otherwise returns `-1`.
`nk_arena_init_final()`	Purpose Initializes the arena descriptor containing only one segment. Parameters • [out] `arena` – pointer to the arena descriptor. • [out] `ptr` – pointer to the arena chunk descriptor. • [in] `start` – pointer to the start of the arena. • [in] `count` – number of objects for which the arena chunk is intended. Macro values N/A
`nk_arena_alloc()`	Purpose

	Reserves an arena chunk for the defined number of objects of the specified type. Parameters • [in] `type` – type of objects for which the arena chunk is intended. • [in,out] `arena` – pointer to the arena descriptor. • [out] `ptr` – pointer to the arena chunk descriptor. • [in] `count` – number of objects for which the arena chunk is intended. Macro values It has the address of the reserved arena chunk if successful, otherwise `NK_NULL`.
`nk_arena_get()`	Purpose Gets the address of an arena chunk and the number of objects of the specified type that can be put into this chunk. Parameters • [in] `type` – type of objects for which the arena chunk is intended. • [in] `arena` – pointer to the arena descriptor. • [in] `ptr` – pointer to the arena chunk descriptor. • [out] `count` – pointer to the number of objects that can be put into the arena chunk. Macro values It has the address of the arena chunk if successful, otherwise `NK_NULL`. Additional information If the size of the arena chunk is not a multiple of the size of the type of objects for which this chunk is intended, it has the `NK_NULL` value.
`nk_arena_shrink()`	Purpose Reduces the size of an arena chunk. Parameters • [in] `type` – type of objects for which the reduced arena chunk is intended. • [in,out] `arena` – pointer to the arena descriptor. • [in,out] `ptr` – pointer to the arena chunk descriptor.

	• [in] `count` – number of objects for which the reduced arena chunk is intended. Macro values It has the address of the reduced arena chunk if successful, otherwise `NK_NULL`. Additional information If the required size of the arena chunk exceeds the current size, it has the `NK_NULL` value. If the alignment of the arena chunk that needs to be reduced does not match the type of objects for which the reduced chunk is intended, it has the `NK_NULL` value. If the arena chunk that needs to be reduced is the last chunk in the arena, the freed part of this chunk will become available for reservation of subsequent chunks.
`_nk_arena_shrink()`	Purpose Reduces the size of an arena chunk. Parameters • [in,out] `self` – pointer to the arena descriptor. • [in,out] `ptr` – pointer to the arena chunk descriptor. • [in] `size` – size of the reduced arena chunk, in bytes. • [in] `align` – value used by the function to verify alignment of the arena chunk that needs to be reduced. The arena chunk address can be unaligned (*align=1*) or aligned (*align=2,4,...,2^N*) to the boundary of a *2^N*-byte sequence (for example, two-byte or four-byte). Returned values Returns the address of the reduced arena chunk if successful, otherwise returns `NK_NULL`. Additional information If the required size of the arena chunk exceeds the current size, it returns `NK_NULL`. If the alignment of the arena chunk that needs to be reduced does not match the specified alignment, it returns `NK_NULL`. If the arena chunk that needs to be reduced is the last chunk in the arena, the freed part of this chunk will become available for reservation of subsequent chunks.

Transport code in C++

> Before reading this section, you should review the information on the IPC mechanism in KasperskyOS and the IDL, CDL, and EDL descriptions.

Implementation of interprocess interaction requires transport code, which is responsible for generating, sending, receiving, and processing IPC messages.

However, a developer of a KasperskyOS-based solution does not have to write their own transport code. Instead, you can use the special tools and libraries included in the KasperskyOS SDK. These libraries enable a solution component developer to generate transport code based on IDL, CDL and EDL descriptions related to this component.

Transport code

The KasperskyOS SDK includes the `nkppmeta` compiler for generating transport code in C++.

The `nkppmeta` compiler lets you generate transport C++ proxy objects and stubs for use by both a client and a server.

Proxy objects are used by the client to pack the parameters of the called method into an IPC request, execute the IPC request, and unpack the IPC response.

Stubs are used by the server to unpack the parameters from the IPC request, dispatch the call to the appropriate method implementation, and pack the IPC response.

Generating transport code for development in C++

The `CMake` commands add_nk_idl(), add_nk_cdl() and add_nk_edl() are used to generate transport proxy objects and stubs using the `nkppmeta` compiler when building a solution.

C++ types in the *.idl.cpp.h file

Each interface is defined in an IDL description. This description defines the interface name, signatures of interface methods, and data types for the parameters of interface methods.

The `CMake` command add_nk_idl() is used to generate transport code when building a solution. This command creates a `CMake` target for generating header files for the defined IDL file when using the `nkppmeta` compiler.

The generated header files contain a C++ representation for the interface and data types described in the IDL file, and the methods required for use of proxy objects and stubs.

The mapping of data types declared in an IDL file to C++ types are presented in the table below.

Mapping IDL types to C++ types

IDL type	C++ type
`SInt8`	`int8_t`

`SInt16`	`int16_t`
`SInt32`	`int32_t`
`SInt64`	`int64_t`
`UInt8`	`uint8_t`
`UInt16`	`uint16_t`
`UInt32`	`uint32_t`
`UInt64`	`uint64_t`
`Handle`	`Handle` (defined in `coresrv/handle/handletype.h`)
`string`	`std::string`
`union`	`std::variant`
`struct`	`struct`
`array`	`std::array`
`sequence`	`std::vector`
`bytes`	`std::vector<std::byte>`

Working with transport code in C++

The scenarios for developing a client and server that exchange IPC messages are presented in the sections titled Statically creating IPC channels for C++ development and Dynamically creating IPC channels for C++ development.

Statically creating IPC channels for C++ development

To implement a client program that calls a method of an endpoint provided by a server program:

1. Include the generated header file (`*.edl.cpp.h`) of the client program description.
2. Include the generated header files of the descriptions of the utilized interfaces (`*.idl.cpp.h`).
3. Include the header files:
   - `/opt/KasperskyOS-Community-Edition-<version>/sysroot-*-kos/include/kosipc/application.h`
   - `/opt/KasperskyOS-Community-Edition-<version>/sysroot-*-kos/include/kosipc/api.h`
   - `/opt/KasperskyOS-Community-Edition-<version>/sysroot-*-kos/include/kosipc/connect_static_channel.h`
4. Initialize the application object by calling the `kosipc::MakeApplicationAutodetect()` function. (You can also use the `kosipc::MakeApplication()` and `kosipc::MakeApplicationPureClient()` functions.)
5. Get the client IPC handle of the channel and the endpoint ID (`riid`) by calling the `kosipc::ConnectStaticChannel()` function.

   This function gets the name of the IPC channel (from the init.yaml file) and the qualified name of the endpoint (from the CDL and EDL descriptions of the solution component).

6. Initialize the proxy object for the utilized endpoint by calling the `MakeProxy()` function.

Example

```
// Create and initialize the application object
kosipc::Application app = kosipc::MakeApplicationAutodetect();

// Create and initialize the proxy object
auto proxy = app.MakeProxy<IDLInterface>(
     kosipc::ConnectStaticChannel(channelName, endpointName))

// Call the method of the required endpoint
proxy->DoSomeWork();
```

To implement a server program that provides endpoints to other programs:

1. Include the generated header file `*.edl.cpp.h` containing a description of the component structure of the program, including all provided endpoints.

2. Include the header files:

   - `/opt/KasperskyOS-Community-Edition-<version>/sysroot-*-kos/include/kosipc/event_loop.h`
   - `/opt/KasperskyOS-Community-Edition-<version>/sysroot-*-kos/include/kosipc/api.h`
   - `/opt/KasperskyOS-Community-Edition-<version>/sysroot-*-kos/include/kosipc/serve_static_channel.h`

3. Create classes containing the implementations of interfaces that this program and its components provide as endpoints.

4. Initialize the application object by calling the `kosipc::MakeApplicationAutodetect()` function.

5. Initialize the `kosipc::components::Root` structure, which describes the component structure of the program and describes the interfaces of all endpoints provided by the program.

6. Bind fields of the `kosipc::components::Root` structure to the objects that implement the corresponding endpoints.

   Fields of the `Root` structure replicate the hierarchy of components and endpoints that are collectively defined by the CDL and EDL files.

7. Get the server IPC handle of the channel by calling the `ServeStaticChannel()` function.

   This function gets the name of the IPC channel (from the init.yaml file) and the structure created at step 5.

8. Create the `kosipc::EventLoop` object by calling the `MakeEventLoop()` function.

9. Start the loop for dispatching incoming IPC messages by calling the `Run()` method of the `kosipc::EventLoop` object.

Example

```
// Create class objects that implement interfaces
// provided by the server as endpoints
```

```
MyIDLInterfaceImp_1 impl_1;
MyIDLInterfaceImp_2 impl_2;

// Create and initialize the application object
kosipc::Application app = kosipc::MakeApplicationAutodetect();

// Create and initialize the root object that describes
// the components and endpoints of the server
kosipc::components::Root    root;

// Bind the root object to the class objects that implement the server endpoints
root.component1.endpoint1 = &impl_1;
root.component2.endpoint2 = &impl_2;

// Create and initialize the object that implements the
// loop for dispatching incoming IPC messages
kosipc::EventLoop    loop = app.MakeEventLoop(ServeStaticChannel(channelName, root));

// Start the loop in the current thread
loop.Run();
```

Dynamically creating IPC channels for C++ development

Dynamic creation of an IPC channel on the client side includes the following steps:

1. Include the generated description header file (`*.edl.cpp.h`) in the client program.
2. Include the generated header files of the descriptions of the utilized interfaces (`*.idl.cpp.h`).
3. Include the header files:
   - `/opt/KasperskyOS-Community-Edition-<version>/sysroot-*-kos/include/kosipc/application.h`
   - `/opt/KasperskyOS-Community-Edition-<version>/sysroot-*-kos/include/kosipc/make_application.h`
   - `/opt/KasperskyOS-Community-Edition-<version>/sysroot-*-kos/include/kosipc/connect_dynamic_channel.h`
4. Get the pointers to the server name and the qualified name of the endpoint by using a name server, which is a special kernel service provided by the `NameServer` program. To do so, you must connect to the name server by calling the `NsCreate()` function and find the server that provides the required endpoint by using the `NsEnumServices()` function. For more details, refer to Dynamically creating IPC channels (cm_api.h, ns_api.h).
5. Create an application object by calling the `kosipc::MakeApplicationAutodetect()` function. (You can also use the `kosipc::MakeApplication()` and `kosipc::MakeApplicationPureClient()` functions.)
6. Create a proxy object for the required endpoint by calling the `MakeProxy()` function. Use the `kosipc::ConnectDynamicChannel()` function call as the input parameter of the `MakeProxy()` function. Pass the pointers for the server name and qualified name of the endpoint obtained at step 4 to the `kosipc::ConnectDynamicChannel()` function.

After successful initialization of the proxy object, the client can call methods of the required endpoint.

Example

```
NsHandle ns;

// Connect to a name server
Retcode rc = NsCreate(RTL_NULL, INFINITE_TIMEOUT, &ns);

char serverName[kl_core_Types_UCoreStringSize];
char endpointName[kl_core_Types_UCoreStringSize];

// Get pointers to the server name and qualified name of the endpoint
rc = NsEnumServices(
     ns, interfaceName, 0,
     serverName, kl_core_Types_UCoreStringSize,
     endpointName, kl_core_Types_UCoreStringSize);

// Create and initialize the application object
kosipc::Application app = kosipc::MakeApplicationAutodetect();

// Create and initialize the proxy object
auto proxy = app.MakeProxy<IDLInterface>(
     kosipc::ConnectDynamicChannel(serverName, endpointName))

// Call the method of the required endpoint
proxy->DoSomeWork();
```

Dynamic creation of an IPC channel on the server side includes the following steps:

1. Include the generated header file (`*.edl.cpp.h`) containing a description of the component structure of the server, including all provided endpoints, in the server program.

2. Include the header files:

   - `/opt/KasperskyOS-Community-Edition-<version>/sysroot-*-kos/include/kosipc/application.h`
   - `/opt/KasperskyOS-Community-Edition-<version>/sysroot-*-kos/include/kosipc/event_loop.h`
   - `/opt/KasperskyOS-Community-Edition-<version>/sysroot-*-kos/include/kosipc/make_application.h`
   - `/opt/KasperskyOS-Community-Edition-<version>/sysroot-*-kos/include/kosipc/root_component.h`
   - `/opt/KasperskyOS-Community-Edition-<version>/sysroot-*-kos/include/kosipc/serve_dynamic_channel.h`
   - `/opt/KasperskyOS-Community-Edition-<version>/sysroot-*-kos/include/kosipc/simple_connection_acceptor.h`

3. Create classes containing the implementations of interfaces that the server provides as endpoints. Create and initialize the objects of these classes.

4. Create an application object by calling the `kosipc::MakeApplicationAutodetect()` function.

5. Create and initialize the `kosipc::components::Root` class object that describes the structure of components and endpoints of the server. This structure is generated from the descriptions in the CDL and EDL files.

6. Bind the `kosipc::components::Root` class object to the class objects created at step 3.

7. Create and initialize the `kosipc::EventLoop` class object that implements a loop for dispatching incoming IPC messages by calling the `MakeEventLoop()` function. Use the `ServeDynamicChannel()` function call as an input parameter of the `MakeEventLoop()` function. Pass the `kosipc::components::Root` class object created at step 5 to the `ServeDynamicChannel()` function.

8. Start the loop for dispatching incoming IPC messages in a separate thread by calling the `Run()` method of the `kosipc::EventLoop` object.

9. Create and initialize the object that implements the handler for receiving incoming requests to dynamically create an IPC channel.

   When creating an object, you can use the `kosipc::SimpleConnectionAcceptor` class, which is the standard implementation of the `kosipc::IConnectionAcceptor` interface. (The `kosipc::IConnectionAcceptor` interface is defined in the file named `/opt/KasperskyOS-Community-Edition-<version>/sysroot-*-kos/include/kosipc/connection_acceptor.h`.) In this case, the handler will implement the following logic: if the endpoint requested by the client was published on the server, the request from the client will be accepted. Otherwise, it will be rejected.

   If you need to create your own handler, you should implement your own request handling logic in the `OnConnectionRequest()` method inherited from the `kosipc::IConnectionAcceptor` interface. This method will be called by the server when it receives a request for dynamic IPC channel creation from the client.

10. Create a `kosipc::EventLoop` class object that implements a loop for receiving incoming requests to dynamically create an IPC channel by calling the `MakeEventLoop()` function. Use the `ServeConnectionRequests()` function call as an input parameter of the `MakeEventLoop()` function. Pass the object created at step 9 to the `ServeConnectionRequests()` function.

    > There can only be one loop for receiving incoming requests to dynamically create an IPC channel. The loop must work in one thread. The loop for receiving incoming requests to dynamically create an IPC channel must be created after the loop for dispatching incoming IPC channels is created (see step 7).

11. Start the loop for receiving incoming requests for a dynamic connection in the current thread by calling the `Run()` method of the `kosipc::EventLoop` object.

Example

```
// Create class objects that implement interfaces
// provided by the server as endpoints
MyIDLInterfaceImp_1 impl_1;
MyIDLInterfaceImp_2 impl_2;

// Create and initialize the application object
kosipc::Application app = kosipc::MakeApplicationAutodetect();

// Create and initialize the root object that describes
// the components and endpoints of the server
kosipc::components::Root    root;

// Bind the root object to the class objects that implement the server endpoints.
// The fields of the root object repeat the description of components and endpoints
// defined collectively by the CDL and EDL files.
```

```
root.component1.endpoint1 = &impl_1;
root.component2.endpoint2 = &impl_2;

// Create and initialize the object that implements the
// loop for dispatching incoming IPC messages
kosipc::EventLoop   loopDynamicChannel = app.MakeEventLoop(ServeDynamicChannel(root));

// Start the loop for dispatching incoming IPC messages in a separate thread
std::thread     dynChannelThread(
    [&loopDynamicChannel]() {
        loopDynamicChannel.Run();
    }
);

// Create an object that implements a standard handler for receiving incoming requests
// to dynamically create an IPC channel
kosipc::SimpleConnectionAcceptor    acceptor(root);

// Create an object that implements a loop for receiving incoming requests
// to dynamically create an IPC channel
kosipc::EventLoop   loopDynamicChannel =
app.MakeEventLoop(ServeConnectionRequests(&acceptor));

// Start the loop for receiving incoming requests to dynamically create an IPC channel
in the current thread
loopConnectionReq.Run();
```

If necessary, you can create and initialize multiple `kosipc::components::Root` class objects combined into a list of objects of the `ServiceList` type using the `AddServices()` method. For example, use of multiple objects enables you to separate components and endpoints of the server into groups or publish endpoints under different names.

Example

```
// Create and initialize the group_1 object
kosipc::components::Root    group_1;

group_1.component1.endpoint1 = &impl_1;
group_1.component2.endpoint2 = &impl_2;

// Create and initialize the group_2 object
kosipc::components::Root    group_2;

group_2.component1.endpoint1 = &impl_3;
group_2.component2.endpoint2 = &impl_4;

// Create and initialize the group_3 object
kosipc::components::Root group_3;

group_3.component1.endoint1 = &impl_5;

// Create a list of objects
ServiceList endpoints;
endpoints.AddServices(group_1);
endpoints.AddServices(group_2);
endpoints.AddServices(group_3.component1.endpoint1, "SomeCustomEndpointName");

// Create an object that implements the handler for receiving incoming requests
// to dynamically create an IPC channel
kosipc::SimpleConnectionAcceptor    acceptor(std::move(endpoints));
```

```
// Create an object that implements a loop for receiving incoming requests
// to dynamically create an IPC channel
kosipc::EventLoop   loopDynamicChannel =
app.MakeEventLoop(ServeConnectionRequests(&acceptor));
```

Return codes

Overview

In a KasperskyOS-based solution, the return codes of functions of various APIs (for example, APIs of the `libkos` and `kdf` libraries, drivers, transport code, and application software) are 32-bit signed integers. This type is defined in the `sysroot-*-kos/include/rtl/retcode.h` header file from the KasperskyOS SDK as follows:

```
typedef __INT32_TYPE__ Retcode;
```

The set of return codes consists of a success code with a value of `0` and error codes. An error code is interpreted as a data structure whose format is described in the `sysroot-*-kos/include/rtl/retcode.h` header file from the KasperskyOS SDK. This format provides for multiple fields that contain not only information about the results of a function call, but also the following additional information:

- Flag in the `Customer` field indicating that the error code was defined by the developers of the KasperskyOS-based solution and not by the developers of software from the KasperskyOS SDK.

  Thanks to the flag in the `Customer` field, developers of a KasperskyOS-based solution and developers of software from the KasperskyOS SDK can define error codes from non-overlapping sets.

- Global ID of the error code in the `Space` field.

  Global IDs let you define non-overlapping sets of error codes. Error codes can be generic or specific. Generic error codes can be used in the APIs of any solution components and in the APIs of any constituent parts of solution components (for example, a driver or VFS may be a constituent part of a solution component). Specific error codes are used in the APIs of one or more solution components or in the APIs of one or more constituent parts of solution components.

  For example, the `RC_SPACE_GENERAL` ID corresponds to generic errors, the `RC_SPACE_KERNEL` ID corresponds to error codes of the kernel, and the `RC_SPACE_DRIVERS` ID corresponds to error codes of drivers.

- Local ID of the error code in the `Facility` field.

  Local IDs let you define non-overlapping subsets of error codes within the set of error codes corresponding to one global ID. For example, the set of error codes with the global ID `RC_SPACE_DRIVERS` includes non-overlapping subsets of error codes with the local IDs `RC_FACILITY_I2C`, `RC_FACILITY_USB`, and `RC_FACILITY_BLKDEV`.

The global and local IDs of specific error codes are assigned by the developers of a KasperskyOS-based solution and by the developers of software from the KasperskyOS SDK independently of each other. In other words, two sets of global IDs are generated. Each global ID has a unique meaning within one set. Each local ID has a unique meaning within a set of local IDs related to one global ID. Generic error codes can be used in any API.

This type of centralized approach helps avoid situations in which the same error codes have various meanings within a KasperskyOS-based solution. This is necessary to eliminate a potential problem transmitting error codes through different APIs. For example, this problem occurs when drivers call `kdf` library functions, receive error codes, and return these codes through their own APIs. If error codes are generated without a centralized approach, the same error code can have different meanings for the `kdf` library and for the driver. Under these conditions, drivers return correct error codes only if the error codes of the `kdf` library are converted into error codes of each driver. In other words, error codes in a KasperskyOS-based solution are assigned in such way that does not require conversion of these codes during their transit through various APIs.

The information about return codes provided here does not apply to functions of a POSIX interface or the APIs of third-party software used in KasperskyOS-based solutions.

Generic return codes

Return codes that are generic for APIs of all solution components and their constituent parts are defined in the `sysroot-*-kos/include/rtl/retcode.h` header file from the KasperskyOS SDK. Descriptions of generic return codes are provided in the table below.

Generic return codes

Return code	Description
`rcOk` (corresponds to the `0` value)	The function completed successfully.
`rcInvalidArgument`	Invalid function parameter.
`rcNotConnected`	No connection between the client and server sides of interaction. For example, there is no server IPC handle.
`rcOutOfMemory`	Insufficient memory to perform the operation.
`rcBufferTooSmall`	Insufficient buffer size.
`rcInternalError`	The function ended with an internal error related to incorrect logic. Some examples of internal errors include values outside of the permissible limits, and null indicators and values where they are not permitted.
`rcTransferError`	Error sending an IPC message.
`rcReceiveError`	Error receiving an IPC message.
`rcSourceFault`	IPC message was not transmitted due to the IPC message source.
`rcTargetFault`	IPC message was not transmitted due to the IPC message recipient.
`rcIpcInterrupt`	IPC was interrupted by another process thread.
`rcRestart`	Indicates that the function needs to be called again.
`rcFail`	The function ended with an error.
`rcNoCapability`	The operation cannot be performed on the resource.
`rcNotReady`	Initialization failed.
`rcUnimplemented`	The function was not implemented.
`rcBufferTooLarge`	Large buffer size.
`rcBusy`	Resource temporarily unavailable.
`rcResourceNotFound`	Resource not found.
`rcTimeout`	Timed out.
`rcSecurityDisallow`	The operation was denied by security mechanisms.
`rcFutexWouldBlock`	The operation will result in a block.
`rcAbort`	The operation was aborted.
`rcInvalidThreadState`	Invalid function called in the interrupt handler.
	Set of elements already contains the element being added.

`rcAlreadyExists`	
`rcInvalidOperation`	Operation cannot be completed.
`rcHandleRevoked`	Resource access rights were revoked.
`rcQuotaExceeded`	Resource quota exceeded.
`rcDeviceNotFound`	Device not found.
`rcOverflow`	An overflow occurred.
`rcAlreadyDone`	Operation has already been completed.

Defining error codes

To define an error code, the developer of a KasperskyOS-based solution needs to use the `MAKE_RETCODE()` macro defined in the `sysroot-*-kos/include/rtl/retcode.h` header file from the KasperskyOS SDK. The developer must also use the `customer` parameter to pass the symbolic constant `RC_CUSTOMER_TRUE`.

Example:

```
#define LV_EBADREQUEST MAKE_RETCODE(RC_CUSTOMER_TRUE, RC_SPACE_APPS,
RC_FACILITY_LogViewer, 5, "Bad request")
```

> An error description that is passed via the `desc` parameter is not used by the `MAKE_RETCODE()` macro. This description is needed to create a database of error codes when building a KasperskyOS-based solution. At present, a mechanism for creating and using such a database has not been implemented.

Reading error code structure fields

The `RC_GET_CUSTOMER()`, `RC_GET_SPACE()`, `RC_GET_FACILITY()` and `RC_GET_CODE()` macros defined in the `sysroot-*-kos/include/rtl/retcode.h` header file from the KasperskyOS SDK let you read error code structure fields.

The `RETCODE_HR_PARAMS()` and `RETCODE_HR_FMT()` macros defined in the `sysroot-*-kos/include/rtl/retcode_hr.h` header file from the KasperskyOS SDK are used for formatted display of error details.

libkos library

The `libkos` library is the basic KasperskyOS library that provides the set of APIs that allow programs and other libraries (for example, `libc` and `kdf`) to use core endpoints. The APIs provided by the `libkos` library enable solution developers to do the following:

- Manage processes, threads, and virtual memory.
- Control access to resources.
- Perform input/output operations.
- Create IPC channels.

- Manage power.
- Obtain statistical data on the system.
- Use other capabilities supported by core endpoints.

This section contains detailed descriptions for working with some `libkos` library interfaces. Descriptions of other interfaces can be found in corresponding header files.

The header files that define the `libkos` library API are located in the following directories:

- `sysroot-*-kos/include/coresrv/`
- `sysroot-*-kos/include/kos/`

Managing handles (handle_api.h)

The API is defined in the `sysroot-*-kos/include/coresrv/handle/handle_api.h` header file from the KasperskyOS SDK.

The API is intended for performing operations with handles. Handles have the `Handle` type, which is defined in the header file `sysroot-*-kos/include/handle/handletype.h` from the KasperskyOS SDK.

Locality of handles

Each process receives handles from its own handle space irrespective of other processes. The handle spaces of different processes are absolutely identical in that they consist of the same set of values. Therefore, a handle is unique (has a unique value) only within the handle space of the single process that owns the particular handle. In other words, different processes may have identical handles that identify different resources, or may have different handles that identify the same resource.

Handle permissions mask

A handle permissions mask has a size of 32 bits and consists of a general part and a specialized part. The general part describes the general rights that are not specific to any particular resource (the flags of these rights are defined in the header file `sysroot-*-kos/include/services/ocap.h` from the KasperskyOS SDK). For example, the general part contains the `OCAP_HANDLE_TRANSFER` flag, which defines the permission to transfer the handle. The specialized part describes the rights that are specific to the particular user resource or system resource. The flags of the specialized part's permissions for system resources are defined in the `ocap.h` header file. The structure of the specialized part for user resources is defined by the resource provider by using the `OCAP_HANDLE_SPEC()` macro that is defined in the `ocap.h` header file. The resource provider must export the public header files describing the flags of the specialized part.

When the handle of a system resource is created, the permissions mask is defined by the KasperskyOS kernel, which applies permissions masks from the `ocap.h` header file. It applies permissions masks with names such as `OCAP_*_FULL` (for example, `OCAP_IOPORT_FULL`, `OCAP_TASK_FULL`, `OCAP_FILE_FULL`) and `OCAP_IPC_*` (for example, `OCAP_IPC_SERVER`, `OCAP_IPC_LISTENER`, `OCAP_IPC_CLIENT`).

When the handle of a user resource is created, the permissions mask is defined by the user.

When a handle is transferred, the permissions mask is defined by the user but the transferred access rights cannot be elevated above the access rights of the process.

Creating handles

Creating handles of system resources

Handles of system resources are created when these resources are created. For example, handles are created when an interrupt or MMIO memory region is registered, and when a DMA buffer, thread, or process is created.

Creating handles of user resources

Handles of user resources are created by the providers of these resources by using the `KnHandleCreateUserObject()` or `KnHandleCreateUserObjectEx()` function.

The context of a user resource must be defined through the `context` parameter. The *user resource context* consists of data that allows the resource provider to identify the resource and its state when access to the resource is requested by other processes. This normally consists of a data set with various types of data (structure). For example, the context of a file may include the name, path, and cursor position. The user resource context is used as the resource transfer context or is used together with multiple resource transfer contexts.

You must use the `rights` parameter to define the handle permissions mask.

Creating IPC handles

An *IPC handle* is a handle that identifies an IPC channel. IPC handles are used to execute system calls. A client IPC handle is necessary for executing a `Call()` system call. A server IPC handle is necessary for executing the `Recv()` and `Reply()` system calls. A *listener handle* is a server IPC handle that has extended rights allowing it to add IPC channels to the set of IPC channels identified by this handle. A *callable handle* is a client IPC handle that simultaneously identifies the IPC channel to a server and an endpoint of this server.

A server creates a callable handle and passes it to a client so that the client can use the server endpoint. The client initializes IPC transport by using the callable handle that it received. In addition, the client specifies the `INVALID_RIID` value as the endpoint ID (RIID) in the proxy object initialization function. To create a callable handle, call the `KnHandleCreateUserObjectEx()` function and specify the server IPC handle and the endpoint ID (RIID) in the `ipcChannel` and `riid` parameters, respectively. Use the `context` parameter to specify the data to be associated with the callable handle. The server will be able to receive the pointer to this data when dereferencing the callable handle. (Even though the callable handle is an IPC handle, the kernel puts it into the `base_.self` field of the constant part of an IPC request.)

To create the client IPC handle, server IPC handle, and listener IPC handle and associate them with each other, call the `KnHandleConnect()` or `KnHandleConnectEx()` function. These functions are used to statically create IPC channels. The `KnHandleConnect()` function creates IPC handles from the handle space of the calling process. However, the client IPC handle can be transferred to another process. The `KnHandleConnectEx()` function can create IPC handles from the handle space of the calling process or from the handle spaces of other processes, such as the client and server.

When calling the `KnHandleConnect()` or `KnHandleConnectEx()` function with the `INVALID_HANDLE` value in the parameter that defines the listener handle, a new listener handle is created. However, the server IPC handle and listener IPC handle in the output parameters are the same handle. If a listener handle is specified when calling the `KnHandleConnect()` or `KnHandleConnectEx()` function, the created server IPC handle will provide the capability to receive IPC requests over all IPC channels associated with this listener handle. In this case, the server IPC handle and listener IPC handle in the output parameters are different handles. (The first IPC channel associated with the listener handle is created when calling the `KnHandleConnect()` or `KnHandleConnectEx()` function with the `INVALID_HANDLE` value in the parameter that defines the listener handle. The second and subsequent IPC channels associated with the listener handle are created during the second and subsequent calls of the `KnHandleConnect()` or `KnHandleConnectEx()` function specifying the listener handle that was obtained during the first call.)

To call a listener handle that is not associated with a client IPC handle and server IPC handle, call the `KnHandleCreateListener()` function. (The `KnHandleConnect()` and `KnHandleConnectEx()` functions create a listener handle associated with a client IPC handle and server IPC handle.) The `KnHandleCreateListener()` function is convenient for creating a listener handle that will be subsequently bound to callable handles.

To create a client IPC handle for querying the Kaspersky Security Module through the security interface, call the `KnHandleSecurityConnect()` function. This function is called by the `libkos` library when initializing IPC transport for querying the security module.

Information about API functions

handle_api.h functions

Function	Information about the function
`KnHandleCreateUserObject()`	Purpose Creates a handle. Parameters • [in] `type` – handle type. Fictitious parameter that must take a value ranging from the `HANDLE_TYPE_USER_FIRST` constant to the `HANDLE_TYPE_USER_LAST` constant as defined in the header file `sysroot-*-kos/include/handle/handletype.h` from the KasperskyOS SDK. • [in] `rights` – handle permissions mask. • [in,optional] `context` – pointer to the data that should be associated with the handle, or `RTL_NULL` if this association is not required. • [out] `handle` – pointer to the handle. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnHandleCreateUserObjectEx()`	Purpose Creates a handle.

	Parameters • [in] `type` – handle type. Fictitious parameter that must take a value ranging from the `HANDLE_TYPE_USER_FIRST` constant to the `HANDLE_TYPE_USER_LAST` constant as defined in the header file `sysroot-*-kos/include/handle/handletype.h` from the KasperskyOS SDK. • [in] `rights` – handle permissions mask. • [in,optional] `context` – pointer to the data that should be associated with the handle, or `RTL_NULL` if this association is not required. • [in,optional] `ipcChannel` – server IPC handle, or `INVALID_HANDLE` if you do not need to create a callable handle. • [in,optional] `riid` – endpoint ID (RIID), or `INVALID_RIID` if you do not need to create a callable handle. • [out] `handle` – pointer to the handle. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnHandleConnect()`	Purpose Creates and connects the client, server, and listener IPC handles. Parameters • [in,optional] `ls` – listener handle, or `INVALID_HANDLE` if you need to create it. • [out,optional] `outLs` – pointer to the listener handle. You can specify `RTL_NULL` if the `ls` parameter is used to define the listener handle. • [out,optional] `outSr` – pointer to the server IPC handle, or `RTL_NULL` to not create a server IPC handle if the `ls` parameter is used to define the listener handle. • [out] `outCl` – pointer to the client IPC handle. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnHandleConnectEx()`	Purpose Creates and connects the client, server, and listener IPC handles. Parameters

	• [in] `server` – handle of the server process. • [in,optional] `srListener` – listener handle from the handle space of the server process, or `INVALID_HANDLE` if you need to create it. • [in] `client` – handle of the client process. • [out,optional] `outSrListener` – pointer to the listener handle from the handle space of the server process. You can specify `RTL_NULL` if the `srListener` parameter is used to define the listener handle. • [out,optional] `outSrEndpoint` – pointer to the server IPC handle from the handle space of the server process, or `RTL_NULL` to not create a server IPC handle if the `srListener` parameter is used to define the listener handle. • [out] `outClEndpoint` – pointer to the client IPC handle from the handle space of the client process. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnHandleSecurityConnect()`	Purpose Creates a client IPC handle for querying the Kaspersky Security Module through the security interface. Parameters • [out] `client` – pointer to the handle. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnHandleCreateListener()`	Purpose Creates a listener handle that is not associated with a client IPC handle and server IPC handle. Parameters • [out] `listener` – pointer to the listener handle. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.

Transferring handles

Overview

Handles are transferred between processes so that resource consumers can gain access to required resources. Due to the specific locality of handles, a handle transfer initiates the creation of a handle from the handle space of the recipient process. This handle is registered as a descendant of the transferred handle and identifies the same resource.

One handle can be transferred multiple times to one or more processes. Each transfer initiates the creation of a new descendant of the transferred handle on the recipient process side. A process can transfer handles that it received from other processes or the KasperskyOS kernel. For this reason, a handle may have multiple generations of descendants. The generation hierarchy of handles for each resource is stored in the KasperskyOS kernel in the form of a *handle inheritance tree*.

A process can transfer handles for user resources and system resources if the access rights of these handles permit such a transfer (the `OCAP_HANDLE_TRANSFER` flag is set in the permissions mask). A descendant may have less access rights than an ancestor. For example, a transferring process with read-and-write permissions for a file can transfer read-only permissions. The transferring process can also prohibit the recipient process from further transferring the handle. Access rights are defined in the transferred permissions mask for the handle.

Conditions for transferring handles

To enable processes to transfer handles to other processes, the following conditions must be met:

1. An IPC channel is created between the processes.
2. The solution security policy (`security.psl`) allows interaction between process classes.
3. Interface methods are implemented for transferring handles.

> The API task.h enables a parent process to pass handles to a child process that is not yet running.

In an IDL description, signatures of interface methods for transferring handles have input (`in`) and/or output (`out`) parameters of the `Handle` type or `array` type with elements of the `Handle` type. Up to 255 handles can be passed through the input parameters of one method. This same number of handles can be received through output parameters.

Example IDL description that defines the signatures of interface methods for transferring handles:

```
package IpcTransfer
interface {
    PublishResource1(in Handle handle, out UInt32 result);
    PublishResource7(in Handle handle1, in Handle handle2,
                     in Handle handle3, in Handle handle4,
                     in Handle handle5, in Handle handle6,
                     in Handle handle7, out UInt32 result);
    OpenResource(in UInt32 ID, out Handle handle);
}
```

For each parameter of the `Handle` type, the NK compiler generates a field of the `nk_handle_desc_t` type (hereinafter also referred to as the *transport container of the handle*) in the `*_req` IPC request structure and/or `*_res` IPC response structure. This type is declared in the header file `sysroot-*-kos/include/nk/types.h` from the KasperskyOS SDK and comprises a structure consisting of the following three fields: `handle` field for the handle, `rights` field for the handle permissions mask, and the `badge` field for the resource transfer context.

Resource transfer context

The *resource transfer context* consists of data that allows the server to identify the resource and its state when access to the resource is requested via descendants of the transferred handle. This normally consists of a data set with various types of data (structure). For example, the transfer context of a file may include the name, path, and cursor position. The server receives a pointer to the resource transfer context when dereferencing a handle.

Regardless of whether or not the server is the resource provider, the server can associate each handle transfer with a separate resource transfer context. This resource transfer context is bound only to the handle descendants (handle inheritance subtree) that were generated as a result of a specific transfer of the handle. This lets you define the state of a resource in relation to a separate transfer of the handle of this resource. For example, for cases when one file may be accessed multiple times, the file transfer context lets you define which specific opening of this file corresponds to a received IPC request.

If the server is the resource provider, each transfer of the handle of this resource is associated with the user resource context by default. In other words, the user resource context is used as the resource transfer context for each handle transfer if the particular transfer is not associated with a separate resource transfer context.

A server that is the resource provider can use both the user resource context and the resource transfer context together. For example, the name, path and size of a file is stored in the user resource context while the cursor position can be stored in multiple resource transfer contexts because each client can work with different parts of the file. Technically, joint use of the user resource context and resource transfer contexts is possible because the resource transfer contexts store a pointer to the user resource context.

If the client uses multiple various-type resources of the server, the resource transfer contexts (or contexts of user resources if they are used as resource transfer contexts) must be specialized objects of the `KosObject` type. This is necessary so that the server can verify that the client using a resource has sent the interface method the handle of the specific resource that corresponds to this method. This verification is required because the client could mistakenly send the interface method a resource handle that does not correspond to this method. For example, a client may have received a file handle and sent it to an interface method for working with volumes.

To associate a handle transfer with a resource transfer context, the server puts the handle of the resource transfer context object into the `badge` field of the `nk_handle_desc_t` structure. The *resource transfer context object* is the kernel object that stores the pointer to the resource transfer context. To create a resource transfer context object, call the `KnHandleCreateBadge()` function. This function is bound to the notification mechanism because a server needs to know when a resource transfer context object will be closed and deleted. The server needs this information to free up or re-use memory that was allotted for storing the resource transfer context.

The resource transfer context object will be closed upon the closure or revocation of the handle descendants that comprise the handle inheritance subtree whose root node was generated by the transfer of this handle in association with this object. (A transferred handle may be closed intentionally or unintentionally, such as when a recipient client is unexpectedly terminated.) After receiving a notification regarding the closure of a resource transfer context object, the server closes the handle of this object. After this, the resource transfer context object will be deleted. After receiving a notification regarding the deletion of the resource transfer context object, the server frees up or re-uses the memory that was allotted for storing the resource transfer context.

One resource transfer context object can be associated with only one handle transfer.

Packaging data into the transport container of a handle

To package a handle, handle permissions mask, and resource transfer context object handle into a handle transport container, use the `nk_handle_desc()` macro that is defined in the header file `sysroot-*-kos/include/nk/types.h` from the KasperskyOS SDK. This macro receives a variable number of parameters.

If no parameter is passed to the macro, the `NK_INVALID_HANDLE` value will be written to the `handle` field of the `nk_handle_desc_t` structure. If one parameter is passed to the macro, this parameter is interpreted as the handle. If two parameters are passed to the macro, the first parameter is interpreted as the handle and the second parameter is interpreted as the handle permissions mask. If three parameters are passed to the macro, the first parameter is interpreted as the handle, the second parameter is interpreted as the handle permissions mask, and the third parameter is interpreted as the resource transfer context object handle.

Extracting data from the transport container of a handle

To extract the handle, handle permissions mask, and pointer to the resource transfer context from the transport container of a handle, use the `nk_get_handle()`, `nk_get_rights()` and `nk_get_badge_op()` (or `nk_get_badge()`) functions, respectively, which are declared in the header file `sysroot-*-kos/include/nk/types.h` from the KasperskyOS SDK. The `nk_get_badge_op()` and `nk_get_badge()` functions should be used only when dereferencing handles.

Handle transfer scenarios

The scenario for transferring handles from a client to the server includes the following steps:

1. The client packages the handles and handle permissions masks into fields of the `*_req` IPC requests structure of the `nk_handle_desc_t` type.
2. The client calls the interface method for transferring handles to the server. The `Call()` system call is executed when this method is called.
3. The server receives an IPC request by executing the `Recv()` system call.
4. The dispatcher on the server side calls the method corresponding to the IPC request. This method extracts the handles and handle permissions masks from fields of the `*_req` IPC request structure of the `nk_handle_desc_t` type.

The scenario for transferring handles from the server to a client includes the following steps:

1. The client calls the interface method for receiving handles from the server. The `Call()` system call is executed when this method is called.
2. The server receives an IPC request by executing the `Recv()` system call.
3. The dispatcher on the server side calls the method corresponding to the IPC request. This method packages the handles, handle permissions masks and resource transfer context object handles into fields of the `*_res` IPC response structure of the `nk_handle_desc_t` type.
4. The server responds to the IPC request by executing the `Reply()` system call.
5. On the client side, the interface method returns control. After this, the client extracts the handles and handle permissions masks from fields of the `*_res` IPC response structure of the `nk_handle_desc_t` type.

If the transferring process defines more access rights in the transferred handle permissions mask than the access rights defined for the transferred handle (which it owns), the transfer is not completed. In this case, the `Call()` system call executed by the transferring or recipient client or the `Reply()` system call executed by the transferring server ends with the `rcSecurityDisallow` error.

Information about API functions

handle_api.h functions

Function	Information about the function
`KnHandleCreateBadge()`	Purpose Creates a resource transfer context object and configures a notification mechanism for monitoring the life cycle of this object. Parameters • [in] `notice` – identifier of the notification receiver. • [in] `eventId` – identifier of the "resource–event mask" entry in the notification receiver. • [in,optional] `context` – pointer to the data that should be associated with the handle transfer, or `RTL_NULL` if this association is not required. • [out] `handle` – pointer to the handle of the resource transfer context object. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code. Additional information The notification receiver is configured to receive notifications about events that match the `EVENT_OBJECT_DESTROYED` and `EVENT_BADGE_CLOSED` flags of the event mask.

Duplicating handles

Handle duplication is similar to a handle transfer, but duplication is performed within a process. A handle descendant is created in the same process and from the same handle space. The rights of the handle descendant may be less than or equal to the rights of the original handle. Handle duplication can be associated with a resource transfer context object. This lets you use the notification mechanism to track the closure or revocation of all handle descendants that form the handle inheritance subtree whose root node was generated by the duplication operation. It also provides the capability to revoke these descendants.

To duplicate a handle, call the `KnHandleCopy()` function. To do so, the `OCAP_HANDLE_COPY` flag must be set in the handle permissions mask.

Information about API functions is provided in the table below.

handle_api.h functions

Function	Information about the function
`KnHandleCopy()`	Purpose Duplicates a handle. As a result of duplication, the calling process receives the handle descendant.

Parameters

- [in] `inHandle` – original handle.
- [in] `newRightsMask` – permissions mask of the handle descendant.
- [in,optional] `copyBadge` – handle of the resource transfer context object, or `INVALID_HANDLE` if you do not need to associate handle duplication with this object.
- [out] `outHandle` – pointer to the handle descendant.

Returned values

If successful, the function returns `rcOk`, otherwise it returns an error code.

Dereferencing handles

When *dereferencing a handle*, the client sends the handle to the server, and the server receives a pointer to the resource transfer context, the permissions mask of the sent handle, and the ancestor of the handle sent by the client and already owned by the server. Dereferencing occurs when a resource consumer that called methods for working with a resource (such as read/write or access closure) sends the resource provider the handle that was received from this resource provider when access to the resource was opened.

Dereferencing handles requires fulfillment of the same conditions and utilizes the same mechanisms and data types as when transferring handles. A handle dereferencing scenario includes the following steps:

1. The client packages the handle into a field of the `*_req` IPC request structure of the `nk_handle_desc_t` type.
2. The client calls the interface method for sending the handle to the server for the purpose of performing operations with the resource. The `Call()` system call is executed when this method is called.
3. The server receives the IPC request by executing the `Recv()` system call.
4. The dispatcher on the server side calls the method corresponding to the IPC request. This method verifies that the dereferencing operation was specifically executed instead of a handle transfer. Then the called method has the option to verify that the access rights of the dereferenced handle (that was sent by the client) permit the requested actions with the resource, and extracts the pointer to the resource transfer context from the field of the `*_req` request structure of the `nk_handle_desc_t` type.

To perform verification, the server uses the `nk_is_handle_dereferenced()` and `nk_get_badge_op()` functions that are declared in the header file `sysroot-*-kos/include/nk/types.h` from the KasperskyOS SDK.

types.h (fragment)

```
/**
 * Returns a value different from null if
 * the handle in the transport container of
 * "desc" is received as a result of dereferencing
 * the handle. Returns null if the handle
 * in the transport container of "desc" is received
 * as a result of a handle transfer.
 */
```

```
static inline
nk_bool_t nk_is_handle_dereferenced(const nk_handle_desc_t *desc)

/**
 * Extracts the pointer to the resource transfer context
 * "badge" from the transport container of "desc"
 * if the permissions mask that was put in the transport
 * container of the desc handle has the operation flags set.
 * If successful, the function returns NK_EOK, otherwise it returns an error code.
 */
static inline
nk_err_t nk_get_badge_op(const nk_handle_desc_t *desc,
                         nk_rights_t operation,
                         nk_badge_t *badge)
```

Generally, the server does not require the handle that was received from dereferencing because the server normally retains the handles that it owns, for example, within the contexts of user resources. However, the server can extract this handle from the handle transport container if necessary.

Revoking handles

A process can revoke descendants of a handle that it owns. Handles are revoked according to the handle inheritance tree.

Revoked handles are not closed. However, you cannot query resources via revoked handles. Any function that receives the handle will end with the `rcHandleRevoked` error if the function is called with a revoked handle.

To revoke handle descendants, call the `KnHandleRevoke()` or `KnHandleRevokeSubtree()` function. The `KnHandleRevokeSubtree()` function uses the resource transfer context object that is created when transferring handles.

If each handle of a system resource in all processes that own these handles are closed (see "Closing handles") or revoked, this system resource will be deleted.

Information about API functions is provided in the table below.

handle_api.h functions

Function	Information about the function
`KnHandleRevoke()`	Purpose Closes a handle and revokes its descendants. Parameters • [in] `handle` – a handle. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnHandleRevokeSubtree()`	Purpose Revokes the handles that make up the inheritance subtree of the specified handle.

	Parameters • [in] `handle` – a handle. The handles forming the inheritance subtree of this handle are revoked. • [in] `badge` – handle that identifies the resource transfer context object, which defines the inheritance subtree of the handles to revoke. The root node of this subtree is the handle that was generated by the transfer or duplication of the handle that is defined through the `handle` parameter and is associated with the resource transfer context object. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.

Closing handles

A process can close the handles that it owns. Closing a handle terminates the association between an ID and a resource, thereby releasing the ID. Closing a handle does not invalidate its ancestors and descendants (in contrast to revoking a handle, which actually invalidates the descendants of the handle). In other words, the ancestors and descendants of a closed handle can still be used to provide access to the resource that they identify. Also, closing a handle does not disrupt the handle inheritance tree associated with the resource identified by the particular handle. The place of a closed handle is occupied by its ancestor. In other words, the ancestor of a closed handle becomes the direct ancestor of the descendants of the closed handle.

To close the handle, call the `KnHandleClose()` function.

If each handle of a system resource in all processes that own these handles are revoked (see "Revoking handles") or closed, this system resource will be deleted.

Information about API functions is provided in the table below.

handle_api.h functions

Function	Information about the function
`KnHandleClose()`	Purpose Closes a handle. Parameters • [in] `handle` – a handle. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.

Getting a security ID (SID)

By getting the SID values for different handles, you can determine whether these handles identify different resources or the same resource.

To get an SID for a handle, call the `KnHandleGetSidByHandle()` function. To do so, the `OCAP_HANDLE_GET_SID` flag must be set in the handle permissions mask.

Information about API functions is provided in the table below.

handle_api.h functions

Function	Information about the function
`KnHandleGetSidByHandle()`	Purpose Receives a security ID (SID) based on a handle. Parameters • [in] `handle` – a handle. • [out] `sid` – pointer to the security ID (SID). Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.

OCap usage example

This example describes an OCap usage scenario in which the resource provider provides the following methods for accessing its resources:

- `OpenResource()` – opens access to the resource.
- `UseResource()` – uses the resource.
- `CloseResource()` – closes access to the resource.

The resource consumer uses these methods.

IDL description:

```
package SimpleOCap
interface {
    OpenResource(in UInt32 ID, out Handle handle);
    UseResource(in Handle handle, in UInt8 param, out UInt8 result);
    CloseResource(in Handle handle);
}
```

The scenario includes the following steps:

1. The resource provider creates the user resource context and calls the `KnHandleCreateUserObject()` function to create the resource handle. The resource provider saves the resource handle in the user resource context.

2. The resource consumer calls the `OpenResource()` method to open access to the resource.

a. The resource provider creates the resource transfer context and calls the `KnHandleCreateBadge()` function to create a resource transfer context object and configure the notification receiver to receive notifications regarding the closure and deletion of the resource transfer context object. The resource provider saves the handle of the resource transfer context object and the pointer to the user resource context in the resource transfer context.

b. The resource provider uses the `nk_handle_desc()` macro to package the resource handle, permissions mask of the handle, and pointer to the resource transfer context object into the handle transport container.

c. The handle is transferred from the resource provider to the resource consumer, which means that the resource consumer receives a descendant of the handle owned by the resource provider.

d. The `OpenResource()` method call completes successfully. The resource consumer extracts the handle and permissions mask of the handle from the handle transport container by using the `nk_get_handle()` and `nk_get_rights()` functions, respectively. The handle permissions mask is not required by the resource consumer to query the resource, but is transferred so that the resource consumer can find out its permissions for accessing the resource.

3. The resource consumer calls the `UseResource()` method to utilize the resource.

a. The handle that was received from the resource provider at step 2 is used as a parameter of the `UseResource()` method. Before calling this method, the resource consumer uses the `nk_handle_desc()` macro to package the handle into the handle transport container.

b. The handle is dereferenced, after which the resource provider receives the pointer to the resource transfer context.

c. The resource provider uses the `nk_is_handle_dereferenced()` function to verify that the dereferencing operation was completed instead of a handle transfer.

d. The resource provider verifies that the access rights of the dereferenced handle (that was sent by the resource consumer) allows the requested operation with the resource, and extracts the pointer to the resource transfer context from the handle transport container. To do so, the resource provider uses the `nk_get_badge_op()` function, which extracts the pointer to the resource transfer context from the handle transport container if the received permissions mask has the corresponding flags set for the requested operation.

e. The resource provider uses the resource transfer context and the user resource context to perform the corresponding operation with the resource as requested by the resource consumer. Then the resource provider sends the results of this operation to the resource consumer.

f. The `UseResource()` method call completes successfully. The resource consumer receives the results of the operation performed with the resource.

4. The resource consumer calls the `CloseResource()` method to close access to the resource.

a. The handle that was received from the resource provider at step 2 is used as a parameter of the `CloseResource()` method. Before calling this method, the resource consumer uses the `nk_handle_desc()` macro to package the handle into the handle transport container. After the `CloseResource()` method is called, the resource consumer uses the `KnHandleClose()` function to close the handle.

b. The handle is dereferenced, after which the resource provider receives the pointer to the resource transfer context.

c. The resource provider uses the `nk_is_handle_dereferenced()` function to verify that the dereferencing operation was completed instead of a handle transfer.

d. The resource provider uses the `nk_get_badge()` function to extract the pointer to the resource transfer context from the handle transport container.

e. The resource provider uses the `KnHandleRevokeSubtree()` function to revoke the handle owned by the resource consumer. The resource handle owned by the resource provider and the handle of the resource transfer context object are used as parameters of this function. The resource provider obtains access to these handles through the pointer to the resource transfer context. (Technically, the handle owned by the resource consumer does not have to be revoked because the resource consumer already closed it. However, the revoke operation is performed in case the resource provider is not sure if the resource consumer actually closed the handle).

f. The `CloseResource()` method call completes successfully.

5. The resource provider frees up the memory that was allocated for the resource transfer context and user resource context.

   a. The resource provider calls the `KnNoticeGetEvent()` function to receive a notification that the resource transfer context object was closed, and uses the `KnHandleClose()` function to close the handle of the resource transfer context object.

   b. The resource provider calls the `KnNoticeGetEvent()` function to receive a notification that the resource transfer context object was deleted, and frees up the memory that was allocated for the resource transfer context.

   c. The resource provider uses the `KnHandleClose()` function to close the resource handle and free up the memory that was allocated for the user resource context.

Allocating and freeing memory (alloc.h)

The API is defined in the header file `sysroot-*-kos/include/kos/alloc.h` from the KasperskyOS SDK.

The API is intended for allocating and freeing memory. Allocated memory is a committed virtual memory region that can be accessed for read-and-write operations.

Information about API functions is provided in the table below.

alloc.h functions

Function	Information about the function
`KosMemAllocEx()`	Purpose Allocates memory. Parameters • [in] `size` – size (in bytes) of the allocated memory. • [in] `align` – value defining the alignment of the allocated memory. It must be a power of two. The address of allocated memory can be unaligned (*align=1*) or aligned (*align=2,4,...,2^N*) to the boundary of a *2^N*-byte sequence (for example, two-byte or four-byte). When an address is aligned, the size of the allocated memory may be rounded up to the nearest multiple of *2^N*.

	• [in] `zeroed` – value defining the initialization of the allocated memory (`1` – initialize with zeros, `0` – do not initialize). Returned values If successful, the function returns the pointer to the allocated memory, otherwise it returns `RTL_NULL`.
`KosMemAlloc()`	Purpose Allocates memory. Parameters • [in] `size` – size (in bytes) of the allocated memory. Returned values If successful, the function returns the pointer to the allocated memory, otherwise it returns `RTL_NULL`.
`KosMemZalloc()`	Purpose Allocates memory and initializes it with zeros. Parameters • [in] `size` – size (in bytes) of the allocated memory. Returned values If successful, the function returns the pointer to the allocated memory, otherwise it returns `RTL_NULL`.
`KosMemFree()`	Purpose Deallocates memory. Parameters • [in] `ptr` – pointer to the freed memory. Returned values N/A
`KosMemGetSize()`	Purpose Gets the actual size of allocated memory. The actual size of allocated memory exceeds the requested size because it includes the size of service data and also may be increased due to alignment when the `KosMemAllocEx()` function is called. Parameters • [in] `ptr` – pointer to the allocated memory.

	Returned values Actual size of allocated memory (in bytes).
`KosMemGetOrigSize()`	Purpose Gets the size of memory that was requested when it is allocated. The actual size of allocated memory exceeds the requested size because it includes the size of service data and also may be increased due to alignment when the `KosMemAllocEx()` function is called. Parameters • [in] `ptr` – pointer to the allocated memory. Returned values Size (in bytes) of memory that was requested when it is allocated.

Using DMA (dma.h)

The API is defined in the header file `sysroot-*-kos/include/coresrv/io/dma.h` from the KasperskyOS SDK.

The API is designed to set up data exchange between devices and RAM in *direct memory access* (DMA) mode in which the processor is not used.

Information about API functions is provided in the table below.

Using the API

The standard scenario for API usage includes the following steps:

1. Creating a DMA buffer.

   DMA buffer consists of one or more physical memory regions (blocks) that are used for DMA. A DMA buffer consisting of multiple blocks can be used if the device supports "scatter/gather DMA" mode. A DMA buffer consisting of one block can be used only if the device supports "scatter/gather DMA" or "continuous DMA" mode. The likelihood of creating a DMA buffer consisting of one large block is lower than the likelihood of creating a DMA buffer consisting of multiple small blocks. This is especially relevant when physical memory is highly fragmented.

   > If the device supports only "continuous DMA" mode, you must use a DMA buffer consisting of one block even if IOMMU is enabled.

   To complete this step, call the `KnIoDmaCreate()` or `KnIoDmaCreateContinuous()` function. The `KnIoDmaCreateContinuous()` function creates a DMA buffer consisting of one block. The `KnIoDmaCreate()` function creates a DMA buffer consisting of one block if the *2^order* value is equal to the *memory page size* value, or if the *2^order* value is the next largest value of the *memory page size* in the ascending ordered set *{2^(order-1);memory page size;2^order}*. If the value of the *memory page size* is greater than the *2^order* value, the `KnIoDmaCreate()` function can create a DMA buffer consisting of multiple blocks.

   The DMA buffer handle can be transferred to another process via IPC.

2. Mapping the DMA buffer to the memory of processes.

   One DMA buffer can be mapped to multiple virtual memory regions of one or more processes that own the handle of this DMA buffer. Mapping allows processes to receive read-and/or-write access to the DMA buffer.

   To reserve a virtual memory region and map the DMA buffer to it, call the `KnIoDmaMap()` function.

   A handle received when calling the `KnIoDmaMap()` function cannot be transferred to another process via IPC.

3. Opening access to the DMA buffer for a device via the `KnIoDmaBegin()` function call.

   The `KnIoDmaBegin()` function must be called to create a kernel object containing the addresses and sizes of blocks comprising the DMA buffer. A device needs this information to use the DMA buffer. A device can work with physical addresses and/or virtual addresses depending on whether IOMMU is enabled. If IOMMU is enabled, an object contains virtual addresses of blocks. Otherwise, an object contains physical addresses of blocks.

   A handle received when calling the `KnIoDmaBegin()` function cannot be transferred to another process via IPC.

4. Information about the DMA buffer is received.

   At this step, get the addresses and sizes of blocks from the kernel object that was created by calling the `KnIoDmaBegin()` function. The received addresses and sizes will need to be passed to the device by using MMIO, for example. After receiving this information, the device can write to the DMA buffer and/or read from it (if IOMMU is enabled, a device on the PCIe bus must be attached to the IOMMU domain).

   To complete this step, you need to call the `KnIoDmaGetInfo()` or `KnIoDmaContinuousGetDmaAddr()` function. The `KnIoDmaGetInfo()` function gets the memory page number (`frame`) and the `order` for each block. (The memory page number multiplied by the memory page size results in the block address. The *2^order* value is the block size in memory pages.) The `KnIoDmaContinuousGetDmaAddr()` function can be used if the DMA buffer consists of one block. This function gets the block address. (The accepted block size should be the DMA buffer size that was defined when this buffer was created.)

Closing access to the DMA buffer for a device

If you delete the kernel object that was created when the `KnIoDmaBegin()` function was called and IOMMU is enabled, the device will be denied access to the DMA buffer. To delete this object, call the `KnHandleClose()` function and specify the handle that was received when the `KnIoDmaBegin()` function was called. (The `KnHandleClose()` function is declared in the header file `sysroot-*-kos/include/coresrv/handle/handle_api.h` from the KasperskyOS SDK.)

Deleting a DMA buffer

To delete a DMA buffer, complete the following steps:

1. Free the virtual memory regions that were reserved during `KnIoDmaMap()` function calls.

   To complete this step, use the `KnHandleClose()` function and specify the handles that were received from `KnIoDmaMap()` function calls. (`KnHandleClose()` function is declared in the header file `sysroot-*-kos/include/coresrv/handle/handle_api.h` from the KasperskyOS SDK.)

   This step must be completed for all processes whose memory is mapped to the DMA buffer.

2. Delete the kernel object that was created by the `KnIoDmaBegin()` function call.

   To complete this step, call the `KnHandleClose()` function and specify the handle that was received when the `KnIoDmaBegin()` function was called.

3. Close or revoke each DMA buffer handle in all processes that own these handles.

To complete this step, use the `KnHandleClose()` and/or `KnHandleRevoke()` functions that are declared in the header file `sysroot-*-kos/include/coresrv/handle/handle_api.h` from the KasperskyOS SDK.

Information about API functions

dma.h functions

Function	Information about the function
`KnIoDmaCreate()`	Purpose Creates a DMA buffer. Parameters • [in] `order` – parameter defining the minimum number of memory pages (*2^order*) in a block. • [in] `size` – size (in bytes) of the DMA buffer. It must be a multiple of the memory page size. • [in] `flags` – flags defining the DMA buffer parameters. The parameter type and flags are defined in the header file `sysroot-*-kos/include/io/io_dma.h` from the KasperskyOS SDK. • [out] `outRid` – pointer to the DMA buffer handle. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code. Additional information In the `flags` parameter, you can specify the following flags: • `DMA_DIR_TO_DEVICE` – the device has read-access to the DMA buffer. • `DMA_DIR_FROM_DEVICE` – the device has write-access to the DMA buffer. • `DMA_DIR_BIDIR` – the device has read-and-write access to the DMA buffer. • `DMA_ZONE_DMA32` – only the first four gigabytes of physical memory can be used to create a DMA buffer. • `DMA_ATTR_WRITE_BACK`, `DMA_ATTR_WRITE_THROUGH`, `DMA_ATTR_CACHE_DISABLE`, `DMA_ATTR_WRITE_COMBINE`, `DMA_RULE_CACHE_VOLATILE`, `DMA_RULE_CACHE_FIXED` – cache management.
`KnIoDmaCreateContinuous()`	Purpose

	Creates a DMA buffer consisting of one block. Parameters • [in] `size` – size (in bytes) of the DMA buffer. It must be a multiple of the memory page size. • [in] `flags` – flags defining the DMA buffer parameters. The parameter type and flags are defined in the header file `sysroot-*-kos/include/io/io_dma.h` from the KasperskyOS SDK. • [out] `outRid` – pointer to the DMA buffer handle. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code. Additional information In the `flags` parameter, you can specify the following flags: • `DMA_DIR_TO_DEVICE` – the device has read-access to the DMA buffer. • `DMA_DIR_FROM_DEVICE` – the device has write-access to the DMA buffer. • `DMA_DIR_BIDIR` – the device has read-and-write access to the DMA buffer. • `DMA_ZONE_DMA32` – only the first four gigabytes of physical memory can be used to create a DMA buffer. • `DMA_ATTR_WRITE_BACK`, `DMA_ATTR_WRITE_THROUGH`, `DMA_ATTR_CACHE_DISABLE`, `DMA_ATTR_WRITE_COMBINE`, `DMA_RULE_CACHE_VOLATILE`, `DMA_RULE_CACHE_FIXED` – cache management.
`KnIoDmaMap()`	Purpose Reserves a virtual memory region and maps the DMA buffer to it. Parameters • [in] `rid` – DMA buffer handle. • [in] `offset` – offset (in bytes) in the DMA buffer where mapping should start. It must be a multiple of the memory page size. • [in] `length` – size (in bytes) of the part of the DMA buffer that needs to be mapped. It must be a multiple of the memory page size. The following condition must also be fulfilled: *length<=size of DMA buffer-offset*.

	• [in,optional] `hint` – page-aligned, preferred base address of the virtual memory region, or `0` to select this address automatically. • [in] `vmflags` – flags defining the access rights to the virtual memory region. The flags are defined in the header file `sysroot-*-kos/include/vmm/flags.h` from the KasperskyOS SDK. • [out] `addr` – base address of the virtual memory region. • [out] `handle` – pointer to the handle that is used to free the virtual memory region. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code. Additional information In the `vmflags` parameter, you can specify the following flags: • `VMM_FLAG_READ` – read access. • `VMM_FLAG_WRITE` – write access.
`KnIoDmaModify()`	Purpose Modifies the DMA buffer cache settings. Parameters • [in] `rid` – DMA buffer handle. • [in] `newAttr` – flags defining the DMA buffer caching parameters. The flags are defined in the header file `sysroot-*-kos/include/io/io_dma.h` from the KasperskyOS SDK. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code. Additional information This function can be used if the following conditions are fulfilled: 1. The `DMA_RULE_CACHE_VOLATILE` flag was specified when the DMA buffer was created. 2. The DMA buffer is not mapped to virtual memory. 3. The `DMA_RULE_CACHE_VOLATILE` flag was specified during the previous function call (if completed).

	In the `newAttr` parameter, you can specify the following flags: • `DMA_ATTR_WRITE_BACK`, `DMA_ATTR_WRITE_THROUGH`, `DMA_ATTR_CACHE_DISABLE`, `DMA_ATTR_WRITE_COMBINE`, `DMA_RULE_CACHE_VOLATILE` – cache management.
`KnIoDmaGetInfo()`	Purpose Gets information about a DMA buffer. This information includes the addresses and sizes of blocks. Parameters • [in] `rid` – DMA buffer handle. • [out] `outInfo` – pointer to the address of the object containing information about the DMA buffer. The type of object is defined in the header file `sysroot-*-kos/include/io/io_dma.h` from the KasperskyOS SDK. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnIoDmaContinuousGetDmaAddr()`	Purpose Gets the block address for a DMA buffer consisting of one block. Parameters • [in] `rid` – DMA buffer handle. • [out] `addr` – block address. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnIoDmaBegin()`	Purpose Opens access to a DMA buffer for a device. Parameters • [in] `rid` – DMA buffer handle. • [out] `handle` – pointer to the handle of the kernel object containing the addresses and sizes of blocks that were required for the device to use the DMA buffer. Returned values

	If successful, the function returns `rcOk`, otherwise it returns an error code.

Managing interrupt processing (irq.h)

The API is defined in the header file `sysroot-*-kos/include/coresrv/io/irq.h` from the KasperskyOS SDK.

The API manages the handling of hardware interrupts. A *hardware interrupt* is a signal sent from a device to direct the processor to immediately pause execution of the current program and instead handle an event related to this device. For example, pressing a key on the keyboard invokes a hardware interrupt that ensures the required response to this pressed key (for example, input of a character).

A hardware interrupt occurs when the device queries the interrupt controller. This query can be transmitted through a hardware interrupt line between the device and the interrupt controller or through MMIO memory. In the second case, the device writes to MMIO memory by calling the *Message Signaled Interrupt* (MSI).

> At present, no functions for managing the handling of MSI interrupts have been implemented.

Each hardware interrupt line corresponds to one interrupt with a unique number.

Information about API functions is provided in the table below.

Using the API

To attach an interrupt to its handler, complete the following steps:

1. Registering an interrupt by calling the `KnRegisterIrq()` function.

   One interrupt can be registered multiple times in one or more processes.

   The handle of an interrupt can be transferred to another process via IPC.

2. Attaching a thread to an interrupt by calling the `KnIoAttachIrq()` function.

   This step is performed by the thread in whose context the interrupt will be handled.

   When using the handle received from the `KnRegisterIrq()` function call, you can attach only one thread to an interrupt. To attach multiple threads in one or more processes to an interrupt, use different handles for this interrupt received from separate `KnRegisterIrq()` function calls. In this case, the `KnIoAttachIrq()` function must be called with the same flags in the `flags` parameter.

   A handle received when calling the `KnIoAttachIrq()` function cannot be transferred to another process via IPC.

To deny (mask) an interrupt, call the `KnIoDisableIrq()` function. To allow (unmask) an interrupt, call the `KnIoEnableIrq()` function. Even though these functions receive an interrupt handle that is used to attach only one thread to the interrupt, their action is applied to all threads that are attached to this interrupt. These functions must be called outside of the threads attached to the interrupt. After an interrupt is registered and a thread is attached to it, this interrupt does not require unmasking.

To initiate detachment of a thread from an interrupt, call the `KnIoDetachIrq()` function outside of the thread that is attached to the interrupt. Detachment is performed by the thread attached to the interrupt by calling the `KnThreadDetachIrq()` function declared in the header file `sysroot-*-kos/include/coresrv/thread/thread_api.h` from the KasperskyOS SDK.

Handling an interrupt

After attaching to an interrupt, a thread calls the `Call()` function declared in the header file `sysroot-*-kos/include/coresrv/syscalls.h` from the KasperskyOS SDK. The thread is locked as a result of this call. When an interrupt occurs or the `KnIoDetachIrq()` function is called, the KasperskyOS kernel sends an IPC message to the process that contains this thread. This IPC message contains a request to handle the interrupt or a request to detach the thread from the interrupt. When a process receives an IPC message, the `Call()` function in the thread attached to the interrupt returns control and provides the contents of the IPC message to the thread. The thread extracts the request from the IPC message and either processes the interrupt or detaches from the interrupt. If the interrupt is processed, information about its failure or success upon completion is added to the response IPC message that is sent to the kernel by the next `Call()` function call in the loop.

When processing an interrupt, use the `IoGetIrqRequest()` and `IoSetIrqAnswer()` functions that are declared in the header file `sysroot-*-kos/include/io/io_irq.h` from the KasperskyOS SDK. These functions let you extract data from IPC messages and add data to IPC messages for data exchange between the kernel and the thread attached to the interrupt.

The standard interrupt processing loop includes the following steps:

1. Adding information about the failure or success of interrupt processing to an IPC message by calling the `IoSetIrqAnswer()` function.

2. Sending the IPC message to the kernel and receiving an IPC message from the kernel.

   To complete this step, call the `Call()` functions. In the `handle` parameter, you must specify the handle that was received when the `KnIoAttachIrq()` function was called. You must use the `msgOut` parameter to define the IPC message that will be sent to the kernel, and use the `msgIn` parameter to define the IPC message that will be received from the kernel.

3. Extracting a request from the IPC message received from the kernel by calling the `IoGetIrqRequest()` function.

4. Processing the interrupt or detaching from the interrupt depending on the request.

   If the request requires detachment from the interrupt, exit the interrupt processing loop and call the `KnThreadDetachIrq()` function.

Deregistering an interrupt

To deregister an interrupt, complete the following steps:

1. Detach the thread from the interrupt.

   To complete this step, call the `KnThreadDetachIrq()` function.

2. Close the handle that was received when the `KnIoAttachIrq()` function was called.

   To complete this step, call the `KnHandleClose()` function. (The `KnHandleClose()` function is declared in the header file `sysroot-*-kos/include/coresrv/handle/handle_api.h` from the KasperskyOS SDK.)

3. Close or revoke each interrupt handle in all processes that own these handles.

   To complete this step, use the `KnHandleClose()` and/or `KnHandleRevoke()` functions that are declared in the header file `sysroot-*-kos/include/coresrv/handle/handle_api.h` from the KasperskyOS SDK.

One interrupt can be registered multiple times, but completion of these steps cancels only one registration. The other registrations will remain active. Each registration of one interrupt must be canceled separately.

Information about API functions

irq.h functions

Function	Information about the function
`KnRegisterIrq()`	Purpose Registers an interrupt. Parameters • [in] `irq` – interrupt number. • [out] `outRid` – pointer to the interrupt handle. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnIoAttachIrq()`	Purpose Attaches the calling thread to an interrupt. Parameters • [in] `rid` – interrupt handle. • [in] `flags` – flags defining the interrupt parameters. Flags are defined in the header files `sysroot-*-kos/include/io/io_irq.h` and `sysroot-*-kos/include/hal/irqmode.h` from the KasperskyOS SDK. • [out] `handle` – pointer to the client IPC handle that is used by the interrupt handler. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code. Additional information In the `flags` parameter, you can specify the following flags: • `IRQ_LEVEL_LOW` – the interrupt occurs when the signal level is low. • `IRQ_LEVEL_HIGH` – the interrupt occurs when the signal level is high. • `IRQ_EDGE_RAISE` – the interrupt occurs when the signal level increases. • `IRQ_EDGE_FALL` – the interrupt occurs when the signal level decreases. • `IRQ_PRIO_LOW` – the interrupt has low priority. • `IRQ_PRIO_NORMAL` – the interrupt has medium priority. • `IRQ_PRIO_HIGH` – the interrupt has high priority.

	• `IRQ_PRIO_RT` – the interrupt has the highest priority.
`KnIoDetachIrq()`	Purpose Sends a request to a thread. When this request is fulfilled, the thread must detach from the interrupt. Parameters • [in] `rid` – interrupt handle. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnIoEnableIrq()`	Purpose Allows (unmasks) an interrupt. Parameters • [in] `rid` – interrupt handle. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnIoDisableIrq()`	Purpose Denies (masks) an interrupt. Parameters • [in] `rid` – interrupt handle. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.

Initializing IPC transport for interprocess communication and managing IPC request processing (transport-kos.h, transport-kos-dispatch.h)

APIs are defined in the header files `transport-kos.h` and `transport-kos-dispatch.h` from the KasperskyOS SDK that are located at the path `sysroot-*-kos/include/coresrv/nk`.

API capabilities:

- Initialize IPC transport on the client side and on the server side.

  IPC transport is an add-on that works on top of system calls for sending and receiving IPC messages and works separately with the constant part and arena of IPC messages. Transport code works on top of this add-on.

- Start the loop for processing IPC requests on the server side.

- Copy data to the IPC message arena.

Information about API functions is provided in the tables below.

This section contains API usage examples. In these examples, programs acting as servers have the following formal specification:

FsDriver.edl

```
entity FsDriver
components {
    operationsComp : Operations
}
```

Operations.cdl

```
component Operations
endpoints {
    fileOperations : FileIface
}
```

FileIface.idl

```
package FileIface
interface {
    Open(in array<UInt8, 1024> path);
    Read(out sequence<UInt8, 2048> content);
}
```

Initializing IPC transport for interprocess communication

To initialize IPC transport for interaction with other processes, call the `NkKosTransport_Init()` or `NkKosTransportSync_Init()` function declared in the header file `transport-kos.h`.

Example use of the `NkKosTransport_Init()` function on the client side:

```
int main(int argc, const char *argv[])
{
    /* Declare the structure containing the IPC transport parameters */
    NkKosTransport driver_transport;
    /* Declare the proxy object. (The type of proxy object is automatically
     * generated transport code.) */
    struct FileIface_proxy file_operations_proxy;
    /* Declare the structures for saving the constant part of an IPC request and
     * IPC response for the endpoint method. (The types of structures are
automatically
     * generated transport code.) */
    struct FileIface_Open_req req;
    struct FileIface_Open_res res;
    /* Get the client IPC handle and endpoint ID */
    Handle driver_handle;
    rtl_uint32_t file_operations_riid;
    if (KnCmConnect("FsDriver", "operationsComp.fileOperations", INFINITE_TIMEOUT,
                &driver_handle, &file_operations_riid) == rcOk) {
        /* Initialize the structure containing the IPC transport parameters */
```

```
        NkKosTransport_Init(&driver_transport, driver_handle, NK_NULL, 0);
        /* Initialize the proxy object. (The proxy object initialization method is
         * is automatically generated transport code.) */
        FileIface_proxy_init(&file_operations_proxy, &driver_transport.base,
                             (nk_iid_t) file_operations_riid);
    }
...
    /* Call the endpoint method. (The method is automatically
     * generated transport code.) */
    strncpy(req.path, "/example/file/path", sizeof(req.path));
    if (FileIface_Open(file_operations_proxy.base, &req, NULL,
                       &res, NULL) != NK_EOK) {
...
    }
...
}
```

If a client needs to use several endpoints, the same number of proxy objects must be initialized. When initializing each proxy object, you need to specify the IPC transport that is associated through the client IPC handle with the relevant server. When initializing multiple proxy objects pertaining to the endpoints of one server, you can specify the same IPC transport that is associated with this server.

Example use of the `NkKosTransport_Init()` function on the server side:

```
int main(int argc, const char *argv[])
{
...
    /* Declare the structure containing the IPC transport parameters */
    NkKosTransport transport;
    /* Get the listener handle. (Endpoint ID
     * FsDriver_operationsComp_fileOperations_iid is
     * automatically generated transport code.) */
    Handle handle;
    char client[32];
    char endpoint[32];
    Retcode rc = KnCmListen(RTL_NULL, INFINITE_TIMEOUT, client, endpoint);
    if (rc == rcOk)
        rc = KnCmAccept(client, endpoint,
                        FsDriver_operationsComp_fileOperations_iid,
                        INVALID_HANDLE, &handle);
...
    /* Initialize the structure containing the IPC transport parameters */
    NkKosTransport_Init(&transport, handle, NK_NULL, 0);
...
    /* IPC request processing loop */
    do
    {
...
        /* Get the IPC request */
        rc = nk_transport_recv(&transport.base, ...);
        if (rc == NK_EOK) {
            /* Process the IPC request by calling the dispatcher. (The dispatcher
             * is automatically generated transport
             * code.) */
            rc = FsDriver_entity_dispatch(...);
            if (rc == NK_EOK) {
                /* Send an IPC response */
                rc = nk_transport_reply(&transport.base, ...);
            }
        }
```

```
    }
    while (rc == NK_EOK)
    return EXIT_SUCCESS;
}
```

If a server processes IPC requests received through multiple IPC channels, the following special considerations should be taken into account:

- If a listener handle is associated with all IPC channels, IPC interaction with all clients can use the same IPC transport associated with this listener handle.
- If IPC channels are associated with different listener handles, IPC interaction with each group of clients corresponding to the same listener handle must use a separate IPC transport associated with this listener handle. In this case, IPC requests can be processed in parallel threads if you are using a thread-safe implementation of endpoint methods.

The `NkKosTransportSync_Init()` function initializes IPC transport with support for interrupting the `Call()` and `Recv()` locking system calls. (For example, an interrupt of these calls may be required for correct termination of the process that is executing them.) To interrupt the `Call()` and `Recv()` system calls, use the API ipc_api.h.

The `NkKosSetTransportTimeouts()` function declared in the header file `transport-kos.h` defines the maximum lockout duration for `Call()` and `Recv()` system calls used for IPC transport.

Starting the IPC request processing loop

The IPC request processing loop on a server includes the following steps:

1. Receive an IPC request.
2. Process the IPC request.
3. Send an IPC response.

Each step of this loop can be completed separately by sequentially calling the `nk_transport_recv()`, dispatcher, and `nk_transport_reply()` functions. (The `nk_transport_recv()` and `nk_transport_reply()` functions are declared in the header file `sysroot-*-kos/include/nk/transport.h` from the KasperskyOS SDK.) You can also call the `NkKosTransport_Dispatch()` or `NkKosDoDispatch()` function in which this loop is completed in its entirety. (The `NkKosTransport_Dispatch()` and `NkKosDoDispatch()` functions are declared in the header files `transport-kos.h` and `transport-kos-dispatch.h`, respectively.) It is more convenient to use the `NkKosDoDispatch()` function because it requires fewer preparatory operations (for example, you do not need to initialize IPC transport).

You can initialize the structure passed to the `NkKosDoDispatch()` function through the `info` parameter by using the macros defined in the header file `transport-kos-dispatch.h`.

The `NkKosTransport_Dispatch()` and `NkKosDoDispatch()` functions can be called from parallel threads if you are using a thread-safe implementation of endpoint methods.

Example use of the `NkKosDoDispatch()` function:

```
/* This function implements the endpoint method. */
static nk_err_t Open_impl(...)
{
...
```

```
}

/* This function implements the endpoint method. */
static nk_err_t Read_impl(...)
{
...
}

/* This function initializes the pointers to functions implementing the endpoint
methods.
 * (These pointers are used by the dispatcher to call functions implementing the
 * endpoint methods. The types of structures are automatically generated
 * transport code.) */
static struct FileIface *CreateFileOperations()
{
    static const struct FileIface_ops ops = {
        .Open = Open_impl,
        .Read = Read_impl
    };
    static struct FileIface impl = {
        .ops = &ops
    };
    return &impl;
}

int main(int argc, const char *argv[])
{
...
    /* Declare the structure that is required for the
     * NkKosDoDispatch() function to use transport code. */
    NkKosDispatchInfo info;
    /* Declare the stubs. (The types of stubs are automatically generated
     * transport code. */
    struct Operations_component component;
    struct FsDriver_entity entity;
    /* Get the listener handle */
    Handle handle = ServiceLocatorRegister("driver_connection", NULL, 0, &iid);
    assert(handle != INVALID_HANDLE);
    /* Initialize the stubs. (Methods for initializing stubs are
     * automatically generated transport code. Function
     * CreateFileOperations() is implemented by the developer of the
     * KasperskyOS-based solution to initialize
     * pointers to functions implementing the endpoint methods.) */
    Operations_component_init(&component, CreateFileOperations());
    FsDriver_entity_init(&entity, &component);
    /* Initialize the structure that is required for the
     * NkKosDoDispatch() function to use transport code. */
    info = NK_TASK_DISPATCH_INFO_INITIALIZER(FsDriver, entity);
    /* Start the IPC request processing loop */
    NkKosDoDispatch(handle, info);
    return EXIT_SUCCESS;
}
```

Example use of the `NkKosTransport_Dispatch()` function:

```
/* This function implements the endpoint method. */
static nk_err_t Open_impl(...)
{
...
}
```

```
/* This function implements the endpoint method. */
static nk_err_t Read_impl(...)
{
...
}

/* This function initializes the pointers to functions implementing the endpoint
methods.
 * (These pointers are used by the dispatcher to call functions implementing the
 * endpoint methods. The types of structures are automatically generated
 * transport code.) */
static struct FileIface *CreateFileOperations()
{
    static const struct FileIface_ops ops = {
        .Open = Open_impl,
        .Read = Read_impl
    };
    static struct FileIface impl = {
        .ops = &ops
    };
    return &impl;
}

int main(int argc, const char *argv[])
{
...
    /* Declare the structure containing the IPC transport parameters */
    NkKosTransport transport;
    /* Declare the stubs. (The types of stubs are automatically generated
     * transport code. */
    struct Operations_component component;
    struct FsDriver_entity entity;
    /* Declare the unions of the constant part of IPC requests and
     * IPC responses. (Types of unions are automatically generated
     * transport code.) */
    union FsDriver_entity_req req;
    union FsDriver_entity_res res;
    /* Declare the array for the IPC response arena. (The array size is
     * automatically generated transport code.) */
    char res_buffer[FsDriver_entity_res_arena_size];
    /* Declare and initialize the arena descriptor of the IPC response.
     * (The type of handle and its initialization macro are defined in the header file
     * sysroot-*-kos/include/nk/arena.h from the KasperskyOS SDK.) */
    struct nk_arena res_arena = NK_ARENA_INITIALIZER(res_buffer,
                                                     res_buffer + sizeof(res_buffer));
    /* Get the listener handle */
    Handle handle = ServiceLocatorRegister("driver_connection", NULL, 0, &iid);
    assert(handle != INVALID_HANDLE);
    /* Initialize the structure containing the IPC transport parameters */
    NkKosTransport_Init(&transport, handle, NK_NULL, 0);
    /* Initialize the stubs. (Methods for initializing stubs are
     * automatically generated transport code. Function
     * CreateFileOperations() is implemented by the developer of the
     * KasperskyOS-based solution to initialize
     * pointers to functions implementing the endpoint methods.) */
    Operations_component_init(&component, CreateFileOperations());
    FsDriver_entity_init(&entity, &component);
    /* Start the IPC request processing loop. (The dispatcher FsDriver_entity_dispatch
     * is automatically generated transport code.) */
    NkKosTransport_Dispatch(&transport.base, FsDriver_entity_dispatch,
                            &entity, &req, sizeof(FsDriver_entity_req),
```

```
                                RTL_NULL, &res, &res_arena);
    return EXIT_SUCCESS;
}
```

Copying data to the IPC message arena

To copy a string to the IPC message arena, call the `NkKosCopyStringToArena()` function declared in the header file `transport-kos.h`. This function reserves a segment of the arena and copies a string to this segment.

Example use of the `NkKosCopyStringToArena()` function:

```
static nk_err_t Read_impl(struct FileIface *self,
                          const struct FileIface_Read_req *req,
                          const struct nk_arena* req_arena,
                          struct FileIface_Read_res* res,
                          struct nk_arena* res_arena)
{
    /* Copy the string to the IPC response arena */
    if (NkKosCopyStringToArena(&res_arena, &res.content,
                               "CONTENT OF THE FILE") != rcOk) {
...
    }
    return NK_EOK;
}
```

Information about API functions

transport-kos.h functions

Function	Information about the function
`NkKosTransport_Init()`	Purpose Initializes IPC transport. Parameters • [out] `transport` – pointer to the structure containing the IPC transport parameters. • [in] `handle` – client or server IPC handle. • [in] `view` – parameter that must have the value `NK_NULL`. • [in] `size` – parameter that must have the value `0`. Returned values N/A
`NkKosTransportSync_Init()`	Purpose Initializes IPC transport with support for interrupting the `Call()` and/or `Recv()` system calls.

	Parameters • [out] `transport` – pointer to the structure containing the IPC transport parameters. • [in] `handle` – client or server IPC handle. • [in,optional] `callSyncHandle` – handle of the IPC synchronization object for `Call()` system calls, or `INVALID_HANDLE` if an interrupt of `Call()` system calls is not required. • [in,optional] `recvSyncHandle` – handle of the IPC synchronization object for `Recv()` system calls, or `INVALID_HANDLE` if an interrupt of `Recv()` system calls is not required. Returned values N/A
`NkKosSetTransportTimeouts()`	Purpose Defines the maximum lockout duration for `Call()` and `Recv()` system calls used for IPC transport. Parameters • [out] `transport` – pointer to the structure containing the IPC transport parameters. • [in] `recvTimeout` – maximum lockout duration for `Recv()` system calls in milliseconds, or `INFINITE_TIMEOUT` to define an unlimited lockout duration. • [in] `callTimeout` – maximum lockout duration for `Call()` system calls in milliseconds, or `INFINITE_TIMEOUT` to define an unlimited lockout duration. Returned values N/A
`NkKosTransport_Dispatch()`	Purpose Starts the IPC request processing loop. Parameters • [in] `transport` – pointer to the `base` field of the structure containing the IPC transport parameters. • [in] `dispatch` – pointer to the dispatcher (dispatch method) from the transport code. The dispatcher is named `<process class name>_entity_dispatch`. • [in] `impl` – pointer to the stub, which consists of a structure with the type `<process class name>_entity` from the transport

	code. The dispatcher uses this structure to get the pointers to functions implementing endpoint methods. • [out] `req` – pointer to the union with the type `<process class name>_entity_req` from the transport code. This union is intended for storing the constant part of IPC requests for any methods of endpoints provided by the server. • [in] `req_size` – maximum size (in bytes) of the constant part of IPC requests. It is defined as `sizeof(<process class name>_entity_req)`, where `<process class name>_entity_req` is the type from the transport code. • [in,out,optional] `req_arena` – pointer to the IPC request arena descriptor, or `RTL_NULL` if an IPC request arena is not in use. The type of handle is defined in the header file `sysroot-*-kos/include/nk/arena.h` from the KasperskyOS SDK. • [out] `res` – pointer to the union with the type `<process class name>_entity_res` from the transport code. This union is intended for storing the constant part of IPC responses for any methods of endpoints provided by the server. • [in,out,optional] `res_arena` – pointer to the IPC response arena descriptor, or `RTL_NULL` if an IPC response arena is not in use. The type of handle is defined in the header file `sysroot-*-kos/include/nk/arena.h` from the KasperskyOS SDK. Returned values If unsuccessful, it returns an error code.
`NkKosCopyStringToArena()`	Purpose Reserves a segment of the arena and copies a string to this segment. Parameters • [in,out] `arena` – pointer to the arena descriptor. The type of handle is defined in the header file `sysroot-*-kos/include/nk/arena.h` from the KasperskyOS SDK. • [out] `field` – pointer to the arena chunk descriptor where the string is copied. The type of handle is defined in the header file `sysroot-*-kos/include/nk/types.h`. • [in] `src` – pointer to the string to be copied to the IPC message arena. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.

transport-kos-dispatch.h functions

Function	Information about the function

`NkKosDoDispatch()`	Purpose Starts the IPC request processing loop. Parameters • [in] `h` – server IPC handle. • [in] `info` – pointer to the structure containing the data required by the function to use transport code (including the names of types, sizes of the constant part and IPC message arena). Returned values N/A

Initializing IPC transport for querying the security module (transport-kos-security.h)

The API is defined in the header file `sysroot-*-kos/include/coresrv/nk/transport-kos-security.h` from the KasperskyOS SDK.

The API initializes IPC transport for querying the Kaspersky Security Module via the security interface. Transport code works on top of IPC transport.

Information about API functions is provided in the table below.

This section contains an API usage example. In this example, the program that queries the security module has the following formal specification:

Verifier.edl

```
entity Verifier
security Approve
```

Approve.idl

```
package Approve
interface {
    Check(in UInt32 port);
}
```

Fragment of the policy description in the example:

security.psl

```
...
security src=Verifier, method=Check { assert (message.port > 80) }
...
```

Using the API

To initialize IPC transport for querying the security module, call the `NkKosSecurityTransport_Init()` function.

Example use of the `NkKosSecurityTransport_Init()` function:

```
int main(void)
{
    /* Declare the structure containing the IPC transport parameters for querying the
     * security module */
    NkKosSecurityTransport security_transport;
    /* Declare the proxy object. (The type of proxy object is automatically
     * generated transport code.) */
    struct Approve_proxy security_proxy;
    /* Declare the structures for saving the constant part of an IPC request and IPC
response for the
     * security interface method. (The types of structures are automatically generated
     * transport code.) */
    struct Approve_Check_req security_req;
    struct Approve_Check_res security_res;
    /* Initialize the structure containing the IPC transport parameters for querying
the
     * security module */
    if (NkKosSecurityTransport_Init(&security_transport, NK_NULL, 0) == NK_EOK) {
        /* Initialize the proxy object. (The proxy object initialization method and
the
         * security interface ID Verifier_securityIid are
         * automatically generated transport code.) */
        Approve_proxy_init(&security_proxy, &security_transport.base,
Verifier_securityIid);
    }
...
    /* Call the security interface method. (The method is automatically generated
     * transport code. The method does not pass any data through the security_res
parameter.
     * This parameter should be specified only if required by the method
implementation.) */
    security_req.port = 80;
    nk_err_t result = Approve_Check(&security_proxy.base, &security_req,
                      NULL, &security_res, NULL);
    if (result == NK_EOK)
        fprintf(stderr, "Granted");
    if (result == NK_EPERM)
        fprintf(stderr, "Denied");
    else
        fprintf(stderr, "Error");
    return EXIT_SUCCESS;
}
```

If a process needs to use several security interfaces, the same number of proxy objects must be initialized by specifying the same IPC transport and the unique IDs of the security interfaces.

Information about API functions

transport-kos-security.h functions

Function	Information about the function

`NkKosSecurityTransport_Init()`	Purpose Initializes IPC transport for querying the Kaspersky Security Module through the security interface. Parameters • [out] `transport` – pointer to the structure containing the IPC transport parameters for querying the security module. • [in] `view` – parameter that must have the value `NK_NULL`. • [in] `size` – parameter that must have the value `0`. Returned values If successful, the function returns `NK_EOK`, otherwise it returns an error code.

Generating random numbers (random_api.h)

The API is defined in the header file `sysroot-*-kos/include/kos/random/random_api.h` from the KasperskyOS SDK.

The API generates random numbers and includes functions that can be used to ensure high entropy (high level of unpredictability) of the seed value of the random number generator. The *start number of the random number generator* (seed) determines the sequence of the generated random numbers. In other words, if the same seed value is set, the generator creates identical sequences of random numbers. (The entropy of these numbers is fully determined by the entropy of the seed value, which means that these numbers are not entirely random, but pseudorandom.)

The random number generator of one process does not depend on the random number generators of other processes.

Information about API functions is provided in the table below.

Using the API

To generate a sequence of random byte values, call the `KosRandomGenerate()` or `KosRandomGenerateEx()` function.

Example use of the `KosRandomGenerate()` function:

```
size_t random_number;
if (KosRandomGenerate(sizeof random_number, &random_number) == rcOk) {
...
}
```

The `KosRandomGenerateEx()` function gets the quality level of the generated random values through the output parameter `quality`. The quality level can be high or low. High-quality random values are random values that are generated while fulfilling all of the following conditions:

1. When the seed value is changed, at least one entropy source is registered and data is successfully received from all registered entropy sources.

   To register the entropy source, call the `KosRandomRegisterSrc()` function. This function uses the `callback` parameter to receive the pointer to a callback function of the following type:

   ```
   typedef Retcode (*KosRandomSeedMethod)(void      *context,
                                          rtl_size_t size,
                                          void      *output);
   ```

   Using the `context` parameters, this callback function receives data with the specified `size` of bytes from the entropy source and writes this data to the `output` buffer. If the function returns `rcOk`, it is assumed that data was successfully received from the entropy source. An entropy source can be a digitalized signal of a sensor or a hardware-based random number generator, for example.

   To deregister an entropy source, call the `KosRandomUnregisterSrc()` function.

2. The random number generator is initialized if the quality level was low before changing the seed value while fulfilling condition 1.

   If the quality level is low, it cannot be changed to high without initializing the random number generator.

   To initialize a random number generator, call the `KosRandomInitSeed()` function. The entropy of data passed through the `seed` parameter must be guaranteed by the calling process.

3. The counter of random byte values that were generated after changing the seed value while fulfilling condition 1 does not exceed the system-defined limit.

4. The counter of time that has elapsed since changing the seed value while fulfilling condition 1 does not exceed the system-defined limit.

If at least one of these conditions is not fulfilled, the generated random values are deemed low-quality values.

When a process is started, the seed value is automatically defined by the system. Then the seed value is modified when doing the following:

- Generating a sequence of random values.

  Each successful call of the `KosRandomGenerateEx()` function with the `size` parameter greater than zero and each successful call of the `KosRandomGenerate()` function results in a change of the seed value of the random number generator, but not each seed change results in the receipt of data from registered entropy sources. The registered entropy sources are used only when condition 3 or 4 is not fulfilled. If at least one entropy source is registered, the time counter for the change in the seed value is reset. If data from at least one entropy source is successfully received, the counter of generated random byte values is also reset.

  The quality level may change from high to low.

- Initializing a random number generator.

  Each successful call of the `KosRandomInitSeed()` function changes the seed value by using the data that is passed through the `seed` parameter and received from registered entropy sources. If at least one registered entropy source is available, the counters for generated byte values and the time of a change in the seed value are reset. Otherwise, only the counter of generated random byte values is reset.

  The quality level may change from high to low, and vice versa.

- Registering an entropy source.

  Each successful call of the `KosRandomRegisterSrc()` function changes the seed value by using the data only from the registered entropy source. The counter of the generated random byte values is also reset.

  The quality level may not change.

A possible scenario for generating high-quality random values includes the following steps:

1. Register at least one source of entropy by calling the `KosRandomRegisterSrc()` function.
2. Generate a sequence of random values by calling the `KosRandomGenerateEx()` function.
3. Check the quality level of the random values.

   If the quality level is low, initialize the random number generator by calling the `KosRandomInitSeed()` function, and proceed to step 2.

   If the quality level is high, proceed to step 4.
4. Use random values.

To get the quality level without generating random values, call the `KosRandomGenerateEx()` function with the values `0` and `RTL_NULL` in the `size` and `output` parameters, respectively.

Information about API functions

random_api.h functions

Function	Information about the function
`KosRandomInitSeed()`	Purpose Initializes the random number generator. Parameters • [in] `seed` – pointer to the byte array that is used to change the seed value. The array must have a size of 32 bytes. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KosRandomGenerate()`	Purpose Generates a sequence of random byte values. Parameters • [in] `size` – size (in bytes) of the buffer used to store the sequence. • [out] `output` – pointer to the buffer used to store the sequence. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KosRandomGenerateEx()`	Purpose Generates a sequence of random byte values. Parameters

	• [in] `size` – size (in bytes) of the buffer used to store the sequence. • [out] `output` – pointer to the buffer used to store the sequence. • [out] `quality` – pointer to the boolean value that is true if the generated random values have high quality, and false if the generated random values have low quality. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KosRandomRegisterSrc()`	Purpose Registers an entropy source. Parameters • [in] `callback` – pointer to the function that receives data from the entropy source to change the seed value. • [in,optional] `context` – pointer to the parameters passed to the function defined through the `callback` parameter, or `RTL_NULL` if there are no parameters. • [in] `size` – size (in bytes) of the data that should be received from the entropy source when calling the function defined through the `callback` parameter. The size must be at least 32 bytes. • [out] `handle` – address of the pointer used to deregister the entropy source. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KosRandomUnregisterSrc()`	Purpose Deregisters the source of entropy. Parameters • [in] `handle` – pointer that is received when registering the source of entropy. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.

Getting and changing time values (time_api.h)

The API is defined in the header file `sysroot-*-kos/include/coresrv/time/time_api.h` from the KasperskyOS SDK.

Main capabilities of the API:

- Get and modify the system time
- Get the monotonic time that has elapsed since the moment the KasperskyOS kernel was started
- Get the resolution of the sources of system time and monotonic time

Information about API functions is provided in the table below.

time_api.h functions

Function	Information about the function
`KnGetSystemTimeRes()`	Purpose Gets the resolution of the system time source. Parameters • [out] `res` – pointer to the structure containing the resolution of the system time source (in nanoseconds) in the `nsec` field. The type of structure is defined in the header file `sysroot-*-kos/include/rtl/rtc.h` from the KasperskyOS SDK. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnSetSystemTime()`	Purpose Sets the system time. Parameters • [in] `time` – pointer to the structure containing the `sec` field, which indicates the number of seconds that have elapsed since January 1, 1970, and the `nsec` field, which indicates the number of nanoseconds that have elapsed since the time defined in the `sec` field. The type of structure is defined in the header file `sysroot-*-kos/include/rtl/rtc.h` from the KasperskyOS SDK. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnGetSystemTime()`	Purpose Gets the system time. Parameters • [out] `time` – pointer to the structure containing the `sec` field, which indicates the number of seconds that have elapsed since January 1, 1970, and the `nsec` field, which indicates the number of nanoseconds that have

	elapsed since the time defined in the `sec` field. The type of structure is defined in the header file `sysroot-*-kos/include/rtl/rtc.h` from the KasperskyOS SDK. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnGetUpTimeRes()`	Purpose Gets the resolution of the source of monotonic time that has elapsed since the KasperskyOS kernel was started. Parameters • [out] `res` – pointer to the structure containing the `nsec` field, which indicates the resolution of the source of monotonic time (in nanoseconds) that has elapsed since the KasperskyOS kernel was started. The type of structure is defined in the header file `sysroot-*-kos/include/rtl/rtc.h` from the KasperskyOS SDK. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnGetUpTime()`	Purpose Gets the monotonic time that has elapsed since the moment the KasperskyOS kernel was started. Parameters • [out] `time` – pointer to the structure containing the `sec` field, which indicates the number of seconds that have elapsed since the KasperskyOS kernel started, and the `nsec` field, which indicates the number of nanoseconds that have elapsed since the time defined in the `sec` field. The type of structure is defined in the header file `sysroot-*-kos/include/rtl/rtc.h` from the KasperskyOS SDK. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnGetRtcTime()`	Purpose Gets the system time. Parameters • [out] `rt` – pointer to the structure containing the following time data: year, month, day, hours, minutes, seconds, and milliseconds. The type of structure is defined in the header file `sysroot-*-kos/include/rtl/rtc.h` from the KasperskyOS SDK. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.

`KnGetMSecSinceStart()`	Purpose Gets the monotonic time that has elapsed since the moment the KasperskyOS kernel was started. Parameters N/A Returned values Monotonic time (in milliseconds) that has elapsed since the KasperskyOS kernel was started.
`KnAdjSystemTime()`	Purpose Starts gradual adjustment of the system time. Parameters • [in] `adj` – pointer to the structure containing the amount of time by which the system time must be adjusted (*sec*10^9+nsec* nanoseconds), or `RTL_NULL` if you do not need to start an adjustment but instead only need information about a previously run adjustment (through the `prev` parameter). The type of structure is defined in the header file `sysroot-*-kos/include/rtl/rtc.h` from the KasperskyOS SDK. • [in] `slew` – rate of system time adjustment (microseconds per second). • [out] `prev` – pointer to the structure containing the amount of time correction that remained (or remains if `RTL_NULL` was indicated in the `adj` parameter) for the already running gradual adjustment to fully complete (*sec*10^9+nsec* nanoseconds). The type of structure is defined in the header file `sysroot-*-kos/include/rtl/rtc.h` from the KasperskyOS SDK. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code. Additional information If a new adjustment is started before a previously running adjustment is finished, the previously running adjustment is interrupted.

Using notifications (notice_api.h)

The API is defined in the `sysroot-*-kos/include/coresrv/handle/notice_api.h` header file from the KasperskyOS SDK.

The API can track events that occur to (both system and user) resources, and inform other processes and threads about events involving user resources.

Information about API functions is provided in the table below.

Using the API

The notification mechanism uses an event mask. An *event mask* is a value whose bits are interpreted as events that should be tracked or that have already occurred. An event mask has a size of 32 bits and consists of a general part and a specialized part. The common part describes events that are not specific to any resources. The specialized part describes events that are specific to certain resources. Specialized part flags for system resources and common part flags are defined in the `sysroot-*-kos/include/handle/event_descr.h` header file from KasperskyOS SDK. (For example, the common part flag `EVENT_OBJECT_DESTROYED` signifies resource termination, and the specialized part flag `EVENT_TASK_COMPLETED` signifies process termination.) Specialized part flags for a user resource are defined by the resource provider with the help of the `OBJECT_EVENT_SPEC()` and `OBJECT_EVENT_USER()` macros, which are defined in the `sysroot-*-kos/include/handle/event_descr.h` header file from the KasperskyOS SDK. The resource provider must export the public header files describing the flags of the specialized part.

The standard scenario for receiving notifications about events occurring to resources consists of the following steps:

1. Creating a *notification receiver* (KasperskyOS kernel object that collects notifications) by calling the `KnNoticeCreate()` function.

2. Adding "resource—event mask" entries to the notification receiver to configure it to get notifications about events that occur to relevant resources.

   To add a "resource—event mask" entry to the notification receiver, you need to call the `KnNoticeSubscribeToObject()` function. (The `OCAP_HANDLE_GET_EVENT` flag should be set in the handle permissions mask of the resource stated in the `object` parameter.) Several "resource—event mask" entries can be added for one resource, and the entry identifiers do not need to be unique. Tracked events for each "resource—event mask" entry should be defined with an event mask that may match one or several events.

   "Resource—event mask" entries added to the notification receiver can be fully or partially removed to prevent the receiver from getting notifications that match these entries. To remove all "resource—event mask" entries from the receiver, you need to call the `KnNoticeDropAndWake()` function. To remove from the receiver "resource—event mask" entries that refer to the same resource, you need to call the `KnNoticeUnsubscribeFromObject()` function. To remove from the receiver a "resource—event mask" entry with a specific identifier, you need to call the `KnNoticeUnsubscribeFromEvent()` function.

   "Resource—event mask" entries can be added to, or removed from, the notification receiver throughout its life cycle.

3. Extracting notifications from the receiver with the `KnNoticeGetEvent()` function.

   You can set the time-out for notifications to appear in the receiver when calling the `KnNoticeGetEvent()` function. Threads that are locked while waiting for notifications to appear in the receiver will resume when notifications appear, even if these notifications match "resource—event mask" entries added after wait start.

   Threads that are locked while waiting for notifications to appear in the receiver will resume if all "resource—event mask" entries are removed from the receiver by calling the `KnNoticeDropAndWake()` function. If you add at least one "resource—event mask" entry to the notification receiver after calling the `KnNoticeDropAndWake()` function, threads that get notifications from that receiver will be locked again when calling the `KnNoticeGetEvent()` function for the specified time-out duration as long as there are no notifications. If all "resource—event mask" entries are removed from the notification receiver with the `KnNoticeUnsubscribeFromObject()` and/or `KnNoticeUnsubscribeFromEvent()` functions, threads waiting for notifications to appear in the receiver will not resume until the time-out elapses.

4. Removing a notification receiver by calling the `KnNoticeRelease()` function.

   Threads that are locked while waiting for notifications to appear in the receiver will resume when the receiver is removed by calling the `KnNoticeRelease()` function.

To notify other processes and/or threads about events that occurred to the user resource, you need to call the `KnNoticeSetObjectEvent()` function. Calling the function results in notifications appearing in receivers configured to get events defined with the `evMask` parameter that occur to the user resource defined with the `object` parameter. You cannot set flags of the general part of an event mask in the `evMask` parameter, because only the kernel can signal about events that match the general part of an event mask. If the process calling the `KnNoticeSetObjectEvent()` function created the user resource handle stated in the `object` parameter, you can set flags defined by the `OBJECT_EVENT_SPEC()` and `OBJECT_EVENT_USER()` macros in the `evMask` parameter. If the process calling the `KnNoticeSetObjectEvent()` function received the user resource handle stated in the `object` parameter from another process, you can set only those flags defined by the `OBJECT_EVENT_USER()` macro in the `evMask` parameter, while the permissions mask of the resulting handle must have a `OCAP_HANDLE_SET_EVENT` flag set.

Information about API functions

notice_api.h functions

Function	Information about the function
`KnNoticeCreate()`	Purpose Creates a notification receiver. Parameters • [out] `notice` – pointer to the identifier of the notification receiver. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnNoticeSubscribeToObject()`	Purpose Adds a "resource–event mask" entry to the notification receiver so that it can receive notifications about events that occur with the defined resource and match the defined event mask. Parameters • [in] `notice` – identifier of the notification receiver. • [in] `object` – resource handle. • [in] `evMask` – event mask. • [in] `evId` – ID of the "resource–event mask" entry. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnNoticeGetEvent()`	Purpose Extracts notifications from the receiver.

	Parameters • [in] `notice` – identifier of the notification receiver. • [in] `msec` – time-out before notifications appearing in the receiver, in milliseconds, or `INFINITE_TIMEOUT` to set an unlimited time-out. • [in] `countMax` – maximum number of notifications extracted with one function call. • [out] `events` – pointer to a set of notifications that represent structures containing the identifier of a "resource—event mask" entry and the mask of the events that occurred to the resource. • [out] `count` – number of notifications extracted. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code. If the time-out for notifications to appear in the receiver has elapsed, returns `rcTimeout`. If the time-out for notifications appear in the receiver is interrupted by a call to the `KnNoticeRelease()` or `KnNoticeDropAndWake()` functions, returns `rcResourceNotFound`.
`KnNoticeUnsubscribeFromObject()`	Purpose Removes from the notification receiver "resource—event mask" entries that match the specified resource to prevent the receiver from getting notifications about events that match these entries. Parameters • [in] `notice` – identifier of the notification receiver. • [in] `object` – resource handle. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code. Additional information Notifications that correspond to the removed "resource—event mask" entries will be removed from the receiver.
`KnNoticeUnsubscribeFromEvent()`	Purpose

	Removes from the notification receiver "resource—event mask" entries with the specified identifier to prevent the receiver from getting notifications about events that match these entries. Parameters • [in] `notice` – identifier of the notification receiver. • [in] `evId` – ID of the "resource–event mask" entry. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code. Additional information Notifications that correspond to the removed "resource—event mask" entries will be removed from the receiver.
`KnNoticeDropAndWake()`	Purpose Removes all "resource—event mask" entries from the specified notification receiver and resumes all threads that are waiting for notifications to appear in the specified receiver. Parameters • [in] `notice` – identifier of the notification receiver. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnNoticeRelease()`	Purpose Removes the specified notification receiver and resumes all threads that are waiting for notifications to appear in the specified receiver. Parameters • [in] `notice` – identifier of the notification receiver. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnNoticeSetObjectEvent()`	Purpose Signals that events matching the specified event mask occurred to the specified user resource. Parameters • [in] `object` – user resource handle.

	• [in] `evMask` – mask of events to be signaled. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.

Dynamically creating IPC channels (cm_api.h, ns_api.h)

APIs are defined in the header files from the KasperskyOS SDK:

- `sysroot-*-kos/include/coresrv/cm/cm_api.h`
- `sysroot-*-kos/include/coresrv/ns/ns_api.h`

The API dynamically creates IPC channels.

Information about API functions is provided in the tables below.

Using the API

To ensure that servers can notify clients about the endpoints that they provide, the solution should include a name server, which is provided by the `NameServer` system program (executable file `sysroot-*-kos/bin/ns` from the KasperskyOS SDK). IPC channels from clients and servers to a name server can be statically created (these IPC channels must be named `kl.core.NameServer`). If this is not done, attempts will be made to dynamically create these IPC channels whenever clients and servers call the `NsCreate()` function. A name server does not have to be included in a solution if the clients initially already have information about the names of servers and the endpoints provided by these servers.

The names of endpoints and interfaces should be defined according to the formal specifications of solution components. (For information about the qualified name of an endpoint, see "Binding methods of security models to security events") Instead of the qualified name of an endpoint, you can use any conditional name of this endpoint. The names of clients and servers are defined in the init description. You can also get a process name by calling the `KnTaskGetName()` function from the API task_api.h.

Dynamic creation of an IPC channel on the server side includes the following steps:

1. Connect to the name server by calling the `NsCreate()` function.
2. Publish the provided endpoints on the name server by using the `NsPublishService()` function.

   To unpublish an endpoint, call the `NsUnPublishService()` function.
3. Receive a client request to create an IPC channel by calling the `KnCmListen()` function.

   The `KnCmListen()` function gets the first request in the queue without deleting this request but instead putting it at the end of the queue. If there is only one request in the queue, multiple consecutive calls of the `KnCmListen()` function will provide the same result. A request is deleted from the queue when the `KnCmAccept()` or `KnCmDrop()` function is called.
4. You can accept a client request to create an IPC channel by calling the `KnCmAccept()` function.

   To decline a client request, call the `KnCmDrop()` function.

A listener handle is created when the `KnCmAccept()` function is called with the `INVALID_HANDLE` value in the `listener` parameter. If a listener handle is specified, the created server IPC handle will provide the capability to receive IPC requests over all IPC channels associated with this listener handle. (The first IPC channel associated with the listener handle is created when the `KnCmAccept()` function is called with the `INVALID_HANDLE` value in the `listener` parameter. The second and subsequent IPC channels associated with the listener handle are created during the second and subsequent calls of the `KnCmAccept()` function specifying the handle that was obtained during the first call.) In the `listener` parameter of the `KnCmAccept()` function, you can specify the listener handle received using the `KnHandleConnect()`, `KnHandleConnectEx()` and `KnHandleCreateListener()` functions from the API handle_api.h, and the `ServiceLocatorRegister()` function declared in the header file `sysroot-*-kos/include/coresrv/sl/sl_api.h` from the KasperskyOS SDK.

Dynamic creation of an IPC channel on the client side includes the following steps:

1. Connect to the name server by calling the `NsCreate()` function.
2. Find the server providing the required endpoint by using the `NsEnumServices()` function.

   To get a full list of endpoints with a defined interface, call the function several times while incrementing the index until you receive the `rcResourceNotFound` error.
3. Fulfill the request to create an IPC channel with the necessary server by calling the `KnCmConnect()` function.

You can connect multiple clients and servers to the name server. Each client and server can create multiple connections to the name server. A server can unpublish an endpoint that was published by another server.

Deleting dynamically created IPC channels

A dynamically created IPC channel will be deleted when its client IPC handle and server IPC handle are closed.

Information about API functions

ns_api.h functions

Function	Information about the function
`NsCreate()`	Purpose Creates a connection to a name server. Parameters • [in,optional] `name` – pointer to the name of the name server process, or `RTL_NULL` to assign the default name (corresponds to the `NS_SERVER_NAME` macro value). • [in] `msecs` – timeout (in milliseconds) for creating a connection to the name server, or `INFINITE_TIMEOUT` to define an unlimited timeout. • [out] `ns` – pointer to the ID of the connection to the name server. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`NsPublishService()`	Purpose

	Publishes an endpoint on a name server. Parameters • [in] `ns` – ID of the connection to the name server. • [in] `type` – pointer to the name of the endpoint interface. • [in,optional] `server` – pointer to the name of the server providing the endpoint, or `RTL_NULL` to use the name of the calling process. • [in] `service` – pointer to the qualified name of the endpoint. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`NsUnPublishService()`	Purpose Unpublishes an endpoint on a name server. Parameters • [in] `ns` – ID of the connection to the name server. • [in] `type` – pointer to the name of the endpoint interface. • [in,optional] `server` – pointer to the name of the server providing the endpoint, or `RTL_NULL` to use the name of the calling process. • [in] `service` – pointer to the qualified name of the endpoint. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`NsEnumServices()`	Purpose Enumerates the endpoints published on a name server. Parameters • [in] `ns` – ID of the connection to the name server. • [in] `type` – pointer to the name of the interface of endpoints. • [in] `index` – index for enumerating endpoints. Enumeration starts with zero. • [out] `server` – pointer to the buffer for the name of the server providing the endpoint. • [in] `serverSize` – buffer size (in bytes) for the name of the server providing the endpoint. • [out] `service` – pointer to the buffer for the qualified name of the endpoint.

	• [in] `serviceSize` – buffer size (in bytes) for the qualified name of the endpoint. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.

cm_api.h functions

Function	Information about the function
`KnCmConnect()`	Purpose Requests to create an IPC channel with a server for use of the defined endpoint. Parameters • [in] `server` – pointer to the server name. • [in] `service` – pointer to the qualified name of the endpoint. • [in] `msecs` – timeout (in milliseconds) for fulfilling a request, or `INFINITE_TIMEOUT` to define an unlimited timeout. • [out] `handle` – pointer to the client IPC handle. • [out] `rsid` – pointer to the endpoint ID (RIID). Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnCmListen()`	Purpose Receives a client request to create an IPC channel for use of an endpoint. Parameters • [in] `filter` – fictitious parameter that must have the value `RTL_NULL`. • [in] `msecs` – timeout (in milliseconds) for the appearance of a client request, or `INFINITE_TIMEOUT` to define an unlimited timeout. • [out] `client` – pointer to the client name. • [out] `service` – pointer to the qualified name of the endpoint. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnCmDrop()`	Purpose Rejects a client request to create an IPC channel for use of the defined endpoint. Parameters • [in] `client` – pointer to the client name.

	• [in] `service` – pointer to the qualified name of the endpoint. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnCmAccept()`	Purpose Accepts a client request to create an IPC channel for use of the defined endpoint. Parameters • [in] `client` – pointer to the client name. • [in] `service` – pointer to the qualified name of the endpoint. • [in] `rsid` – endpoint ID (RIID). • [in,optional] `listener` – listener handle, or `INVALID_HANDLE` if you need to create it. • [out] `handle` – pointer to the server IPC handle. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.

Using synchronization primitives (event.h, mutex.h, rwlock.h, semaphore.h, condvar.h)

The `libkos` library provides APIs that enable use of the following synchronization primitives:

- Events (`event.h`)
- Mutexes (`mutex.h`)
- Read-write locks (`rwlock.h`)
- Semaphores (`semaphore.h`)
- Conditional variables (`condvar.h`)

The header files are located in the KasperskyOS SDK at `sysroot-*-kos/include/kos`.

The APIs are intended for synchronizing threads that belong to the same process.

Events

An *event* is a synchronization primitive that is used to notify one or more threads about the fulfillment of a condition required by these threads. The notified thread waits for the event to switch from a non-signaling state to a signaling state, and the notifying thread changes the state of this event.

The standard API usage scenario for working with events includes the following steps:

1. An event is initialized via the `KosEventInit()` function call.
2. The event is used by threads:
   - The notified threads wait for the event to switch from non-signaling state to signaling state via the `KosEventWait()` or `KosEventWaitTimeout()` function call.
   - The notifying threads change the state of the event via the `KosEventSet()` and `KosEventReset()` function calls.

Information about the API event functions is provided in the table below.

event.h functions

Function	Information about the function
`KosEventInit()`	Purpose Initializes an event. The event is in a non-signaling state after it is initialized. Parameters • [out] `event` – pointer to the event. The event type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values N/A
`KosEventSet()`	Purpose Sets the event state to signaling. Parameters • [out] `event` – pointer to the event. The event type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values N/A
`KosEventReset()`	Purpose Sets the event state to non-signaling. Parameters • [out] `event` – pointer to the event. The event type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK.

	Returned values N/A
`KosEventWait()`	Purpose Waits for the event to change its state from non-signaling to signaling. Parameters • [in,out] `event` – pointer to the event. The event type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. • [in] `reset` – value that defines whether the event state should be changed set to non-signaling after the time-out has elapsed (`rtl_true` – yes, `rtl_false` – no). The parameter type is defined in the `sysroot-*-kos/include/rtl/stdbool.h` header file from the KasperskyOS SDK. Returned values N/A
`KosEventWaitTimeout()`	Purpose Waits on the event to change its state from non-signaling to signaling for a period that does not exceed the specified time. Parameters • [in,out] `event` – pointer to the event. The event type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. • [in] `reset` – value that defines whether the event state should be changed set to non-signaling after the time-out has elapsed (`rtl_true` – yes, `rtl_false` – no). The parameter type is defined in the `sysroot-*-kos/include/rtl/stdbool.h` header file from the KasperskyOS SDK. • [in] `mdelay` – time-out (in milliseconds) or `INFINITE_TIMEOUT` to set an unlimited time-out. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code. Returns `rcTimeout` if the time-out has elapsed.

Mutexes

A *mutex* is a synchronization primitive that ensures mutually exclusive execution of *critical sections* (areas of code where resources shared between threads are queried). One thread captures the mutex and executes a critical section. Meanwhile, other threads wait for the mutex to be freed and attempt to capture this mutex to execute other critical sections. A mutex can be freed only by the specific thread that captured it. You can use a *recursive mutex*, which can be captured by the same thread multiple times.

The standard API usage scenario for working with mutexes includes the following steps:

1. A mutex is initialized via the `KosMutexInit()` or `KosMutexInitEx()` function call.
2. The mutex is used by threads:
   a. The mutex is captured via the `KosMutexTryLock()`, `KosMutexLock()` or `KosMutexLockTimeout()` function call.
   b. The mutex is freed via the `KosMutexUnlock()` function call.

Information about the API mutex functions is provided in the table below.

mutex.h functions

Function	Information about the function
`KosMutexInit()`	Purpose Initializes a non-recursive mutex. Parameters • [out] `mutex` – pointer to the mutex. The mutex type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values N/A
`KosMutexInitEx()`	Purpose Initializes a mutex. Parameters • [out] `mutex` – pointer to the mutex. The mutex type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. • [in] `recursive` – value that defines whether the mutex should be recursive (`1` – yes, `0` – no). Returned values N/A
`KosMutexTryLock()`	Purpose Acquires the mutex. If the mutex is already acquired, returns control rather than waits for the mutex to be released. Parameters

	• [in,out] `mutex` – pointer to the mutex. The mutex type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code. If the mutex is already acquired, returns `rcBusy`.
`KosMutexLock()`	Purpose Acquires the mutex. If the mutex is already acquired, waits indefinitely for it to be released. Parameters • [in,out] `mutex` – pointer to the mutex. The mutex type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values N/A
`KosMutexUnlock()`	Purpose Releases the mutex. Parameters • [in,out] `mutex` – pointer to the mutex. The mutex type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values N/A
`KosMutexLockTimeout()`	Purpose Acquires the mutex. If the mutex is already acquired, waits for it to be released for a period that does not exceed the specified time. Parameters • [in,out] `mutex` – pointer to the mutex. The mutex type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. • [in] `mdelay` – time-out (in milliseconds) or `INFINITE_TIMEOUT` to set an unlimited time-out. Returned values

	If successful, the function returns `rcOk`, otherwise it returns an error code. Returns `rcTimeout` if the time-out has elapsed.

Read-write locks

A *read-write lock* is a synchronization primitive used to allow access to resources shared between threads: write access for one thread or read access for multiple threads at the same time.

The standard API usage scenario for working with read-write locks includes the following steps:

1. A read-write lock is initialized by the `KosRWLockInit()` function call.
2. The read-write lock is used by threads:
   a. The read-write lock is captured for write operations (via the `KosRWLockWrite()` or `KosRWLockTryWrite()` function call) or for read operations (via the `KosRWLockRead()` or `KosRWLockTryRead()` function call).
   b. The read-write lock is freed via the `KosRWLockUnlock()` function call.

Information about the API read-write lock functions is provided in the table below.

rwlock.h functions

Function	Information about the function
`KosRWLockInit()`	Purpose Initializes a read-write lock. Parameters • [out] `rwlock` – pointer to a read-write lock. The read-write lock type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values N/A
`KosRWLockRead()`	Purpose Acquires a read-write lock for reading. If the read-write lock is already acquired for writing, or if there are threads waiting on the lock to be acquired for writing, waits indefinitely for the lock to be released. Parameters • [in,out] `rwlock` – pointer to the read-write lock. The read-write lock type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values

	N/A
`KosRWLockTryRead()`	Purpose Acquires the read-write lock for reading. If the read-write lock is already acquired for writing, or if there are threads waiting on the lock to be acquired for writing, returns control, rather than waits for the lock to be released. Parameters • [in,out] `rwlock` – pointer to the read-write lock. The read-write lock type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KosRWLockWrite()`	Purpose Acquires the read-write lock for writing. If the read-write lock is already acquired for writing or reading, waits indefinitely for the lock to be released. Parameters • [in,out] `rwlock` – pointer to the read-write lock. The read-write lock type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values N/A
`KosRWLockTryWrite()`	Purpose Acquires the read-write lock for writing. If the read-write lock is already acquired for writing or reading, returns control, rather than waits for the lock to be released. Parameters • [in,out] `rwlock` – pointer to the read-write lock. The read-write lock type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KosRWLockUnlock()`	Purpose Releases the read-write lock.

	Parameters • [in,out] `rwlock` – pointer to the read-write lock. The read-write lock type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values N/A Additional information If the read-write lock is acquired for reading, it remains acquired for reading until released by every reading thread.

Semaphores

A *semaphore* is a synchronization primitive that is based on a counter whose value can be atomically modified. The value of the counter normally reflects the number of available resources shared between threads. To execute a critical section, the thread waits until the counter value becomes greater than zero. If the counter value is greater than zero, it is decremented by one and the thread executes the critical section. After the critical section is executed, the thread signals the semaphore and the counter value is increased.

The standard API usage scenario for working with semaphores includes the following steps:

1. A semaphore is initialized via the `KosSemaphoreInit()` function call.
2. The semaphore is used by threads:
   a. They wait for the semaphore via the `KosSemaphoreWait()`, `KosSemaphoreWaitTimeout()` or `KosSemaphoreTryWait()` function call.
   b. The semaphore is signaled via the `KosSemaphoreSignal()` or `KosSemaphoreSignalN()` function call.
3. Deallocating semaphore resources by calling the `KosSemaphoreDeinit()` function.

Information about the API semaphore functions is provided in the table below.

semaphore.h functions

Function	Information about the function
`KosSemaphoreInit()`	Purpose Initializes a semaphore. Parameters • [out] `semaphore` – pointer to the semaphore. The semaphore type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. • [in] `count` – counter value. Returned values

	If successful, the function returns `rcOk`, otherwise it returns an error code. If the value of the `count` parameter exceeds the `KOS_SEMAPHORE_VALUE_MAX` constant, returns `rcInvalidArgument`. (The `KOS_SEMAPHORE_VALUE_MAX` constant is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK.)
`KosSemaphoreDeinit()`	Purpose Deallocates semaphore resources. Parameters • [in] `semaphore` – pointer to the semaphore. The semaphore type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code. If there are threads waiting on the semaphore, returns `rcBusy`.
`KosSemaphoreSignal()`	Purpose Signals the semaphore and increases the counter by one. Parameters • [in, out] `semaphore` – pointer to the semaphore. The semaphore type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KosSemaphoreSignalN()`	Purpose Signals the semaphore and increases the counter by the specified number. Parameters • [in, out] `semaphore` – pointer to the semaphore. The semaphore type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. • [in] `n` – natural number by which to increase the counter. Returned values

	If successful, the function returns `rcOk`, otherwise it returns an error code.
`KosSemaphoreWaitTimeout()`	Purpose Waits on the semaphore for a period that does not exceed the specified time. Parameters • [in, out] `semaphore` – pointer to the semaphore. The semaphore type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. • [in] `mdelay` – semaphore time-out in milliseconds or `INFINITE_TIMEOUT` to set an unlimited time-out. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code. Returns `rcTimeout` if the time-out has elapsed.
`KosSemaphoreWait()`	Purpose Waits on the semaphore indefinitely. Parameters • [in, out] `semaphore` – pointer to the semaphore. The semaphore type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KosSemaphoreTryWait()`	Purpose Waits on the semaphore. If the semaphore counter has a zero value, returns control, rather than waits for the semaphore counter to increase. Parameters • [in, out] `semaphore` – pointer to the semaphore. The semaphore type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values

	If successful, the function returns `rcOk`, otherwise it returns an error code. If the semaphore counter has a zero value, returns `rcBusy`.

Conditional variables

A *conditional variable* is a synchronization primitive that is used to notify one or more threads about the fulfillment of a condition required by these threads. A conditional variable is used together with a mutex. The notifying and notified threads capture a mutex to execute critical sections. During execution of a critical section, the notified thread verifies that its required condition was fulfilled (for example, the data has been prepared by the notifying thread). If the condition is fulfilled, the notified thread executes the critical section and frees the mutex. If the condition is not fulfilled, the notified thread is locked at the conditional variable and waits for the condition to be fulfilled. When this happens, the mutex is automatically freed. During execution of a critical section, the notifying thread verifies fulfillment of the condition required by the notified thread. If the condition is fulfilled, the notifying thread signals this fulfillment through the conditional variable and frees the mutex. The notified thread that was locked and waiting for the fulfillment of its required condition resumes execution of the critical section while automatically capturing the mutex. After the critical section is executed, the notified thread frees the mutex.

The standard API usage scenario for working with conditional variables includes the following steps:

1. The conditional variable and mutex are initialized.

   To initialize a conditional variable, you need to call the `KosCondvarInit()` function.

2. The conditional variable and mutex are used by threads.

Use of a conditional variable and mutex by notified threads includes the following steps:

1. The mutex is captured.
2. Condition fulfillment is verified.
3. The `KosCondvarWait()` or `KosCondvarWaitTimeout()` function is called to wait for condition fulfillment.

   After the `KosCondvarWait()` or `KosCondvarWaitTimeout()` function is returned, you normally need to re-verify that the condition is fulfilled because another notified thread also received the signal and may have voided this condition again. (For example, another thread could have extracted the data prepared by the notifying thread). To do so, you need to use the following construct:

   ```
   while(<condition>)
   <call of KosCondvarWait() or KosCondvarWaitTimeout()>
   ```

4. The mutex is freed.

Use of a conditional variable and mutex by notifying threads includes the following steps:

1. The mutex is captured.
2. Condition fulfillment is verified.
3. Fulfillment of the condition is signaled via the `KosCondvarSignal()` or `KosCondvarBroadcast()` function call.
4. The mutex is freed.

Information about the API conditional variable functions is provided in the table below.

condvar.h functions

Function	Information about the function
`KosCondvarInit()`	Purpose Initializes a conditional variable. Parameters • [out] `condvar` – pointer to the conditional variable. The conditional variable type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values N/A
`KosCondvarWaitTimeout()`	Purpose Waits for condition fulfillment for a period that does not exceed the specified time. Parameters • [in] `condvar` – pointer to the conditional variable. The conditional variable type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. • [in,out] `mutex` – pointer to the mutex. The mutex type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. • [in] `mdelay` – condition fulfillment time-out in milliseconds, or `INFINITE_TIMEOUT` to set an unlimited time-out. Returned values Returns `rcOk` if successful. Returns `rcTimeout` if the time-out has elapsed.
`KosCondvarWait()`	Purpose Waits indefinitely for condition fulfillment. Parameters • [in] `condvar` – pointer to the conditional variable. The conditional variable type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK.

	• [in,out] `mutex` – pointer to the mutex. The mutex type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KosCondvarSignal()`	Purpose Signals condition fulfillment to one of the threads waiting for it. Parameters • [in, out] `condvar` – pointer to the conditional variable. The conditional variable type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values N/A
`KosCondvarBroadcast()`	Purpose Signals condition fulfillment to all threads waiting for it. Parameters • [in, out] `condvar` – pointer to the conditional variable. The conditional variable type is defined in the `sysroot-*-kos/include/kos/sync_types.h` header file from the KasperskyOS SDK. Returned values N/A

Managing I/O memory isolation (iommu_api.h)

The API is defined in the `sysroot-*-kos/include/coresrv/iommu/iommu_api.h` header file from the KasperskyOS SDK.

The API is intended for managing the isolation of physical memory regions used by devices on a PCIe bus for DMA. (Isolation is provided by the IOMMU.)

Information about API functions is provided in the table below.

Using the API

A device on the PCIe bus cannot use DMA unless the device is attached to the IOMMU domain. After a device is attached to the IOMMU domain, the device can access all DMA buffers that are associated with this IOMMU domain. A device can be attached to only one IOMMU domain at a time, but multiple devices can be attached to the same IOMMU domain. A DMA buffer can be associated with multiple IOMMU domains at the same time. Each process is associated with a separate IOMMU domain.

The API attaches devices on the PCIe bus to an IOMMU domain associated with the calling process, and performs the inverse operation. A device is normally attached to an IOMMU domain when its driver is initialized. A device is usually detached from an IOMMU domain when errors are encountered during driver initialization or driver finalization.

A DMA buffer is associated with an IOMMU domain when calling the `KnIoDmaBegin()` function that is included in the API dma.h.

Information about API functions

iommu_api.h functions

Function	Information about the function
`KnIommuAttachDevice()`	Purpose Attaches a device on a PCIe bus to the IOMMU domain associated with the calling process. Parameters • [in] `bdf` – address of the device on the PCIe bus in BDF format. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code. Additional information If IOMMU is not enabled, `rcOk` is returned.
`KnIommuDetachDevice()`	Purpose Detaches a device on a PCIe bus from the IOMMU domain associated with the calling process. Parameters • [in] `bdf` – address of the device on the PCIe bus in BDF format. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code. Additional information If IOMMU is not enabled, `rcOk` is returned.

Using queues (queue.h)

The API is defined in the header file `sysroot-*-kos/include/kos/queue.h` from the KasperskyOS SDK.

The API sets up data exchange between threads owned by one process via a queuing mechanism that does not lock threads. In other words, you can add or extract elements of a queue without locking other threads that add or extract elements of this queue.

Information about API functions is provided in the table below.

Using the API

The standard scenario for API usage includes the following steps:

1. Create a queue abstraction.

   A queue abstraction consists of a structure containing queue metadata and a queue buffer intended for storing elements of the queue. A queue buffer is logically divided into equal segments, each of which is intended for an individual element of the queue. The number of segments in a queue buffer matches the maximum number of elements in the queue. The alignment of segment addresses corresponds to the data types of elements in the queue.

   To complete this step, call the `KosQueueCreate()` function. This function can allocate memory for the queue buffer or use already allocated memory. The size of the already allocated memory must be sufficient to accommodate the maximum number of elements in the queue. Also take into account that the size of a segment in the queue buffer is rounded to the next largest multiple of the alignment value defined through the `objAlign` parameter. The initial address of the already allocated memory must also be aligned to correspond to the data types of queue elements. If the memory address alignment specified in the `buffer` parameter is less than the value defined through the `objAlign` parameter, the function returns `RTL_NULL`.

2. Exchange data between threads by adding and extracting elements of the queue.

   To add one element to the end of the queue, you must reserve a segment in the queue buffer by calling the `KosQueueAlloc()` function, copy this element to the reserved segment, and call the `KosQueuePush()` function.

   To add a sequence of elements to the end of the queue, you must reserve the necessary number of segments in the queue buffer via `KosQueueAlloc()` function calls, copy the elements of this sequence to the reserved segments, and call the `KosQueuePushArray()` function. The order of elements in a sequence is not changed after this sequence is added to the queue. In other words, elements are added to the queue in the same order in which the pointers to reserved segments in the queue buffer are put into the array that is passed through the `objs` parameter of the `KosQueuePushArray()` function.

   To extract the first element of the queue, you must call the `KosQueuePop()` function. This function returns the pointer to the reserved segment in the queue buffer that contains the first element of the queue. After using an extracted element (for example, after checking or saving the value of an element), you must free the queue buffer segment occupied by this element. To do so, call the `KosQueueFree()` function.

   To clear the queue and free all registered segments in the queue buffer, you must call the `KosQueueFlush()` function.

3. Delete the queue abstraction.

   To complete this step, call the `KosQueueDestroy()` function. This function deletes the queue buffer if only the memory for this buffer was allocated by the `KosQueueCreate()` function. Otherwise, you must separately delete the queue buffer.

queue.h functions

Function	Information about the function
`KosQueueCreate()`	Purpose Creates a queue abstraction. Parameters • [in] `objCount` – maximum number of elements in the queue. • [in] `objSize` – size (in bytes) of an element in the queue. • [in] `objAlign` – alignment of segment addresses in the queue buffer. The addresses of segments in the queue buffer may be unaligned (*objAlign=1*) or aligned (*objAlign=2,4,...,2^N*) to the boundary of a *2^N*-byte sequence (for example, two-byte or four-byte). • [in,optional] `buffer` – pointer to the allocated memory for the queue buffer, or `RTL_NULL` to automatically allocate the memory. Returned values If successful, the function returns the queue abstraction ID, otherwise it returns `RTL_NULL`.
`KosQueueDestroy()`	Purpose Deletes a queue abstraction. Parameters • [in] `queue` – queue abstraction ID. Returned values N/A
`KosQueueAlloc()`	Purpose Reserves a segment in the queue buffer. Parameters • [in] `queue` – queue abstraction ID. Returned values If successful, the function returns the pointer to the reserved segment in the queue buffer, otherwise it returns `RTL_NULL`.
`KosQueueFree()`	Purpose Resets the reservation of the defined segment in the queue buffer.

	Parameters • [in] `queue` – queue abstraction ID. • [in] `obj` – pointer to the reserved segment in the queue buffer. Returned values N/A
`KosQueuePush()`	Purpose Adds an element to the end of the queue. Parameters • [in] `queue` – queue abstraction ID. • [in] `obj` – pointer to the reserved segment in the queue buffer. Returned values N/A
`KosQueuePushArray()`	Purpose Adds a sequence of elements to the end of the queue. Parameters • [in] `queue` – queue abstraction ID. • [in] `objs` – array of pointers to reserved segments in the queue buffer. • [in] `count` – number of elements in the sequence. Returned values N/A
`KosQueuePop()`	Purpose Extracts the first element of the queue. Parameters • [in] `queue` – queue abstraction ID. • [in] `timeout` – timeout (in milliseconds) for an element to appear in the queue, or `INFINITE_TIMEOUT` to set an unlimited timeout. Returned values If successful, this function returns the pointer to the reserved segment in the queue buffer containing the first element of the queue. Otherwise it returns `RTL_NULL`.

`KosQueueFlush()`	Purpose Clears the queue and resets the reservation of all registered segments in the queue buffer. Parameters • [in] `queue` – queue abstraction ID. Returned values N/A

Using memory barriers (barriers.h)

This API is defined in the header file `sysroot-*-kos/include/coresrv/io/barriers.h` from the KasperskyOS SDK.

The API sets barriers for reading from memory and/or writing to memory. A *memory barrier* is an instruction for a compiler or processor that guarantees that memory access operations specified in source code before setting a barrier will be executed before the memory access operations specified in source code after setting a barrier. Use of memory barriers is required if the specific order of memory write and memory read operations is important. Otherwise, the optimization mechanisms of a compiler and/or processor could cause these operations to be executed in a different order than the order specified in the source code.

Information about API functions is provided in the table below.

barriers.h functions

Function	Information about the function
`IoReadBarrier()`	Purpose Sets a barrier for reading from memory. Parameters N/A Returned values N/A
`IoWriteBarrier()`	Purpose Sets a barrier for writing to memory. Parameters N/A Returned values N/A
`IoReadWriteBarrier()`	Purpose

	Sets a barrier for writing to memory and reading from memory. Parameters N/A Returned values N/A

Executing system calls (syscalls.h)

This API is defined in the header file `sysroot-*-kos/include/coresrv/syscalls.h` from the KasperskyOS SDK.

The API allows execution of the `Call()`, `Recv()`, and `Reply()` system calls for sending and receiving IPC messages.

Information about API functions is provided in the table below.

Using the API

Pointers to buffers containing the constant part and arena of IPC messages are passed to API functions by using an IPC message header whose type is defined in the header file `sysroot-*-kos/include/ipc/if_rend.h` from the KasperskyOS SDK. Prior to API function calls, the headers of IPC messages must be bound to buffers containing the constant part and arena of IPC messages. To do so, use the `PackInMsg()` and `PackOutMsg()` functions that are declared in the header file `sysroot-*-kos/include/services/rtl/nk_msg.h` from the KasperskyOS SDK.

The `Call()`, `CallEx()`, `Recv()`, and `RecvEx()` functions lock execution of the calling thread while waiting for the system calls to complete. The `CallEx()` and `RecvEx()` functions let you define the timeout for completion of a system call. When this timeout is reached, an uncompleted system call is interrupted and the thread that is waiting for its completion resumes execution. A system call is also interrupted if an error occurs during its execution (such as an error due to termination of a server process). If a thread waiting on the completion of a system call is terminated externally, this system call is also interrupted. A system call executed by the `CallEx()` or `RecvEx()` function can be interrupted (for example, for correct termination of a process) by using the API ipc_api.h.

If a system call was interrupted using the API ipc_api.h, the `CallEx()` and `RecvEx()` functions return the error code `rcIpcInterrupt`. If IPC message transmission is prohibited by security mechanisms (such as the Kaspersky Security Module or a capability-based security mechanism implemented by the KasperskyOS kernel), the `Call()`, `CallEx()`, and `Reply()` functions return the error code `rcSecurityDisallow`.

Information about API functions

syscalls.h functions

Function	Information about the function
`Call()`	Purpose Executes the `Call()` system call with an unlimited timeout for its completion.

	Parameters • [in] `handle` – client IPC handle. • [in] `msgOut` – pointer to the header of IPC requests. • [in,out] `msgIn` – pointer to the header of IPC responses. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`CallEx()`	Purpose Executes the `Call()` system call with a defined timeout for its completion and the capability to interrupt its execution. Parameters • [in] `handle` – client IPC handle. • [in] `msgOut` – pointer to the header of IPC requests. • [in,out] `msgIn` – pointer to the header of IPC responses. • [in] `mdelay` – timeout (in milliseconds) for completion of a `Call()` system call, or `INFINITE_TIMEOUT` to define an unlimited timeout. • [in,optional] `syncHandle` – handle of the IPC synchronization object, or `INVALID_HANDLE` if an interrupt of the `Call()` system call is not required. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`Reply()`	Purpose Executes the `Reply()` system call. Parameters • [in] `handle` – server IPC handle. • [in] `msgOut` – pointer to the header of IPC responses. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`Recv()`	Purpose Executes the `Recv()` system call with an unlimited timeout for its completion. Parameters • [in] `handle` – server IPC handle.

	• [in,out] `msgIn` – pointer to the header of IPC requests. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`RecvEx()`	Purpose Executes the `Recv()` system call with a defined timeout for its completion and the capability to interrupt its execution. Parameters • [in] `handle` – server IPC handle. • [in,out] `msgIn` – pointer to the header of IPC responses. • [in] `mdelay` – timeout (in milliseconds) for completion of a `Recv()` system call, or `INFINITE_TIMEOUT` to define an unlimited timeout. • [in,optional] `syncHandle` – handle of the IPC synchronization object, or `INVALID_HANDLE` if an interrupt of the `Recv()` system call is not required. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.

IPC interrupt (ipc_api.h)

This API is defined in the header file `sysroot-*-kos/include/coresrv/ipc/ipc_api.h` from the KasperskyOS SDK.

The API interrupts the `Call()` and `Recv()` system calls if one or more process threads are locked while waiting for these system calls to complete. For example, you may need to interrupt these system calls to correctly terminate a process so that threads waiting for the completion of these system calls can resume execution.

Information about API functions is provided in the table below.

Using the API

The API interrupts system calls in process threads that were locked after the `CallEx()` or `RecvEx()` function was called from the API syscalls.h if these functions were called while specifying the IPC synchronization object handle in the `syncHandle` parameter. To create an IPC synchronization object, call the `KnIpcCreateSyncObject()` function. (The handle of an IPC synchronization object cannot be transferred to another process because the necessary flag for this operation is not set in the permissions mask of this handle.)

The `KnIpcSetInterrupt()` function switches an IPC synchronization object to a state that allows interruption of the system calls in those process threads that have been locked after a `CallEx()` or `RecvEx()` function call specifying the handle of this IPC synchronization object in the `syncHandle` parameter. A system call can be interrupted only during certain stages of its execution. A system call that is executed by the `CallEx()` function can be interrupted only when the server has not yet received a `Recv()` or `RecvEx()` function call for the IPC channel whose client IPC handle was specified during the `CallEx()` function call. A system call executed by the `RecvEx()` function can be interrupted only while waiting for an IPC request from a client.

The `KnIpcClearInterrupt()` function cancels the action of the `KnIpcSetInterrupt()` function.

To delete an IPC synchronization object, close its handle by calling the `KnHandleClose()` function that is declared in the header file `sysroot-*-kos/include/coresrv/handle/handle_api.h` from the KasperskyOS SDK.

Information about API functions

ipc_api.h functions

Function	Information about the function
`KnIpcCreateSyncObject()`	Purpose Creates an IPC synchronization object. Parameters • [out] `syncHandle` – pointer to the handle of the IPC synchronization object. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnIpcSetInterrupt()`	Purpose Switches the defined IPC synchronization object to a state in which the `Call()` and `Recv()` system calls are interrupted. Parameters • [in] `syncHandle` – handle of the IPC synchronization object. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.
`KnIpcClearInterrupt()`	Purpose Switches the defined IPC synchronization object to a state in which the `Call()` and `Recv()` system calls are not interrupted. Parameters • [in] `syncHandle` – handle of the IPC synchronization object. Returned values If successful, the function returns `rcOk`, otherwise it returns an error code.

POSIX support

POSIX support limitations

KasperskyOS has a limited implementation of POSIX oriented toward the POSIX.1-2008 standard. These limitations are primarily due to security precautions.

> There is no XSI support or optional functionality.

Limitations affect the following:

- Interaction between processes
- Interaction between threads via signals
- Asynchronous input/output
- Use of robust mutexes
- Terminal operations
- Shell operations
- File handle management
- Clock usage
- Getting system parameters

Limitations include:

- Unimplemented interfaces
- Interfaces that are implemented with deviations from the POSIX.1-2008 standard
- Stub interfaces that do not perform any operations except assign the `ENOSYS` value to the `errno` variable and return the value `-1`

> In KasperskyOS, signals cannot interrupt the `Call()`, `Recv()`, and `Reply()` system calls that support the operation of libraries that implement the POSIX interface.
> The KasperskyOS kernel does not transmit signals.

Limitations on interaction between processes

Interface	Purpose	Implementation	Header file based on the POSIX.1-2008 standard
`fork()`	Create a new (child) process.	Not implemented	`unistd.h`

`pthread_atfork()`	Register the handlers that are called before and after the child process is created.	Not implemented	`pthread.h`
`wait()`	Wait for the child process to stop or complete.	Stub	`sys/wait.h`
`waitid()`	Wait for the state of the child process to change.	Not implemented	`sys/wait.h`
`waitpid()`	Wait for the child process to stop or complete.	Stub	`sys/wait.h`
`execl()`	Run the executable file.	Stub	`unistd.h`
`execle()`	Run the executable file.	Stub	`unistd.h`
`execlp()`	Run the executable file.	Stub	`unistd.h`
`execv()`	Run the executable file.	Not implemented	`unistd.h`
`execve()`	Run the executable file.	Not implemented	`unistd.h`
`execvp()`	Run the executable file.	Stub	`unistd.h`
`fexecve()`	Run the executable file.	Stub	`unistd.h`
`setpgid()`	Move the process to another group or create a group.	Stub	`unistd.h`
`setsid()`	Create a session.	Stub	`unistd.h`
`getpgrp()`	Get the group ID of	Stub	`unistd.h`

	the calling process.		
`getpgid()`	Get the group ID.	Stub	`unistd.h`
`getppid()`	Get the ID of the parent process.	Stub	`unistd.h`
`getsid()`	Get the session ID.	Stub	`unistd.h`
`times()`	Get the time values for the process and its descendants.	Stub	`sys/times.h`
`kill()`	Send a signal to the process or group of processes.	Only the `SIGTERM` signal can be sent. The `pid` parameter is ignored.	`signal.h`
`pause()`	Wait for a signal.	Stub	`unistd.h`
`sigpending()`	Check for received blocked signals.	Not implemented	`signal.h`
`sigqueue()`	Send a signal to the process.	Not implemented	`signal.h`
`sigtimedwait()`	Wait for a signal from the defined set of signals.	Not implemented	`signal.h`
`sigwaitinfo()`	Wait for a signal from the defined set of signals.	Not implemented	`signal.h`
`sem_init()`	Create an unnamed semaphore.	You cannot create an unnamed semaphore for synchronization between processes. If a non-zero value is passed through the `pshared` parameter, it will return only the value `-1` and will assign the `ENOTSUP` value to the `errno` variable.	`semaphore.h`
`sem_open()`	Create/open a named semaphore.	You cannot open a named semaphore that was created by another process. Named semaphores (like unnamed semaphores) are local, which means that they are accessible only to the process that created them.	`semaphore.h`
`pthread_ spin_init()`	Create a spin lock.	You cannot create a spin lock for synchronization between processes. If the `PTHREAD_PROCESS_SHARED` value is passed through the `pshared` parameter, this value will be ignored.	`pthread.h`

`mmap()`	Map to memory.	You cannot perform memory mapping for interaction between processes. If the `MAP_SHARED` and `PROT_WRITE` values are passed through the `flags` and `prot` parameters, respectively, it will return only the `MAP_FAILED` value and will assign the `EACCES` value to the `errno` variable. For all other possible values of the `prot` parameter, the `MAP_SHARED` value of the `flags` parameter is ignored. In addition, you cannot pass combinations of the `PROT_WRITE|PROT_EXEC` and `PROT_READ|PROT_WRITE|PROT_EXEC` flags through the `prot` parameter. In this case, it will return only the `MAP_FAILED` value and will assign the `ENOMEM` value to the `errno` variable.	`sys/mman.h`
`mprotect()`	Define the memory access permissions.	For security purposes, some configurations of the KasperskyOS kernel prohibit granting simultaneous write-and-execute access to virtual memory regions. If this type of kernel configuration is in use and you pass the `PROT_WRITE|PROT_EXEC` value through the `prot` parameter, it will only return the `-1` value and will assign the `ENOTSUP` value to the `errno` variable.	`sys/mman.h`
`pipe()`	Create an unnamed channel.	You cannot use an unnamed channel for data transfer between processes. Unnamed channels are local, which means that they are accessible only to the process that created them.	`unistd.h`
`mkfifo()`	Create a special FIFO file (named channel).	Stub	`sys/stat.h`
`mkfifoat()`	Create a special FIFO file (named channel).	Not implemented	`sys/stat.h`

Limitations on interaction between threads via signals

Interface	Purpose	Implementation	Header file based on the POSIX.1-2008 standard
`pthread_kill()`	Send a signal to a thread.	You cannot send a signal to a thread. If a signal number is passed through the `sig` parameter, only the `ENOSYS` value is returned.	`signal.h`
`siglongjmp()`	Restore the state of the control thread and the signals mask.	Not implemented	`setjmp.h`
`sigsetjmp()`	Save the state of the control thread and the signals mask.	Not implemented	`setjmp.h`

Asynchronous input/output limitations

Interface	Purpose	Implementation	Header file based on the POSIX.1-2008 standard
`aio_cancel()`	Cancel input/output requests that are waiting to be handled.	Not implemented	`aio.h`
`aio_error()`	Receive an error from an asynchronous input/output operation.	Not implemented	`aio.h`
`aio_fsync()`	Request the execution of input/output operations.	Not implemented	`aio.h`
`aio_read()`	Request a file read operation.	Not implemented	`aio.h`
`aio_return()`	Get the status of an asynchronous input/output operation.	Not implemented	`aio.h`
`aio_suspend()`	Wait for the completion of asynchronous input/output operations.	Not implemented	`aio.h`
`aio_write()`	Request a file write operation.	Not implemented	`aio.h`
`lio_listio()`	Request execution of a set of input/output operations.	Not implemented	`aio.h`

Limitations on the use of robust mutexes

Interface	Purpose	Implementation	Header file based on the POSIX.1-2008 standard
`pthread_mutex_consistent()`	Return a robust mutex to a consistent state.	Not implemented	`pthread.h`
`pthread_mutexattr_getrobust()`	Get a robust mutex attribute.	Not implemented	`pthread.h`
`pthread_mutexattr_setrobust()`	Define a robust mutex attribute.	Not implemented	`pthread.h`

Terminal operation limitations

Interface	Purpose	Implementation	Header file based on the POSIX.1-2008 standard
`ctermid()`	Get the path to the file of the control terminal.	Only returns or passes an empty string through the `s` parameter.	`stdio.h`
`tcsetattr()`	Define the terminal settings.	The input speed, output speed, and other settings specific to hardware terminals are ignored.	`termios.h`
`tcdrain()`	Wait for output completion.	Returns only the value `-1`.	`termios.h`
`tcflow()`	Suspend or resume receipt or transmission of data.	Suspending output and resuming suspended output are not	`termios.h`

		supported.	
`tcflush()`	Clear the input queue or output queue, or both of these queues.	Returns only the value `-1`.	`termios.h`
`tcsendbreak()`	Break the connection with the terminal for a set time.	Returns only the value `-1`.	`termios.h`
`ttyname()`	Get the path to the terminal file.	Returns only a null pointer.	`unistd.h`
`ttyname_r()`	Get the path to the terminal file.	Returns only an error value.	`unistd.h`
`tcgetpgrp()`	Get the ID of a group of processes using the terminal.	Returns only the value `-1`.	`unistd.h`
`tcsetpgrp()`	Define the ID for a group of processes using the terminal.	Returns only the value `-1`.	`unistd.h`
`tcgetsid()`	Get the ID of a group of processes for the leader of the session connected to the terminal.	Returns only the value `-1`.	`termios.h`

Shell operation limitations

Interface	Purpose	Implementation	Header file based on the POSIX.1-2008 standard
`popen()`	Create a child process for command execution and an unnamed channel with this process.	Only assigns the `ENOSYS` value to the `errno` variable and returns the `NULL` value.	`stdio.h`
`pclose()`	Close the unnamed channel with the child process created by `popen()`, and wait for the child process to terminate.	Cannot be used because `popen()` always returns `NULL` instead of the handle of the unnamed channel that serves as an input parameter for `pclose()`.	`stdio.h`
`system()`	Create a child process for command execution.	Stub	`stdlib.h`
`wordexp()`	Perform a shell-like expansion of the string.	Not implemented	`wordexp.h`
`wordfree()`	Free up the memory allocated for the results from calling `wordexp()`.	Not implemented	`wordexp.h`

Limitations on file handle management

Interface	Purpose	Implementation	Header file based on the POSIX.1-2008 standard
`dup()`	Make a copy	Handles of regular files, standard I/O streams, sockets and	`fcntl.h`

	of the handle of an opened file.	channels are supported. There is no guarantee that the lowest available handle will be received.	
`dup2()`	Make a copy of the handle of an opened file.	Handles of regular files, standard I/O streams, sockets and channels are supported. The handle of an opened file needs to be passed through the `fildes2` parameter.	`fcntl.h`

Limitations on clock usage

Interface	Purpose	Implementation	Header file based on the POSIX.1-2008 standard
`clock_gettime()`	Get the time value.	If the `CLOCK_PROCESS_CPUTIME_ID` value or `CLOCK_THREAD_CPUTIME_ID` value is passed through the `clock_id` parameter, it will return only the value `-1` and will assign the `EINVAL` value to the `errno` variable.	`time.h`
`clock()`	Get the CPU time spent on execution of the calling process.	Returns the amount of time (in milliseconds) that has elapsed since the KasperskyOS kernel was started.	`time.h`

Getting system parameters

Interface	Purpose	Implementation	Header file based on the POSIX.1-2008 standard
`confstr()`	Get a system parameter.	Stub	`unistd.h`

POSIX implementation specifics

In KasperskyOS, the specific implementation of some POSIX interfaces not entirely defined by the POSIX.1-2008 standard differs from the implementation of these interfaces in Linux and other UNIX-like operating systems. Information about these interfaces is provided in the table below.

POSIX interfaces and their implementation specifics

Interface	Purpose	Implementation	Header file based on the POSIX.1-2008 standard
`bind()`	Assign a name to a socket.	When using a VFS version that supports only network operations, files of sockets in the `AF_UNIX` family are saved in a special file system implemented by this VFS version when `bind()` is called. A socket file can be created only in the root of the file system or in the `/tmp` directory, and it can be re-used after the socket is closed.	`sys/socket.h`

`mmap()`	Map to memory.	Mapping more than 4 GB is not supported on hardware platforms running an AArch64 (ARM64) processor architecture.	`sys/mman.h`
`read()`	Read from a file.	If the size of the `buf` buffer exceeds the size of the read data, the remainder of this buffer is filled with zeros.	`unistd.h`

Concurrently using POSIX and the libkos API

In a thread that is created using Pthreads, you cannot use the following `libkos` APIs:

- event.h, mutex.h, rwlock.h, semaphore.h, condvar.h
- thread.h, thread_api.h
- dma.h
- ports.h
- mmio.h
- irq.h

The following `libkos` APIs can be used together with Pthreads (and other POSIX APIs):

- handle_api.h
- notice_api.h
- task.h, task_api.h
- cm_api.h, ns_api.h
- queue.h

POSIX interfaces cannot be used in threads that were created using the thread.h and thread_api.h APIs.

The syscalls.h API can be used in any threads that were created using Pthreads or the thread.h and thread_api.h APIs.

Obtaining statistical data on the system

The `libkos` and `libc` libraries provide APIs for obtaining statistical data on the system. This data includes the following information:

- CPU time usage by the system and by an individual process
- Memory usage by the system and by an individual process
- Info on processes and threads
- Info on file systems and network interfaces

Obtaining statistical data on the system through the libkos library API

The `libkos` library provides an API that obtains statistical data on CPU time and memory usage, and info on processes and threads. This API is defined in the header file `sysroot-*-kos/include/coresrv/stat/stat_api.h` from the KasperskyOS SDK.

> The API defined in the header file `sysroot-*-kos/include/coresrv/stat/stat_api.h` from the KasperskyOS SDK includes functions that "wrap" the `KnProfilerGetCounters()` function declared in the header file `sysroot-*-kos/include/coresrv/profiler/profiler_api.h` from the KasperskyOS SDK. This function requests the values of performance counters. To get this statistical data, you need to build a solution with a KasperskyOS kernel version that supports performance counters (for details, see "Image library").

Receiving information about CPU time

Uptime of CPUs (processor cores) is counted from the startup of the KasperskyOS kernel.

To obtain information about CPU time usage, use the `KnGroupStatGetParam()`, `KnTaskStatGetParam()` and `KnCpuStatGetParam()` functions. The values provided in the table below need to be passed in the `param` parameter of these functions.

Information about CPU time

Function	Value of the param parameter	Obtained value
`KnGroupStatGetParam()`	`GROUP_PARAM_CPU_KERNEL`	Uptime of all processors in kernel mode
`KnGroupStatGetParam()`	`GROUP_PARAM_CPU_USER`	Uptime of all processors in user mode
`KnGroupStatGetParam()`	`GROUP_PARAM_CPU_IDLE`	Uptime of all processors in idle mode
`KnTaskStatGetParam()`	`TASK_PARAM_TIME_TOTAL`	Uptime of all processors used for execution of the defined process
`KnTaskStatGetParam()`	`TASK_PARAM_TIME_USER`	Uptime of all processors used for execution of the defined process in user mode
`KnCpuStatGetParam()`	`CPU_STAT_PARAM_IDLE`	Uptime of the defined processor in idle mode
`KnCpuStatGetParam()`	`CPU_STAT_PARAM_USER`	Uptime of the defined processor in user mode
`KnCpuStatGetParam()`	`CPU_STAT_PARAM_KERNEL`	Uptime of the defined processor in kernel mode

The CPU time obtained by calling the `KnGroupStatGetParam()`, `KnTaskStatGetParam()` or `KnCpuStatGetParam()` function is presented in nanoseconds.

The CPU index (enumeration starts with zero) is the input parameter of the `KnCpuStatGetParam()` function. To get the total number of processors on a hardware platform, use the `KnHalGetCpuCount()` function declared in the header file `sysroot-*-kos/include/coresrv/hal/hal_api.h` from the KasperskyOS SDK.

Receiving information about memory usage

To receive information about memory usage, you need to use the `KnGroupStatGetParam()` and `KnTaskStatGetParam()` functions. The values provided in the table below need to be passed in the `param` parameter of these functions.

Information about memory usage

Function	Value of the param parameter	Obtained value
`KnGroupStatGetParam()`	`GROUP_PARAM_MEM_TOTAL`	Size of all installed physical memory
`KnGroupStatGetParam()`	`GROUP_PARAM_MEM_FREE`	Size of free physical memory
`KnGroupStatGetParam()`	`GROUP_PARAM_MEM_EXEC`	Size of physical memory with the "execution access" attribute
`KnGroupStatGetParam()`	`GROUP_PARAM_MEM_SHARED`	Size of physical memory used as shared memory
`KnTaskStatGetParam()`	`TASK_PARAM_MEM_PHY`	Size of physical memory used by the defined process
`KnTaskStatGetParam()`	`TASK_PARAM_MEM_VIRT`	Size of virtual memory of the defined process
`KnTaskStatGetParam()`	`TASK_PARAM_MEM_SHARED`	Size of virtual memory of the defined process mapped to shared physical memory
`KnTaskStatGetParam()`	`TASK_PARAM_MEM_PAGE_TABLE`	Size of the page table of the defined process

The memory size obtained by calling the `KnGroupStatGetParam()` or `KnTaskStatGetParam()` function is presented as the number of memory pages. The size of a memory page is 4 KB for all hardware platforms supported by KasperskyOS.

> The size of physical memory used by a process refers only to the memory allocated directly for this process. For example, if the memory of a process is mapped to an MDL buffer created by another process, the size of this buffer is not included in this value.

Obtaining information on processes and threads

In addition to information about CPU time and memory usage, the `KnGroupStatGetParam()` and `KnTaskStatGetParam()` functions also let you obtain information on processes and threads. To receive this information, the values provided in the table below need to be passed through the `param` parameter of these functions.

Information on processes and threads

Function	Value of the param parameter	Obtained value
`KnGroupStatGetParam()`	`GROUP_PARAM_TASKS`	Number of user processes (not counting the kernel process)
`KnGroupStatGetParam()`	`GROUP_PARAM_THREADS`	Total number of threads (including kernel threads)
`KnTaskStatGetParam()`	`TASK_PARAM_PPID`	ID of the parent process of the defined process (PPID)
`KnTaskStatGetParam()`	`TASK_PARAM_PRIO`	Priority of the initial thread of the defined process

`KnTaskStatGetParam()`	`TASK_PARAM_STATE`	State of the defined process (according to the list of `TaskExecutionStates` defined in the header file `sysroot-*-kos/include/task/pcbpage.h` from the KasperskyOS SDK)
`KnTaskStatGetParam()`	`TASK_PARAM_IMGSIZE`	Size of the memory-loaded image of the program running in the context of the defined process, in bytes
`KnTaskStatGetParam()`	`TASK_PARAM_TIME_START`	Time (in nanoseconds) between startup of the kernel and startup of the defined process
`KnTaskStatGetParam()`	`TASK_PARAM_HANDLES`	Number of handles owned by the defined process
`KnTaskStatGetParam()`	`TASK_PARAM_THREADS`	Number of threads in the defined process

In addition to the `KnGroupStatGetParam()` and `KnTaskStatGetParam()` functions, information on processes and threads can also be obtained by using the following functions:

- `KnTaskStatGetName()` – gets the name of the defined process.
- `KnTaskStatGetPath()` – gets the name of the executable file in ROMFS that was used to start the defined process.

  This function can be used only if the process was started from an executable file in ROMFS. Otherwise, the function call will result in an empty string.
- `KnTaskStatGetId()` – gets the ID of the defined process (PID).
- `KnProfilerGetCounters()` – gets the values of performance counters.

  For example, to get the number of kernel threads and the total number of handles, pass the `kl.core.Core.threads` and `handles.total` values through the `names` parameter.

Obtaining information on CPU time and memory usage by each process

To get information about CPU time and memory usage by each process, do the following:

1. Get the list of processes by calling the `KnGroupStatGetTaskList()` function.
2. Get the number of items on the list of processes by calling the `KnTaskStatGetTasksCount()` function.
3. Iterate through the list of processes, repeating the following steps:
   a. Get an item from the list of processes by calling the `KnTaskStatEnumTaskList()` function.
   b. Get the process name by calling the `KnTaskStatGetName()` function.

      This is necessary to identify the process for which the information about CPU time and memory usage will be received.
   c. Get information about CPU time and memory usage by calling the `KnTaskStatGetParam()` function.
   d. Verify that the process was not terminated. If the process has terminated, discard the obtained information about the CPU time and memory used by this process.

To verify that the process was not terminated, you need to call the `KnTaskStatGetParam()` function, using the `param` parameter to pass the `TASK_PARAM_STATE` value. A value other than `TaskStateTerminated` should be received.

e. Finish working with the item on the list of processes by calling the `KnTaskStatCloseTask()` function.

4. Finish working with the list of processes by calling the `KnTaskStatCloseTaskList()` function.

Calculating CPU load

Indicators of load on CPUs (processor cores) may be the following values:

- Percent load of all processors
- Percent load of all processors by each process
- Percent load of each processor

These indicators are calculated for a specific time interval, at the start and end of which the information about CPU time utilization was received. (For example, CPU load can be monitored with periodic receipt of information about CPU time utilization.) The values obtained at the start of the interval need to be subtracted from the values obtained at the end of the interval. In other words, the following increments need to be obtained for the interval:

- *TK* – uptime of all processors in kernel mode.
- *TKi [i=1,2,...,n]* – uptime of the *i*th processor in kernel mode.
- *TU* – uptime of all processors in user mode.
- *TUi [i=1,2,...,n]* – uptime of the *i*th processor in user mode.
- *TIDLE* – uptime of all processors in idle mode.
- *TIDLEi [i=1,2,...,n]* – uptime of the *i*th processor in idle mode.
- *Tj [j=1,2,...,m]* – CPU time spent on execution of the *j*th process.

The percent load of all processors is calculated as follows:

(TK+TU)/(TK+TU+TIDLE).

The percent load of the *i*th processor is calculated as follows:

(TKi+TUi)/(TKi+TUi+TIDLEi).

The percent load of all processors caused by the *j*th process is calculated as follows:

Tj/(TK+TU+TIDLE).

Obtaining statistical data on the system through the libc library API

The `libkos` library provides APIs that let you obtain statistical data on file systems and network interfaces managed by VFS. The functions of these APIs are presented in the table below.

Function	Header file from the KasperskyOS SDK	Obtained information
`statvfs()`	`sysroot-*-kos/include/strict/posix/sys/statvfs.h`	File system information, such as the block size, number of blocks, and number of available blocks
`getvfsstat()`	`sysroot-*-kos/include/sys/statvfs.h`	The information on all mounted file systems is identical to the information provided by the `statvfs()` function
`getifaddrs()`	`sysroot-*-kos/include/ifaddrs.h`	Information on network interfaces, such as their name, IP address, and subnet mask

MessageBus component

The `MessageBus` component implements the message bus that ensures receipt, distribution and delivery of messages between programs running KasperskyOS. This bus is based on the publisher-subscriber model. Use of a message bus lets you avoid having to create a large number of IPC channels to connect each subscriber program to each publisher program.

> Messages transmitted through the `MessageBus` cannot contain data. These messages can be used only to notify subscribers about events.

The `MessageBus` component provides an additional level of abstraction over KasperskyOS IPC that helps simplify the development and expansion of your programs. `MessageBus` is a separate program that is accessed through IPC. However, developers are provided with a `MessageBus` access library that lets you avoid direct use of IPC calls.

The API of the access library provides the following interfaces:

`IProviderFactory`
: Provides factory methods for obtaining access to instances of all other interfaces.

`IProviderControl`
: Interface for registering and deregistering a publisher and subscriber in the bus.

`IProvider (MessageBus component)`
: Interface for transferring a message to the bus.

`ISubscriber`
: Callback interface for sending a message to a subscriber.

`IWaiter`
: Interface for waiting for a callback when the corresponding message appears.

Message structure

Each message contains two parameters:

`topic`
: Identifier of the message subject.

`id`

Additional parameter that identifies a particular message.

The `topic` and `id` parameters are unique for each message. The interpretation of `topic`+`id` is determined by the contract between the publisher and subscriber. For example, if there are changes to the configuration data used by the publisher and subscriber, the publisher forwards a message regarding the modified data and the `id` of the specific entry containing the new data. The subscriber uses mechanisms outside of the `MessageBus` to receive the new data based on the `id` key.

IProviderFactory interface

The `IProviderFactory` interface provides factory methods for receiving the interfaces necessary for working with the `MessageBus` component.

A description of the `IProviderFactory` interface is provided in the file named `messagebus/i_messagebus_control.h`.

An instance of the `IProviderFactory` interface is obtained by using the free `InitConnection()` function, which receives the name of the IPC channel between your application and the `MessageBus` program. The connection name is defined in the `init.yaml.in` file when describing the solution configuration. If the connection is successful, the output parameter contains a pointer to the `IProviderFactory` interface.

- The interface for registering and deregistering (see "IProviderControl interface") publishers and subscribers in the message bus is obtained by using the `IProviderFactory::CreateBusControl()` method.
- The interface containing the methods enabling the publisher to send messages to the bus (see "IProvider interface (MessageBus component)") is obtained by using the `IProviderFactory::CreateBus()` method.
- The interfaces containing the methods enabling the subscriber to receive messages from the bus (see "ISubscriber, IWaiter and ISubscriberRunner interfaces") are obtained by using the `IProviderFactory::CreateCallbackWaiter` and `IProviderFactory::CreateSubscriberRunner()` methods.

> It is not recommended to use the `IWaiter` interface, because calling a method of this interface is a locking call.

i_messagebus_control.h (fragment)

```
class IProviderFactory
{
...
    virtual fdn::ResultCode CreateBusControl(IProviderControlPtr& controlPtr) = 0;
    virtual fdn::ResultCode CreateBus(IProviderPtr& busPtr) = 0;
    virtual fdn::ResultCode CreateCallbackWaiter(IWaiterPtr& waiterPtr) = 0;
    virtual fdn::ResultCode CreateSubscriberRunner(ISubscriberRunnerPtr& runnerPtr) =
0;
...
};
...
fdn::ResultCode InitConnection(const std::string& connectionId, IProviderFactoryPtr&
busFactoryPtr);
```

IProviderControl interface

The `IProviderControl` interface provides the methods for registering and deregistering publishers and subscribers in the message bus.

A description of the `IProviderControl` interface is provided in the file named `messagebus/i_messagebus_control.h`.

The `IProviderFactory` interface is used to obtain an interface instance.

Registering and deregistering a publisher

The `IProviderControl::RegisterPublisher()` method is used to register the publisher in the message bus. This method receives the message subject and puts the unique ID of the bus client into the output parameter. If the message subject is already registered in the bus, the call will be declined and the client ID will not be filled.

The `IProviderControl::UnregisterPublisher()` method is used to deregister a publisher in the message bus. This method accepts the bus client ID received during registration. If the indicated ID is not registered as a publisher ID, the call will be declined.

i_messagebus_control.h (fragment)

```
class IProviderControl
{
...
    virtual fdn::ResultCode RegisterPublisher(const Topic& topic, ClientId& id) = 0;
    virtual fdn::ResultCode UnregisterPublisher(ClientId id) = 0;
...
};
```

Registering and deregistering a subscriber

The `IProviderControl::RegisterSubscriber()` method is used to register the subscriber in the message bus. This method accepts the subscriber name and the list of subjects of messages for the necessary subscription, and puts the unique ID of the bus client into the output parameter.

The `IProviderControl::UnregisterSubscriber()` method is used to deregister a subscriber in the message bus. This method accepts the bus client ID received during registration. If the indicated ID is not registered as a subscriber ID, the call will be declined.

i_messagebus_control.h (fragment)

```
class IProviderControl
{
...
    virtual fdn::ResultCode RegisterSubscriber(const std::string& subscriberName,
const std::set<Topic>& topics, ClientId& id) = 0;
    virtual fdn::ResultCode UnregisterSubscriber(ClientId id) = 0;
...
};
```

IProvider interface (MessageBus component)

The `IProvider` interface provides the methods enabling the publisher to send messages to the bus.

A description of the `IProvider` interface is provided in the file named `messagebus/i_messagebus.h`.

The `IProviderFactory` interface is used to obtain an interface instance.

Sending a message to the bus

The `IProvider::Push()` method is used to send a message. This method accepts the bus client ID received during registration and the message ID. If the message queue in the bus is full, the call will be declined.

`i_messagebus.h (fragment)`

```
class IProvider
{
public:
...
    virtual fdn::ResultCode Push(ClientId id, BundleId dataId) = 0;
...
};
```

ISubscriber, IWaiter and ISubscriberRunner interfaces

The `ISubscriber`, `IWaiter`, and `ISubscriberRunner` interfaces provide the methods enabling the subscriber to receive messages from the bus and process them.

Descriptions of the `ISubscriber`, `IWaiter` and `ISubscriberRunner` interfaces are provided in the file named `messagebus/i_subscriber.h`.

The `IProviderFactory` interface is used to obtain instances of the `IWaiter` and `ISubscriberRunner` interfaces. The implementation of the `ISubscriber` callback interface is provided by the subscriber application.

Receiving a message from the bus

You can use the `IWaiter::Wait()` or `ISubscriberRunner::Run()` method to switch a subscriber to standby mode, waiting for a message from the bus. These methods accept the bus client ID and the pointer to the `ISubscriber` callback interface. If the client ID is not registered, the call will be declined.

It is not recommended to use the `IWaiter` interface, because calling the `IWaiter::Wait()` method is a locking call.

The `ISubscriber::OnMessage()` method will be called when a message is received from the bus. This method accepts the message subject and message ID.

`i_subscriber.h (fragment)`

```
class ISubscriber
{
...
    virtual fdn::ResultCode OnMessage(const std::string& topic, BundleId id) = 0;
};
...
class IWaiter
{
...
    [[deprecated("Use ISubscriberRunner::Run method instead.")]]
    virtual fdn::ResultCode Wait(ClientId id, const ISubscriberPtr& subscriberPtr) =
0;
};
...
class ISubscriberRunner
{
...
    virtual fdn::ResultCode Run(ClientId id, const ISubscriberPtr& subscriberPtr) = 0;
};
```

ExecutionManager component

The API is defined in the header files located in the directory `sysroot-*-kos/include/component/execution_manager/` from the SDK.

The ExecutionManager component usage scenario is described in the article titled "Starting a process using the KasperskyOS API".

execution_manager_proxy.h interface

The API is defined in the header file `sysroot-*-kos/include/component/execution_manager/kos_ipc/execution_manager_proxy.h`

The interface contains the factory method `CreateExecutionManager()` for getting the pointer to the instance of the `IExecutionManager` interface that is required for working with the ExecutionManager component.

Usage example:

client.cpp

```
#include <component/execution_manager/kos_ipc/execution_manager_proxy.h>
...
namespace execmgr = execution_manager;

int main(int argc, const char *argv[])
{
   //  ...
    execmgr::IExecutionManagerPtr ptr;
    // name of the IPC channel for connecting to the ExecutionManager process. It must
match the MAIN_CONN_NAME value in the CMakeLists.txt file for building
ExecutionManager.
    char mainConnection[] = "ExecMgrEntity";
    execmgr::ipc::ExecutionManagerConfig cfg{mainConnection};
    if (CreateExecutionManager(cfg, ptr) != eka::sOk)
```

```
    {
        std::cerr << "Cannot create execution manager" << std::endl;
        return EXIT_FAILURE;
    }
   // ...
}
```

IExecutionManager interface

The API is defined in the header file `sysroot-*-kos/include/component/execution_manager/i_execution_manager.h`

The `IExecutionManager` interface lets you access pointers to the following interfaces:

- `IApplicationController` – interface for starting and stopping processes.
- `ISystemController` – interface for managing the system.

Usage example:

client.cpp

```
int main(int argc, const char *argv[])
{
    // ...
    execmgr::IApplicationControllerPtr ac;
    if (ptr->GetApplicationController(ac) != eka::sOk)
    {
        std::cerr << "Cannot get application controller" << std::endl;
        return EXIT_FAILURE;
    }

    execmgr::ISystemControllerPtr sc;
    if (ptr->GetSystemController(sc) != eka::sOk)
    {
        std::cerr << "Cannot get system controller" << std::endl;
        return EXIT_FAILURE;
    }

    // ...
}
```

IApplicationController interface

The API is defined in the header file `sysroot-*-kos/include/component/execution_manager/i_application_control.h`

The `IApplicationController` interface provides the following methods that let you change the state of a process:

- `StartEntity(`
  `const std::filesystem::path& runPath,`
  `const StartEntityInfo& info,`

`StartEntityResultInfo& resInfo`) – method for starting a process.

- `RestartEntity(EntityId endId)` – method for restarting a previously started process.
- `ShutdownEntity(EntityId entId)` – method for sending a termination signal to a process.
- `StopEntity(EntityId entId)` – method for immediately stopping execution of a process.

The `StartEntity()` method receives the path to the executable file that should be run and the structure containing the run parameters for the `StartEntityInfo` process, and returns the structure containing the `StartEntityResultInfo` process run results. All fields of the `StartEntityInfo` structure are optional for initialization.

All other methods receive the `EntityId` structure that identifies the started process.

```
struct IApplicationController
{
    // All fields of the StartEntityInfo structure are optional for initialization.
    struct StartEntityInfo
    {
        // Process name. Unless otherwise specified, the process class name will be
used.
        // If the process class name is not specified, the executable file name will
be used.
        std::string              entityName;
        // Process class. Unless otherwise specified, the process name will be used.
If the process name is not specified, the executable file name will be used.
        std::string              eiid;
        std::vector<std::string> args; // Command-line arguments.
        std::vector<std::string> envs; // Environment variables.
        // Policy for restarting a process when it crashes. Available values:
        // EntityRestartPolicy::DoNotRestart – do not restart.
        // EntityRestartPolicy::AlwaysRestart – always restart.
        EntityRestartPolicy      restartPolicy { EntityRestartPolicy::DoNotRestart };
    };

    struct StartEntityResultInfo
    {
        std::string eiid; // Security class assigned to the process.
        EntityId    entId; // Structure that identifies the started process.
        Uid         sid; // Security ID of the started process.
        std::string taskName; // Name of the started process.
    };
};
```

Usage example:

client.cpp

```
int main(int argc, const char *argv[])
{
    // ...
    const fs::path appPath{"/application"};

    execmgr::IApplicationController::StartEntityResultInfo result;
    execmgr::IApplicationController::StartEntityInfo info;

    info.entityName = std::string{"application.Application"};
```

```
    info.eiid = std::string{"application.Application"};
    info.args = std::vector<std::string>{"1", "ARG1", "ARG2" , "ARG3"};
    info.envs = std::vector<std::string>{"ENV1=10", "ENV2=envStr"};

    std::cout << "Starting application from elf\n";

    if (ac->StartEntity(appPath, info, result) != eka::sOk)
    {
        std::cerr << "Can not start application from " << appPath << std::endl;
        return EXIT_FAILURE;
    }

    std::cout << "Application started with process sid " << result.sid << "\n";

    auto AppId = result.entId;

    if (ac->StopEntity(AppId) != eka::sOk)
    {
        std::cerr << "Cannot stop process " << appPath << std::endl;
        return EXIT_FAILURE;
    }

   // ...
}
```

ISystemController interface

The API is defined in the header file `sysroot-*-kos/include/component/execution_manager/i_system_control.h`

The `ISystemController` interface provides the following method for system management:

- `StopAllEntities()` method stops all running processes, then terminates the ExecutionManager process, then sends a device shutdown request to the kernel.

Usage example:

client.cpp

```
int main(int argc, const char *argv[])
{
    // ...

    if (sc->StopAllEntities() != eka::sOk)
    {
        std::cerr << "Cannot stop all processes\n";
        return EXIT_FAILURE;
    }
   // ...
}
```

Building a KasperskyOS-based solution

This section contains the following information:

- Description of the KasperskyOS-based solution build process.
- Descriptions of the scripts, libraries and build templates provided in KasperskyOS Community Edition.
- Information on how to use dynamic libraries in a KasperskyOS-based solution.

Building a solution image

A *KasperskyOS-based solution* consists of system software (including the KasperskyOS kernel and Kaspersky Security Module) and application software integrated for operation within a software/hardware system.

For more details, refer to Structure and startup of a KasperskyOS-based solution.

System programs and application software

Programs are divided into two types according to their purpose:

- *System programs* create the infrastructure for application software. For example, they facilitate hardware operations, support the IPC mechanism, and implement file systems and network protocols. System programs are included in KasperskyOS Community Edition. If necessary, you can develop your own system programs.
- *Application software* is designed for interaction with a solution user and for performing user tasks. Application software is not included in KasperskyOS Community Edition.

Building programs during the solution build process

During a solution build, programs are divided into the following two types:

- System programs provided as executable files in KasperskyOS Community Edition.
- System programs or application software that requires linking to an executable file.

Programs that require linking are divided into the following types:

- System programs that implement an IPC interface whose ready-to-use transport libraries are provided in KasperskyOS Community Edition.
- Application software that implements its own IPC interface. To build this software, transport methods and types need to be generated by using the NK compiler.
- Client programs that do not provide endpoints.

Building a solution image

KasperskyOS Community Edition provides an image of the KasperskyOS kernel and the executable files of some system programs and driver applications that are ready to use in a solution.

A specialized Einit program intended for starting all other programs, and a Kaspersky Security Module are built for each specific solution and are therefore not already provided in KasperskyOS Community Edition. Instead, the toolchain provided in KasperskyOS Community Edition includes the tools for building these resources.

The general step-by-step build scenario is described in the article titled Build process overview. A solution image can be built as follows:

- **[Recommended]** Using scripts of the `CMake` build system, which is provided in KasperskyOS Community Edition.
- [Without CMake] Using other automated build systems or manually with scripts and compilers provided in KasperskyOS Community Edition.

Build process overview

To build a solution image, the following is required:

1. Prepare EDL, CDL and IDL descriptions of applications, an init description file (`init.yaml` by default), and files containing a description of the solution security policy (`security.psl` by default).

   When building with `CMake`, an EDL description can be generated by using the `generate_edl_file()` command.

2. Generate *.edl.h files for all programs except the system programs provided in KasperskyOS Community Edition.

   - When building with `CMake`, the `nk_build_edl_files()` command is used for this purpose.
   - When building without `CMake`, the NK compiler must be used for this.

3. For programs that implement their own IPC interface, generate code of the transport methods and types that are used for generating, sending, receiving and processing IPC messages.

   - When building with `CMake`, the `nk_build_idl_files()` and `nk_build_cdl_files()` commands are used for these purposes.
   - When building without `CMake`, the NK compiler must be used for this.

4. Build all programs that are part of the solution, and link them to the transport libraries of system programs or applications if necessary. To build applications that implement their own IPC interface, you will need the code containing transport methods and types that was generated at step 3.

   - When building with `CMake`, standard build commands are used for this purpose. The necessary cross-compilation configuration is done automatically.
   - When building without `CMake`, the cross compilers included in KasperskyOS Community Edition must be manually used for this purpose.

5. Build the Einit initializing program.

- When building with `CMake`, the `Einit` program is built during the solution image build process using the `build_kos_qemu_image()` and `build_kos_hw_image()` commands.

- When building without `CMake`, the einit tool must be used to generate the code of the `Einit` program. Then the `Einit` application must be built using the cross compiler that is provided in KasperskyOS Community Edition.

6. Build the Kaspersky Security Module.

   - When building with `CMake`, the security module is built during the solution image build process using the `build_kos_qemu_image()` and `build_kos_hw_image()` commands.

   - When building without `CMake`, the `makekss` script must be used for this purpose.

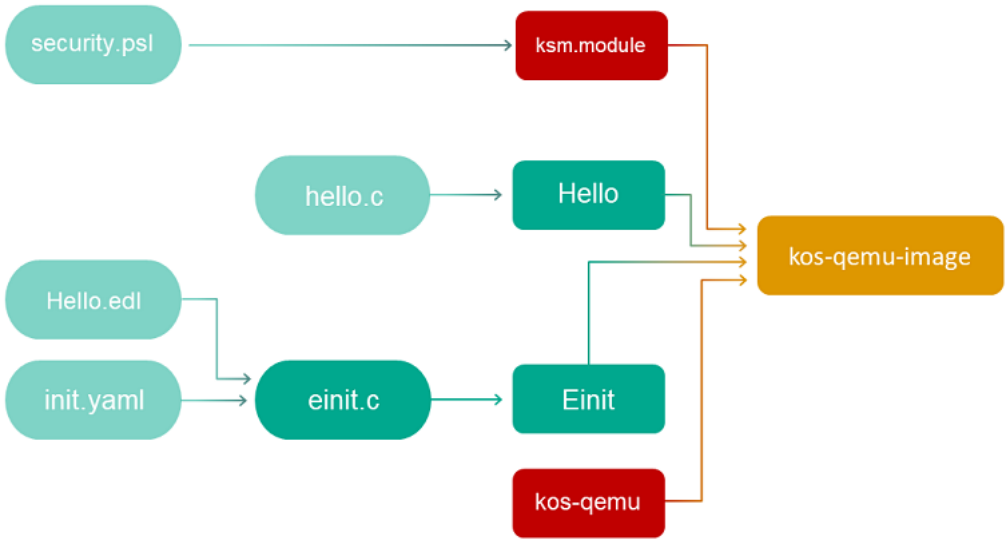
7. Create the solution image.

   - When building with `CMake`, the `build_kos_qemu_image()` and `build_kos_hw_image()` commands are used for this purpose.

   - When building without `CMake`, the `makeimg` script must be used for this.

Example 1

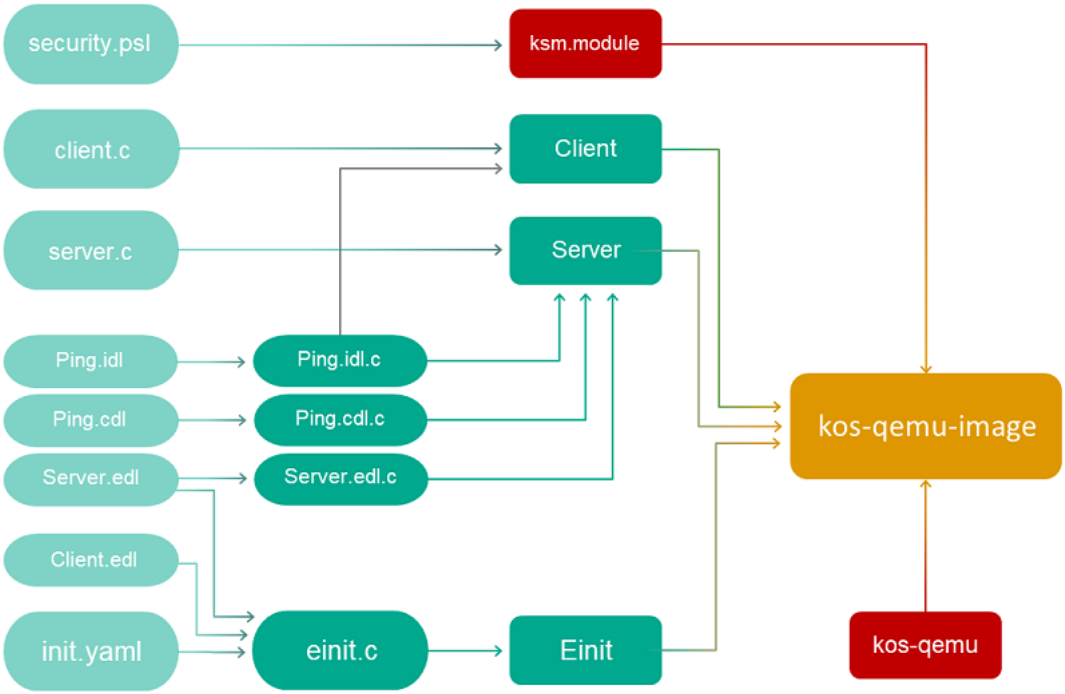
For the basic `hello` example included in KasperskyOS Community Edition that contains one application that does not provide any services, the build scenario looks as follows:



Example 2

The `echo` example included in KasperskyOS Community Edition describes a basic case of interaction between two programs via an IPC mechanism. To set up this interaction, you will need to implement an interface with the `Ping` method on a server and put the `Ping` service into a new component (for example, `Responder`), and an instance of this component needs to be put into the EDL description of the `Server` program.

If a solution contains programs that utilize an IPC mechanism, the build scenario looks as follows:



Using CMake from the contents of KasperskyOS Community Edition

To automate the process of preparing the solution image, you need to configure the `CMake` build system. You can base this system on the build system parameters used in the examples from KasperskyOS Community Edition.

`CMakeLists.txt` files use the standard `CMake` syntax, and commands and macros from libraries provided in KasperskyOS Community Edition.

Recommended structure of project directories

When creating a KasperskyOS-based solution, it is recommended to use the following directory structure in a project:

- In the project root, create a CMakeLists.txt boot file containing the general build instructions for the entire solution.
- The source code of each program being developed should be placed into a separate directory within the `src` subdirectory.
- Create CMakeLists.txt files for building each application in the corresponding directories.
- To generate the source code of the `Einit` program, you should create a separate `einit` directory containing the `src` subdirectory in which you should put the init.yaml.in and security.psl.in templates.

  Any other files that need to be included in the solution image can also be put into this directory.
- Create a CMakeLists.txt file for building the `Einit` program in the `einit` directory.
- The files of EDL, CDL and IDL descriptions should be put into the `resources` directory in the project root.

```
Example structure of project directories
```

```
example$ tree
.
├── CMakeLists.txt
├── hello
│   ├── CMakeLists.txt
│   ├── src
│   │   ├── hello.c
├── einit
│   ├── CMakeLists.txt
│   ├── src
│   │   ├── init.yaml.in
│   │   ├── security.psl.in
├── resources
│   ├── Hello.idl
│   ├── Hello.cdl
│   ├── Hello.edl
```

Building a solution image

To build a solution image, you must use the `cmake` tool (the `toolchain/bin/cmake` executable file from KasperskyOS Community Edition).

Build script example:

build.sh

```
#!/bin/bash

# Script to be run in the project root.
# You can get information about the cmake tool run parameters
# via the shell command cmake --help, and from
# the official CMake documentation.

TARGET="aarch64-kos"
SDK_PREFIX="/opt/KasperskyOS-SDK"

# Initialize the build system
cmake \
 -G "Unix Makefiles" \
 -D CMAKE_BUILD_TYPE:STRING=Release \
 -D CMAKE_TOOLCHAIN_FILE=$SDK_PREFIX/toolchain/share/toolchain-$TARGET.cmake \
 -S . \
 -B build

# Build
# To build a solution image for QEMU, you must specify the target defined in the
# NAME parameter of the CMake command build_kos_qemu_image() in the CMakeLists.txt
file
# for building the Einit program.
# To build a solution image for the hardware platform, you must specify the target
# defined in the NAME parameter of the CMake command build_kos_hw_image() in the
# CMakeLists.txt file for building the Einit program.
# To build a solution image for QEMU and start QEMU with this image, you must
# specify the sim target.
cmake --build build --target sim
```

CMakeLists.txt root file

The `CMakeLists.txt` boot file contains general build instructions for the entire solution.

The `CMakeLists.txt` boot file must contain the following commands:

- `cmake_minimum_required (VERSION 3.25)` indicates the minimum supported version of `CMake`.

  For a KasperskyOS-based solution build, `CMake` version 3.25 or later is required.

  The required version of `CMake` is provided in KasperskyOS Community Edition and is used by default.

- `include (platform)` connects the `platform` library of `CMake`.

- `initialize_platform()` initializes the `platform` library.

- `project_header_default("STANDARD_GNU_11:YES" "STRICT_WARNINGS:NO")` sets the flags of the compiler and linker.

- **[Optional]** Connect and configure packages for the provided system programs and drivers that need to be included in the solution:

  - A package is connected by using the `find_package()` command.

  - After connecting a package, you must add the package-related directories to the list of search directories by using the `include_directories()` command.

  - For some packages, you must also set the values of properties by using the `set_target_properties()` command.

  > `CMake` descriptions of system programs and drivers provided in KasperskyOS Community Edition, and descriptions of their exported variables and properties are located in the corresponding files at `/opt/KasperskyOS-Community-Edition-<version>/sysroot-aarch64-kos/lib/cmake/<program name>/<program name>-config.cmake`

- The `Einit` initializing program must be built using the `add_subdirectory(einit)` command.

- All applications to be built must be added by using the `add_subdirectory(<program directory name>)` command.

Example CMakeLists.txt boot file

CMakeLists.txt

```
cmake_minimum_required(VERSION 3.12)
project (example)

# Initializes the CMake library for the KasperskyOS SDK.
include (platform)
initialize_platform ()
project_header_default ("STANDARD_GNU_11:YES" "STRICT_WARNINGS:NO")
```

```
# Add package importing components for working with Virtual File System.
# Components are imported from the following directory: /opt/KasperskyOS-Community-
Edition-<version>/sysroot-aarch64-kos/lib/cmake/vfs/vfs-config.cmake
find_package (vfs REQUIRED COMPONENTS ENTITY CLIENT_LIB)
include_directories (${vfs_INCLUDE})

# Add a package importing components for building an audit program and
# connecting to it.
find_package (klog REQUIRED)
include_directories (${klog_INCLUDE})

# Build the Einit initializing program
add_subdirectory (einit)

# Build the hello application
add_subdirectory (hello)
```

CMakeLists.txt files for building applications

The `CMakeLists.txt` file for building an application must contain the following commands:

- `include (platform/nk)` connects the `CMake` library for working with the NK compiler.
- `project_header_default ("STANDARD_GNU_11:YES" "STRICT_WARNINGS:NO")` sets the flags of the compiler and linker.
- An EDL description of a process class for a program can be generated by using the `generate_edl_file()` command.
- If the program provides endpoints using an IPC mechanism, the following transport code must be generated:

  a. idl.h files are generated by the `nk_build_idl_files()` command

  b. cdl.h files are generated by the `nk_build_cdl_files()` command

  c. edl.h files are generated by the `nk_build_edl_files()` command
- `add_executable (<program name> "<path to the file containing the program source code>")` adds the program build target.
- `add_dependencies (<program name> <name of the edl.h file build target>)` adds a program build dependency on edl.h file generation.
- `target_link_libraries (<program name> <list of libraries>)` determines the libraries that need to be linked with the program during the build.

  For example, if the program uses file I/O or network I/O, it must be linked with the `${vfs_CLIENT_LIB}` transport library.

> `CMake` descriptions of system programs and drivers provided in KasperskyOS Community Edition, and descriptions of their exported variables and properties are located in the corresponding files at `/opt/KasperskyOS-Community-Edition-<version>/sysroot-aarch64-kos/lib/cmake/<program name>/<program name>-config.cmake`

- To automatically add descriptions of IPC channels to the `init.yaml` file when building a solution, you must define the `EXTRA_CONNECTIONS` property and assign it a value with descriptions of the relevant IPC channels.

  Please note the indentations at the beginning of strings in the `EXTRA_CONNECTIONS` property. These indentations are necessary to correctly insert values into the `init.yaml` file and must comply with its syntax requirements.

  Example of creating an IPC channel between a `Client` process and a `Server` process:

  ```
  set_target_properties (Client PROPERTIES
  EXTRA_CONNECTIONS
  "   - target: Server
      id: server_connection")
  ```

  When building this solution, the description of this IPC channel will be automatically added to the `init.yaml` file when processing macros of the init.yaml.in template.

- To automatically add a list of arguments for the `main()` function and a dictionary of environment variables to the `init.yaml` file when building a solution, you must define the `EXTRA_ARGS` and `EXTRA_ENV` properties and assign the appropriate values to them.

  Note the indentations at the beginning of strings in the `EXTRA_ARGS` and `EXTRA_ENV` properties. These indentations are necessary to correctly insert values into the `init.yaml` file and must comply with its syntax requirements.

  Example of sending the `Client` program the `"-v"` argument of the `main()` function and the environment variable `VAR1` set to `VALUE1`:

  ```
  set_target_properties (Client PROPERTIES
  EXTRA_ARGS
  "    - \"-v\""
  EXTRA_ENV
  "     VAR1: VALUE1")
  ```

  When building this solution, the description of the `main()` function argument and the environment variable value will be automatically added to the `init.yaml` file when processing macros of the init.yaml.in template.

Example CMakeLists.txt file for building a simple application

CMakeLists.txt

```
project (hello)

# Tools for working with the NK compiler.
include (platform/nk)

# Set compile flags.
project_header_default ("STANDARD_GNU_11:YES" "STRICT_WARNINGS:NO")

# Define the name of the project that includes the program.
set (LOCAL_MODULE_NAME "example")

# Define the application name.
set (ENTITY_NAME "Hello")
# Please note the contents of the init.yaml.in and security.psl.in templates
# They define program names as ${LOCAL_MODULE_NAME}.${ENTITY_NAME}
```

```
# Define the targets that will be used to create the generated files of the program.
set (ENTITY_IDL_TARGET ${ENTITY_NAME}_idl)
set (ENTITY_CDL_TARGET ${ENTITY_NAME}_cdl)
set (ENTITY_EDL_TARGET ${ENTITY_NAME}_edl)

# Define the name of the target that will be used to build the program.
set (APP_TARGET ${ENTITY_NAME}_app)

# Add the idl.h file build target.
nk_build_idl_files (${ENTITY_IDL_TARGET}
                    NK_MODULE ${LOCAL_MODULE_NAME}
                    IDL "resources/Hello.idl"
                    )

# Add the cdl.h file build target.
nk_build_cdl_files (${ENTITY_CDL_TARGET}
                    IDL_TARGET ${ENTITY_IDL_TARGET}
                    NK_MODULE ${LOCAL_MODULE_NAME}
                    CDL "resources/Hello.cdl")

# Add the EDL file build target. The EDL_FILE variable is exported
# and contains the path to the generated EDL file.
generate_edl_file (  ${ENTITY_NAME}
                    PREFIX ${LOCAL_MODULE_NAME}
                   )

# Add the edl.h file build target.
nk_build_edl_files (${ENTITY_EDL_TARGET}
                    NK_MODULE ${LOCAL_MODULE_NAME}
                    EDL ${EDL_FILE}
                    )

# Define the target for the program build.
add_executable (${APP_TARGET} "src/hello.c")
# The program name in init.yaml and security.psl must match the name of the executable
file
set_target_properties (${APP_TARGET} PROPERTIES OUTPUT_NAME ${ENTITY_NAME})
# Libraries that are linked to the program during the build
target_link_libraries ( ${APP_TARGET}
                        PUBLIC  ${vfs_CLIENT_LIB}   # The program uses file I/O
                                                    # and must be connected as a
client to VFS
                        )
```

CMakeLists.txt file for building the Einit program

The `CMakeLists.txt` file for building the `Einit` initializing program must contain the following commands:

- `include (platform/image)` connects the `CMake` library that contains the solution image build scripts.
- `project_header_default ("STANDARD_GNU_11:YES" "STRICT_WARNINGS:NO")` sets the flags of the compiler and linker.
- Configure the packages of system programs and drivers that need to be included in the solution.
    - A package is connected by using the `find_package ()` command.

- For some packages, you must also set the values of properties by using the `set_target_properties ()` command.

> `CMake` descriptions of system programs and drivers provided in KasperskyOS Community Edition, and descriptions of their exported variables and properties are located in the corresponding files at `/opt/KasperskyOS-Community-Edition-<version>/sysroot-aarch64-kos/lib/cmake/<program name>/<program name>-config.cmake`

- To automatically add descriptions of IPC channels between processes of system programs to the `init.yaml` file when building a solution, you must add these channels to the `EXTRA_CONNECTIONS` property for the corresponding programs.

  Please note the indentations at the beginning of strings in the `EXTRA_CONNECTIONS` property. These indentations are necessary to correctly insert values into the `init.yaml` file and must comply with its syntax requirements.

  For example, the `VFS` program does not have a channel for connecting to the `Env` program by default. To automatically add a description of this channel to the init.yaml file during a solution build, you must add the following call to the `CMakeLists.txt` file for building the `Einit` program:

  ```
  set_target_properties (${vfs_ENTITY} PROPERTIES
  EXTRA_CONNECTIONS
  "  - target: env.Env
      id: {var: ENV_SERVICE_NAME, include: env/env.h}"
  ```

  When building this solution, the description of this IPC channel will be automatically added to the `init.yaml` file when processing macros of the init.yaml.in template.

- To automatically add a list of arguments for the `main()` function and a dictionary of environment variables to the `init.yaml` file when building a solution, you must define the `EXTRA_ARGS` and `EXTRA_ENV` properties and assign the appropriate values to them.

  Note the indentations at the beginning of strings in the `EXTRA_ARGS` and `EXTRA_ENV` properties. These indentations are necessary to correctly insert values into the `init.yaml` file and must comply with its syntax requirements.

Example of sending the `VfsEntity` program the `"-f fstab"` argument of the `main()` function and the environment variable `ROOTFS` set to `ramdisk0,0 / ext2 0`:

```
set_target_properties (${vfs_ENTITY} PROPERTIES
EXTRA_ARGS
"    - \"-f\"
   - \"fstab\""
EXTRA_ENV
"    ROOTFS: ramdisk0,0 / ext2 0")
```

When building this solution, the description of the `main()` function argument and the environment variable value will be automatically added to the `init.yaml` file when processing macros of the init.yaml.in template.

- `set(ENTITIES <full list of programs included in the solution>)` defines the `ENTITIES` variable containing a list of executable files of all programs included in the solution.

- One or both commands for building the solution image:

  - build_kos_hw_image() creates the target for building a solution image for the hardware platform.

- build_kos_qemu_image() creates the target for building a solution image for QEMU.

Example CMakeLists.txt file for building the Einit program

CMakeLists.txt

```
project (einit)

# Connect the library containing solution image build scripts.
include (platform/image)

# Set compile flags.
project_header_default ("STANDARD_GNU_11:YES" "STRICT_WARNINGS:NO")

# Configure the VFS program.
# By default, the VFS program is not mapped to a program implementing a block device.
# If you need to use a block device, such as ata from the ata component,
# you must define this device in the variable ${blkdev_ENTITY}_REPLACEMENT
# For more information about exported variables and properties of the VFS program,
# see /opt/KasperskyOS-Community-Edition-<version>/sysroot-aarch64-
kos/lib/cmake/vfs/vfs-config.cmake
# find_package(ata)
# set_target_properties (${vfs_ENTITY} PROPERTIES ${blkdev_ENTITY}_REPLACEMENT
${ata_ENTITY})
# In the simplest case, you do not need to interact with a drive.
# For this reason, we set the value of the ${blkdev_ENTITY}_REPLACEMENT variable equal
to an empty string
set_target_properties (${vfs_ENTITY} PROPERTIES ${blkdev_ENTITY}_REPLACEMENT "")

# Define the ENTITIES variable with a list of executable files of programs.
# It is important to include all programs that are part of the project, except the
Einit program.
# Please note that the name of the executable file of a program must
# match the name of the target indicated in add_executable() in the CMakeLists.txt
file for building this program.
set(ENTITIES
    ${vfs_ENTITY}
    Hello_app
    )

# Create the build target named kos-image, which is a solution image for the hardware
platform.
build_kos_hw_image (kos-image
                    EINIT_ENTITY EinitHw
                    CONNECTIONS_CFG "src/init.yaml.in" # template of the init.yaml
file
                    SECURITY_PSL "src/security.psl.in" # template of the security.psl
file
                    IMAGE_FILES ${ENTITIES}
                    )


# Create the build target named kos-qemu-image, which is a solution image for QEMU.
build_kos_qemu_image (kos-qemu-image
                      EINIT_ENTITY EinitQemu
                      CONNECTIONS_CFG "src/init.yaml.in"
                      SECURITY_PSL "src/security.psl.in"
                      IMAGE_FILES ${ENTITIES}
                      )
```

init.yaml.in template

The `init.yaml.in` template is used to automatically generate a *part* of the `init.yaml` file prior to building the `Einit` program using `CMake` tools.

When using the `init.yaml.in` template, you do not have to manually add descriptions of system programs and the IPC channels for connecting to them to the `init.yaml` file.

The `init.yaml.in` template must contain the following data:

- Root `entities` key.
- List of all applications included in the solution.
- For applications that use an IPC mechanism, you must specify a list of IPC channels that connect this application to other applications.

  The IPC channels that connect this application to other *applications* are either indicated manually or specified in the CMakeLists.txt file for this application using the `EXTRA_CONNECTIONS` property.

  To specify a list of IPC channels that connect this application to system programs that are included in KasperskyOS Community Edition, the following macros are used:

  - `@INIT_<program name>_ENTITY_CONNECTIONS@` – during the build, this is replaced with the list of IPC channels containing all system programs that are linked to the application. The `target` and `id` fields are filled according to the `connect.yaml` files from KasperskyOS Community Edition located in `/opt/KasperskyOS-Community-Edition-<version>/sysroot-aarch64-kos/include/<system program name>`).

    This macro needs to be used if the application does not have connections to other applications but instead connects *only to system programs*. This macro *adds* the root `connections` key.

  - `@INIT_<program name>_ENTITY_CONNECTIONS+@` – during the build, the list of IPC channels containing all system programs that are linked to the application is added to the manually defined list of IPC channels. This macro *does not add* the root `connections` key.

    This macro needs to be used if the application has connections to other applications that were manually indicated in the `init.yaml.in` template.

- The `@INIT_<program name>_ENTITY_CONNECTIONS@` and `@INIT_<program name>_ENTITY_CONNECTIONS+@` macros also add the list of connections for each program defined in the `EXTRA_CONNECTIONS` property when building this program.
- If you need to pass `main()` function arguments defined in the `EXTRA_ARGS` property to a program when building this program, you need to use the following macros:

  - `@INIT_<program name>_ENTITY_ARGS@` – during the build, this is replaced with the list of arguments of the `main()` function defined in the `EXTRA_ARGS` property. This macro *adds* the root `args` key.
  - `@INIT_<program name>_ENTITY_ARGS+@` – during the build, this macro adds the list of `main()` function arguments defined in the `EXTRA_ARGS` property to the list of manually defined arguments. This macro *does not add* the root `args` key.

- If you need to pass the values of environment variables defined in the `EXTRA_ENV` property to a program when building this program, you need to use the following macros:

- `@INIT_<program name>_ENTITY_ENV@` – during the build, this is replaced with the dictionary of environment variables and their values defined in the `EXTRA_ENV` property. This macro *adds* the root `env` key.

- `@INIT_<program name>_ENTITY_ENV+@` – during the build, this macro adds the dictionary of environment variables and their values defined in the `EXTRA_ENV` property to the manually defined variables. This macro *does not add* the root `env` key.

- `@INIT_EXTERNAL_ENTITIES@` – during the build, this macro is replaced with the list of system programs linked to the application and their IPC channels, `main()` function arguments, and values of environment variables.

Example init.yaml.in template

init.yaml.in

```
entities:

- name: ping.Client
  connections:
  # The "Client" program can query the "Server".
  - target: ping.Server
    id: server_connection
@INIT_Client_ENTITY_CONNECTIONS+@
@INIT_Client_ENTITY_ARGS@
@INIT_Client_ENTITY_ENV@

- name: ping.Server
@INIT_Server_ENTITY_CONNECTIONS@

@INIT_EXTERNAL_ENTITIES@
```

When building the `Einit` program from this template, the following init.yaml file will be generated:

init.yaml

```
entities:

- name: ping.Client
  connections:
  # The "Client" program can query the "Server"
  - target: ping.Server
    id: server_connection
  - target: kl.VfsEntity
    id: {var: _VFS_CONNECTION_ID, include: vfs/defs.h}
  args:
  - "-v"
  env:
    VAR1: VALUE1

- name: ping.Server
  connections:
  - target: kl.VfsEntity
    id: {var: _VFS_CONNECTION_ID, include: vfs/defs.h}

- name: kl.VfsEntity
  path: VFS
  args:
  - "-f"
```

```
  - "fstab"
  env:
    ROOTFS: ramdisk0,0 / ext2
```

security.psl.in template

The `security.psl.in` template is used to automatically generate a *part* of the `security.psl` file prior to building the `Einit` program using `CMake` tools.

The `security.psl` file contains part of the solution security policy description.

When using the `security.psl.in` template, you do not have to manually add EDL descriptions of system programs to the `security.psl` file.

The `security.psl.in` template must contain a manually created solution security policy description, including the following declarations:

- Set the global parameters of a solution security policy
- Include PSL files in a solution security policy description
- Include EDL files of application software in a solution security policy description
- Create security model objects
- Bind methods of security models to security events
- Create security audit profiles

To automatically include system programs, the `@INIT_EXTERNAL_ENTITIES@` macro must be used.

Example security.psl.in template

security.psl.in

```
execute: kl.core.Execute

use nk.base._

use EDL Einit
use EDL kl.core.Core
use EDL Client
use EDL Server
@INIT_EXTERNAL_ENTITIES@

/* Startup of programs is allowed */
execute {
    grant ()
}
/* Sending and receiving requests, responses and errors is allowed. */
request {
    grant ()
}
```

```
response {
    grant ()
}

error {
    grant ()
}
/* Queries via the security interface are ignored. */
security {
    grant ()
}
```

CMake libraries in KasperskyOS Community Edition

This section contains a description of the libraries that are provided in KasperskyOS Community Edition for automatically building a KasperskyOS-based solution.

platform library

The `platform` library contains the following commands:

- `initialize_platform()` is the command for initializing the `platform` library.

  The `initialize_platform()` command can be called with the `FORCE_STATIC` parameter, which enables forced static linking of executable files:

  - By default, if the toolchain in the KasperskyOS SDK supports dynamic linking, the `initialize_platform()` command causes the `-rdynamic` flag to be used automatically for building all executable files defined via `CMake` `add_executable()` commands.
  - When calling `initialize_platform (FORCE_STATIC)` in the `CMakeLists.txt` root file, the toolchain supporting dynamic linking performs static linking of executable files.

  The `initialize_platform()` command can be called with the `NO_NEW_VERSION_CHECK` parameter, which disables the check for SDK updates and transmission of the SDK version to the Kaspersky server.

  To disable the check for SDK updates and transmission of SDK version data to the Kaspersky server, use the following call during the solution build: `initialize_platform(NO_NEW_VERSION_CHECK)`. For more details about the data provision policy, see Data provision.

- `project_static_executable_header_default()` is the command for enabling forced static linking of executable files defined via subsequent `CMake` `add_executable()` commands in one `CMakeLists.txt` file. The toolchain that supports dynamic linking performs static linking of these executable files.

- `platform_target_force_static()` is the command for enabling forced static linking of an executable file defined via the `CMake` `add_executable()` command. The toolchain that supports dynamic linking performs static linking of this executable file. For example, if the `CMake` commands `add_executable(client "src/client.c")` and `platform_target_force_static(client)` are called, static linking is performed for the `client` program.

- `project_header_default()` is the command for setting compile flags.

Command parameters are defined in pairs consisting of a compile flag and its value: `"FLAG_1:VALUE_1"` `"FLAG_2:VALUE_2"` … `"FLAG_N:VALUE_N"`. The `CMake` `platform` library converts these pairs into compiler parameters. Frequently used compile flags for C and C++ compilers from the GCC set and the values of these flags are presented in the table below.

Compile flags	`YES` value	`NO` value	Default value
STANDARD_ANSI	The ISO C90 and 1998 ISO C++ standards are used. For C and C++ compilers, the value is converted into the parameter `-ansi`.	The ISO C90 and 1998 ISO C++ standards are not used.	`STANDARD_ANSI:NO`
STANDARD_C99	The ISO C99 standard is used. For a C compiler, the value is converted into the parameter `-std=c99`.	The ISO C99 standard is not used.	`STANDARD_C99:NO`
STANDARD_GNU_C99	The ISO C99 standard with GNU extensions is used. For a C compiler, the value is converted into the parameter `-std=gnu99`.	The ISO C99 standard with GNU extensions is not used.	`STANDARD_GNU_C99:NO`
STANDARD_11	The ISO C11 and 2011 ISO C++ standards are used. For a C compiler, the value is converted into the parameter `-std=c11` or `-std=c1x` depending on the compiler version. For a C++ compiler, the value is converted into the parameter `-std=c++11` or `-std=c++0x` depending on the compiler version.	The ISO C11 and 2011 ISO C++ standards are not used.	`STANDARD_11:NO`
STANDARD_GNU_11	The ISO C11 and 2011 ISO C++ standards with GNU extensions are used. For a C compiler, the value is converted into the parameter `-std=gnu1x` or `-std=gnu11` depending on the compiler version. For a C++ compiler, the value is converted into the parameter `-std=gnu++0x` or `-std=gnu++11` depending on the compiler version.	The ISO C11 and 2011 ISO C++ standards with GNU extensions are not used.	`STANDARD_GNU_11:NO`
STANDARD_14	The 2014 ISO C++ standard is used. For a C++ compiler, the value is converted into the parameter `-std=c++14`.	The 2014 ISO C++ standard is not used.	`STANDARD_14:NO`
STANDARD_GNU_14	The 2014 ISO C++ standard with GNU extensions is used.	The 2014 ISO C++ standard with	`STANDARD_GNU_14:NO`

	For a C++ compiler, the value is converted into the parameter `-std=gnu++14`.	GNU extensions is not used.	
STANDARD_17	The ISO C17 and 2017 ISO C++ standards are used. For a C compiler, the value is converted into the parameter `-std=c17`. For a C++ compiler, the value is converted into the parameter `-std=c++17`.	The ISO C17 and 2017 ISO C++ standards are not used.	`STANDARD_17:NO`
STANDARD_GNU_17	The ISO C17 and 2017 ISO C++ standards with GNU extensions are used. For a C compiler, the value is converted into the parameter `-std=gnu17`. For a C++ compiler, the value is converted into the parameter `-std=gnu++17`.	The ISO C17 and 2017 ISO C++ standards with GNU extensions are not used.	`STANDARD_GNU_17:NO`
STRICT_WARNINGS	Warnings are enabled for the detection of potential issues and errors in code written in C and C++. For C and C++ compilers, the value is converted into the following parameters: `-Wcast-qual`, `-Wcast-align`, `-Wundef`. For a C compiler, the parameter `-Wmissing-prototypes` is additionally used.	Warnings are disabled.	`STRICT_WARNINGS:YES`

If compiler flags in the format `STANDART_*` are not defined through command parameters, the parameter `STANDARD_GNU_17:YES` is used by default.

When using the `initialize_platform(FORCE_STATIC)`, `project_static_executable_header_default()` and `platform_target_force_static()` commands, you may encounter linking errors if the static variants of the required libraries are missing (for example, if they were not built or are not included in the KasperskyOS SDK). Even if the static variants of the required libraries are available, these errors may still occur because the build system searches for the dynamic variants of required libraries by default instead of the expected static variants when using the `initialize_platform(FORCE_STATIC)`, `project_static_executable_header_default()` and `platform_target_force_static()` commands. To avoid errors, first make sure that the static variants are available. Then configure the build system to search for static libraries (although this capability may not be available for some libraries), or explicitly define linking with static libraries.

Examples of configuring the build system to search for static libraries:

```
set (fmt_USE_STATIC ON)
find_package (fmt REQUIRED)

set (fdn_USE_STATIC ON)
find_package (fdn REQUIRED)
```

```
set (sqlite_wrapper_USE_STATIC ON)
find_package (sqlite_wrapper REQUIRED)
```

Example that explicitly defines linking with a static library:

```
target_link_libraries(${PROJECT_NAME} PUBLIC logger::logger-static)
```

For more details about using dynamic libraries, see "Using dynamic libraries".

These commands are used in `CMakeLists.txt` files for the Einit program and application software.

nk library

This section contains a description of the commands and macros of the `CMake` library for working with the NK compiler.

generate_edl_file()

This command is declared in the file `/opt/KasperskyOS-Community-Edition-<version>toolchain/share/cmake/Modules/platform/nk2.cmake`.

```
generate_edl_file(NAME ...)
```

This command generates an EDL file containing a description of the process class.

Parameters:

- `NAME` – name of the EDL file being created. Required parameter.
- `PREFIX` – parameter in which you need to specify the name of the process class, excluding the name of the EDL file. For example, if the name of the process class for which the EDL file is being created is defined as `kl.core.NameServer`, the `PREFIX` parameter must pass the value `kl.core`.
- `EDL_COMPONENTS` – name of the component and its instance that will be included in the EDL file. For example: `EDL_COMPONENTS "env: kl.Env"`. To include multiple components, you need to use multiple `EDL_COMPONENTS` parameters.
- `SECURITY` – qualified name of the security interface method that will be included in the EDL file.
- `OUTPUT_DIR` – directory in which the EDL file will be created. The default directory is `${CMAKE_CURRENT_BINARY_DIR}`.

As a result of this command, the `EDL_FILE` variable is exported and contains the path to the generated EDL file.

Example call:

```
generate_edl_file(${ENTITY_NAME} EDL_COMPONENTS "env: kl.Env")
```

For an example of using this command, see the article titled "CMakeLists.txt files for building application software".

nk_build_idl_files()

This command is declared in the file `/opt/KasperskyOS-Community-Edition-<version>toolchain/share/cmake/Modules/platform/nk2.cmake`.

```
nk_build_idl_files(NAME ...)
```

This command creates a `CMake` target for generating `.idl.h` files for one or more defined IDL files using the NK compiler.

Parameters:

- `NAME` – name of the `CMake` target for building `.idl.h` files. If a target has not yet been created, it will be created by using `add_library()` with the specified name. Required parameter.
- `NOINSTALL` – if this option is specified, files will only be generated in the working directory and will not be installed in global directories: `${CMAKE_BINARY_DIR}/_headers_` `${CMAKE_BINARY_DIR}/_headers_/${PROJECT_NAME}`.
- `NK_MODULE` – parameter in which you need to specify the package name, excluding the name of the IDL file. For example, if the package name in the IDL description is defined as `kl.core.NameServer`, the `kl.core` value must be passed in the `NK_MODULE` parameter.
- `WORKING_DIRECTORY` – working directory for calling the NK compiler, which is `${CMAKE_CURRENT_BINARY_DIR}` by default.
- `DEPENDS` – additional build targets on which the IDL file depends.

  To add multiple targets, you need to use multiple `DEPENDS` parameters.
- `IDL` – path to the IDL file for which the idl.h file is being generated. Required parameter.

  To add multiple IDL files, you need to use multiple `IDL` parameters.

  > If one IDL file imports another IDL file, idl.h files need to be generated in the order necessary for compliance with dependencies (with the most deeply nested first).
- `NK_FLAGS` – additional flags for the NK compiler.

Example call:

```
nk_build_idl_files (echo_idl_files NK_MODULE "echo" IDL "resources/Ping.idl")
```

For an example of using this command, see the article titled "CMakeLists.txt files for building application software".

nk_build_cdl_files()

This command is declared in the file `/opt/KasperskyOS-Community-Edition-<version>toolchain/share/cmake/Modules/platform/nk2.cmake`.

```
nk_build_cdl_files(NAME ...)
```

This command creates a `CMake` target for generating `.cdl.h` files for one or more defined CDL files using the NK compiler.

Parameters:

- `NAME` – name of the `CMake` target for building `.cdl.h` files. If a target has not yet been created, it will be created by using `add_library()` with the specified name. Required parameter.
- `NOINSTALL` – if this option is specified, files will only be generated in the working directory and are not installed in global directories: `${CMAKE_BINARY_DIR}/_headers_` `${CMAKE_BINARY_DIR}/_headers_/${PROJECT_NAME}`.
- `IDL_TARGET` – target when building `.idl.h` files for IDL files containing descriptions of endpoints provided by components described in CDL files.
- `NK_MODULE` – parameter in which you need to specify the component name, excluding the name of the CDL file. For example, if the component name in the CDL description is defined as `kl.core.NameServer`, the `kl.core` value must be passed in the `NK_MODULE` parameter.
- `WORKING_DIRECTORY` – working directory for calling the NK compiler, which is `${CMAKE_CURRENT_BINARY_DIR}` by default.
- `DEPENDS` – additional build targets on which the CDL file depends.

  To add multiple targets, you need to use multiple `DEPENDS` parameters.
- `CDL` – path to the CDL file for which the `.cdl.h` file is being generated. Required parameter.

  To add multiple CDL files, you need to use multiple `CDL` parameters.
- `NK_FLAGS` – additional flags for the NK compiler.

Example call:

```
nk_build_cdl_files (echo_cdl_files IDL_TARGET echo_idl_files NK_MODULE "echo" CDL
"resources/Ping.cdl")
```

For an example of using this command, see the article titled "CMakeLists.txt files for building application software".

nk_build_edl_files()

This command is declared in the file `/opt/KasperskyOS-Community-Edition-<version>toolchain/share/cmake/Modules/platform/nk2.cmake`.

```
nk_build_edl_files(NAME ...)
```

This command creates a `CMake` target for generating an `.edl.h` file for one defined EDL file using the NK compiler.

Parameters:

- `NAME` – name of the `CMake` target for building an `.edl.h` file. If a target has not yet been created, it will be created by using `add_library()` with the specified name. Required parameter.
- `NOINSTALL` – if this option is specified, files will only be generated in the working directory and are not installed in global directories: `${CMAKE_BINARY_DIR}/_headers_` `${CMAKE_BINARY_DIR}/_headers_/${PROJECT_NAME}`.
- `CDL_TARGET` – target when building `.cdl.h` files for CDL files containing descriptions of components of the EDL file for which the build is being performed.
- `IDL_TARGET` – target when building .idl.h files for IDL files containing descriptions of interfaces of the EDL file for which the build is being performed.
- `NK_MODULE` – parameter in which you need to specify the name of the process class, excluding the name of the EDL file. For example, if the process class name in the EDL description is defined as `kl.core.NameServer`, the `kl.core` value must be passed in the `NK_MODULE` parameter.
- `WORKING_DIRECTORY` – working directory for calling the NK compiler, which is `${CMAKE_CURRENT_BINARY_DIR}` by default.
- `DEPENDS` – additional build targets on which the EDL file depends.

  To add multiple targets, you need to use multiple `DEPENDS` parameters.
- `EDL` – path to the EDL file for which the edl.h file is being generated. Required parameter.
- `NK_FLAGS` – additional flags for the NK compiler.

Example calls:

```
nk_build_edl_files (echo_server_edl_files CDL_TARGET echo_cdl_files NK_MODULE "echo"
EDL "resources/Server.edl")
nk_build_edl_files (echo_client_edl_files NK_MODULE "echo" EDL "resources/Client.edl")
```

For an example of using this command, see the article titled "CMakeLists.txt files for building application software".

Generating transport code for development in C++

The `CMake` commands add_nk_idl(), add_nk_cdl() and add_nk_edl() are used to generate transport proxy objects and stubs using the `nkppmeta` compiler when building a solution.

add_nk_idl()

This command is declared in the file `/opt/KasperskyOS-Community-Edition-<version>/toolchain/share/cmake/Modules/platform/nk2.cmake`.

```
add_nk_idl(NAME IDL_FILE ...)
```

This command creates a `CMake` target for generating a `*.idl.cpp.h` header file for a defined IDL file using the `nkppmeta` compiler. The command also creates a library containing the transport code for the defined interface. To link to this library, use the `bind_nk_targets()` command.

The generated header files contain a C++ representation for the interface and data types described in the IDL file, and the methods required for use of proxy objects and stubs.

Parameters:

- `NAME` — name of the `CMake` target. Required parameter.
- `IDL_FILE` — path to the IDL file. Required parameter.
- `NK_MODULE` – parameter in which you need to specify the package name, excluding the name of the IDL file. For example, if the package name in the IDL description is defined as `kl.core.NameServer`, the `kl.core` value must be passed in the `NK_MODULE` parameter.
- `LANG` – parameter in which you need to specify the `CXX` value.

Example call:

```
add_nk_idl (ANIMAL_IDL "${CMAKE_SOURCE_DIR}/resources/Animal.idl"
            NK_MODULE  "example"
            LANG       "CXX")
```

add_nk_cdl()

This command is declared in the file `/opt/KasperskyOS-Community-Edition-<version>/toolchain/share/cmake/Modules/platform/nk2.cmake`.

```
add_nk_cdl(NAME CDL_FILE ...)
```

This command creates a `CMake` target for generating a `*.cdl.cpp.h` file for a defined CDL file using the `nkppmeta` compiler. The command also creates a library containing the transport code for the defined component. To link to this library, use the `bind_nk_targets()` command.

The `*.cdl.cpp.h` file contains the tree of embedded components and endpoints provided by the component described in the CDL file.

Parameters:

- `NAME` — name of the `CMake` target. Required parameter.
- `CDL_FILE` — path to the CDL file. Required parameter.

- `NK_MODULE` – parameter in which you need to specify the component name, excluding the name of the CDL file. For example, if the component name in the CDL description is defined as `kl.core.NameServer`, the `kl.core` value must be passed in the `NK_MODULE` parameter.

- `LANG` – parameter in which you need to specify the `CXX` value.

Example call:

```
add_nk_cdl (CAT_CDL    "${CMAKE_SOURCE_DIR}/resources/Cat.cdl"
            NK_MODULE "example"
            LANG       "CXX")
```

add_nk_edl()

This command is declared in the file `/opt/KasperskyOS-Community-Edition-<version>/toolchain/share/cmake/Modules/platform/nk2.cmake`.

```
add_nk_edl(NAME EDL_FILE ...)
```

This command creates a `CMake` target for generating a `*.edl.cpp.h` file for a defined EDL file using the `nkppmeta` compiler. The command also creates a library containing the transport code for the server or client program. To link to this library, use the `bind_nk_targets()` command.

The `*.edl.cpp.h` file contains the tree of embedded components and endpoints provided by the process class described in the EDL file.

Parameters:

- `NAME` — name of the `CMake` target. Required parameter.

- `EDL_FILE` — path to the EDL file. Required parameter.

- `NK_MODULE` – parameter in which you need to specify the name of the process class, excluding the name of the EDL file. For example, if the process class name in the EDL description is defined as `kl.core.NameServer`, the `kl.core` value must be passed in the `NK_MODULE` parameter.

- `LANG` – parameter in which you need to specify the `CXX` value.

Example call:

```
add_nk_edl (SERVER_EDL "${CMAKE_SOURCE_DIR}/resources/Server.edl"
            NK_MODULE  "example"
            LANG       "CXX")
```

image library

This section contains a description of the commands and macros of the `CMake` library named `image` that is included in KasperskyOS Community Edition and contains solution image build scripts.

build_kos_qemu_image()

This command is declared in the file `/opt/KasperskyOS-Community-Edition-<version>toolchain/share/cmake/Modules/platform/image.cmake`.

```
build_kos_qemu_image(NAME ...)
```

The command creates a `CMake` target for building a solution image for QEMU.

Parameters:

- `NAME` – name of the `CMake` target for building a solution image. Required parameter.
- `PERFCNT_KERNEL` – use the kernel with performance counters if it is available in KasperskyOS Community Edition.
- `EINIT_ENTITY` – name of the executable file that will be used to start the `Einit` program.
- `EXTRA_XDL_DIR` – additional directories to include when building the `Einit` program.
- `CONNECTIONS_CFG` – path to the `init.yaml` file or init.yaml.in template.
- `SECURITY_PSL` – path to the `security.psl` file or security.psl.in template.
- `KLOG_ENTITY` – target for building the `Klog` system program, which is responsible for the security audit. If the target is not specified, the audit is not performed.
- `QEMU_FLAGS` – additional flags for running QEMU.
- `IMAGE_BINARY_DIR_BIN` – directory for the final image and other artifacts. It matches `CMAKE_CURRENT_BINARY_DIR` by default.
- `NO_AUTO_BLOB_CONTAINER` – solution image will not include the `BlobContainer` program that is required for working with dynamic libraries in shared memory. For more details, refer to "Including the BlobContainer system program in a KasperskyOS-based solution".
- `PACK_DEPS`, `PACK_DEPS_COPY_ONLY`, `PACK_DEPS_LIBS_PATH`, and `PACK_DEPS_COPY_TARGET` – parameters that define the method used to add dynamic libraries to the solution image.
- `IMAGE_FILES` – executable files of applications and system programs (except the `Einit` program) and any other files to be added to the ROMFS image.

  To add multiple applications or files, you can use multiple `IMAGE_FILES` parameters.
- `<path to files>` – free parameters like `IMAGE_FILES`.

Example call:

```
build_kos_qemu_image (   kos-qemu-image
                         EINIT_ENTITY EinitQemu
                         CONNECTIONS_CFG "src/init.yaml.in"
                         SECURITY_CFG "src/security.cfg.in"
                         IMAGE_FILES ${ENTITIES})
```

For an example of using this command, see the article titled "CMakeLists.txt files for building the Einit program".

build_kos_hw_image()

This command is declared in the file `/opt/KasperskyOS-Community-Edition-<version>toolchain/share/cmake/Modules/platform/image.cmake`.

```
build_kos_hw_image(NAME ...)
```

The command creates a `CMake` target for building a solution image for the hardware platform.

Parameters:

- `NAME` – name of the `CMake` target for building a solution image. Required parameter.
- `PERFCNT_KERNEL` – use the kernel with performance counters if it is available in KasperskyOS Community Edition.
- `EINIT_ENTITY` – name of the executable file that will be used to start the `Einit` program.
- `EXTRA_XDL_DIR` – additional directories to include when building the `Einit` program.
- `CONNECTIONS_CFG` – path to the init.yaml file or init.yaml.in template.
- `SECURITY_PSL` – path to the security.psl file or security.psl.in template.
- `KLOG_ENTITY` – target for building the `Klog` system program, which is responsible for the security audit. If the target is not specified, the audit is not performed.
- `IMAGE_BINARY_DIR_BIN` – directory for the final image and other artifacts. The default directory is `CMAKE_CURRENT_BINARY_DIR`.
- `NO_AUTO_BLOB_CONTAINER` – solution image will not include the `BlobContainer` program that is required for working with dynamic libraries in shared memory. For more details, refer to "Including the BlobContainer system program in a KasperskyOS-based solution".
- `PACK_DEPS`, `PACK_DEPS_COPY_ONLY`, `PACK_DEPS_LIBS_PATH`, and `PACK_DEPS_COPY_TARGET` – parameters that define the method used to add dynamic libraries to the solution image.
- `IMAGE_FILES` – executable files of applications and system programs (except the `Einit` program) and any other files to be added to the ROMFS image.

  To add multiple applications or files, you can use multiple `IMAGE_FILES` parameters.
- `<path to files>` – free parameters like `IMAGE_FILES`.

Example call:

```
build_kos_hw_image ( kos-image
                     EINIT_ENTITY EinitHw
                     CONNECTIONS_CFG "src/init.yaml.in"
                     SECURITY_CFG "src/security.cfg.in"
                     IMAGE_FILES ${ENTITIES})
```

For an example of using this command, see the article titled "CMakeLists.txt files for building the Einit program".

Building without CMake

This section contains a description of the scripts, tools, compilers and build templates provided in KasperskyOS Community Edition.

These tools can be used:

- In other build systems.
- To perform individual steps of the build.
- To analyze the build specifications and write a custom build system.

The general scenario for building a solution image is described in the article titled Build process overview.

Tools for building a solution

This section contains a description of the scripts, tools, compilers and build templates provided in KasperskyOS Community Edition.

Build scripts and tools

KasperskyOS Community Edition includes the following build scripts and tools:

- nk-gen-c

  The NK compiler (`nk-gen-c`) generates transport code based on the IDL, CDL, and EDL descriptions. Transport code is needed for generating, sending, receiving, and processing IPC messages.

- nk-psl-gen-c

  The `nk-psl-gen-c` compiler generates the C-language source code of the Kaspersky Security Module based on the solution security policy description and the IDL, CDL, and EDL descriptions. The `nk-psl-gen-c` compiler also generates the C-language source code of solution security policy tests based on solution security policy tests in PAL.

- einit

  The `einit` tool automates the creation of code for the `Einit` initializing program. This program is the first to start when KasperskyOS is loaded. Then it starts all other programs and creates IPC channels between them.

- makekss

  The `makekss` script creates the Kaspersky Security Module.

- makeimg

  The `makeimg` script creates the final boot image of the KasperskyOS-based solution with all programs to be started and the Kaspersky Security Module.

nk-gen-c

The NK compiler (`nk-gen-c`) generates transport code based on the IDL, CDL, and EDL descriptions.

The `nk-gen-c` compiler receives the IDL, CDL or EDL file and creates the following files:

- A `*.*dl.h` file containing the transport code.
- A `*.*dl.nk.d` file that lists the created `*.*dl.h` file's dependencies on the IDL and CDL files. The `*.*dl.nk.d` file is created for the build system.

Syntax of the shell command for starting the `nk-gen-c` compiler:

```
nk-gen-c [-I <PATH>]... [-o <PATH>] [--types] [--interface] [--endpoints]
[--client] [--server] [--extended-errors] [--trace-client-ipc {headers|dump}]
[--trace-server-ipc {headers|dump}] [--ipc-trace-method-filter <METHOD>[,METHOD]...]
[-h|--help] [--version] <FILE>
```

Basic parameters:

- `FILE`

  Path to the IDL, CDL, or EDL file for which you need to generate transport code.

- `-I <PATH>`

  These parameters are used to define the paths to directories containing the auxiliary files required for generating transport code. (The auxiliary files are located in the `sysroot-*-kos/include` directory from the KasperskyOS SDK.) These parameters can also be used to define the paths to directories containing IDL and CDL files that are referenced by the file defined via the `FILE` parameter.

- `-o <PATH>`

  Path to an existing directory where the created files will be placed. If this parameter is not specified, the created files will be put into the current directory.

- `-h|--help`

  Prints the Help text.

- `--version`

  Prints the version of the `nk-gen-c` compiler.

- `--extended-errors`

  This parameter provides the capability to use interface methods with one or more error parameters of user-defined IDL types. (The client works with error parameters like it works with output parameters.)

> If the `--extended-errors` parameter is not specified, you can use interface methods only with one `status` error parameter of the IDL type `UInt16` whose value is passed to the client via return code of the interface method. This mechanism is obsolete and will no longer be supported in the future, so you are advised to always specify the `--extended-errors` parameter.

Selective generation of transport code

To reduce the volume of generated transport code, you can use flags for selective generation of transport code. For example, you can use the `--server` flag for programs that implement endpoints, and use the `--client` flag for programs that utilize the endpoints.

> If no selective generation flag for transport code is specified, the `nk-gen-c` compiler generates transport code with all possible methods and types for the defined IDL, CDL, or EDL file.

Flags for selective generation of transport code for an IDL file:

- `--types`

  The transport code includes the types corresponding to the IDL types from the defined IDL file, and the types corresponding to this file's imported IDL types that are used in IDL types of the defined IDL file. However, the types corresponding to imported IDL constants and to the aliases of imported IDL types are not included in the `*.idl.h` file. To use the types corresponding to imported IDL constants and to the aliases of imported IDL types, you must separately generate the transport code for the IDL files from which you are importing.

- `--interface`

  The transport code corresponds to the `--types` flag, and includes the types of structures of the constant part of IPC requests and IPC responses for interface methods whose signatures are specified in the defined IDL file. In addition, the transport code contains constants indicating the sizes of IPC message arenas.

- `--client`

  The transport code corresponds to the `--interface` flag, and includes the proxy object type, proxy object initialization method, and the interface methods specified in the defined IDL file.

- `--server`

  The transport code corresponds to the `--interface` flag, and includes the types and dispatcher (dispatch method) used to process IPC requests corresponding to the interface methods specified in the defined IDL file.

Flags for selective generation of transport code for a CDL or EDL file:

- `--types`

  The transport code includes the types corresponding to the IDL types that are used in the method parameters of endpoints provided by the component (for the defined CDL file) or process class (for the defined EDL file).

- `--endpoints`

  The transport code corresponds to the `--types` flag, and includes the types of structures of the constant part of IPC requests and IPC responses for the methods of endpoints provided by the component (for the defined CDL file) or process class (for the defined EDL file). In addition, the transport code contains constants indicating the sizes of IPC message arenas.

- `--client`

The transport code corresponds to the `--types` flag, and includes the types of structures of the constant part of IPC requests and IPC responses for the methods of endpoints provided by the component (for the defined CDL file) or process class (for the defined EDL file). In addition, the transport code contains constants indicating the sizes of IPC message arenas, and the proxy object types, proxy object initialization methods, and methods of endpoints provided by the component (for the defined CDL file) or process class (for the defined EDL file).

- `--server`

  The transport code corresponds to the `--types` flag, and includes the types and dispatchers (dispatch methods) used to process IPC requests corresponding to the endpoints provided by the component (for the defined CDL file) or process class (for the defined EDL file). In addition, the transport code contains constants indicating the sizes of IPC message arenas, and the stub types, stub initialization methods, and the types of structures of the constant part of IPC requests and IPC responses for the methods of endpoints provided by the component (for the defined CDL file) or process class (for the defined EDL file).

Printing diagnostic information about sending and receiving IPC messages

Transport code can generate diagnostic information about sending and receiving IPC messages and print this data via standard error. To generate transport code with these capabilities, use the following parameters:

- `--trace-client-ipc {headers|dump}`

  The code for printing diagnostic information is executed directly before the `Call()` system call is executed and immediately after it is executed. If the `headers` value is specified, the diagnostic information includes the endpoint method ID (MID), the endpoint ID (RIID), the size of the constant part of the IPC message (in bytes), the contents of the IPC message arena handle, the size of the IPC message arena (in bytes), and the size of the utilized part of the IPC message arena (in bytes). If the `dump` value is specified, the diagnostic information additionally includes the contents of the constant part and arena of the IPC message in hexadecimal format.

  When using this parameter, you must either specify the selective generation flag for transport code `--client` or refrain from specifying a selective generation flag for transport code.

- `--trace-server-ipc {headers|dump}`

  The code for printing diagnostic information is executed directly before calling the function that implements the interface method, and immediately after the completion of this function. In other words, it is executed when the dispatcher (dispatch method) is called in the interval between execution of the `Recv()` and `Reply()` system calls. If the `headers` value is specified, the diagnostic information includes the endpoint method ID (MID), the endpoint ID (RIID), the size of the constant part of the IPC message (in bytes), the contents of the IPC message arena handle, the size of the IPC message arena (in bytes), and the size of the utilized part of the IPC message arena (in bytes). If the `dump` value is specified, the diagnostic information additionally includes the contents of the constant part and arena of the IPC message in hexadecimal format.

  When using this parameter, you must either specify the selective generation flag for transport code `--server` or refrain from specifying a selective generation flag for transport code.

- `--ipc-trace-method-filter <METHOD>[,METHOD]...`

  Diagnostic information is printed if only the defined interface methods are called. For the `METHOD` value, you can use the interface method name or the construct `<package name>:<interface method name>`. The package name and interface method name are specified in the IDL file.

  If this parameter is not specified, diagnostic information is printed when any interface method is called.

  This parameter can be specified multiple times. For example, you can specify all required interface methods in one parameter or specify each required interface method in a separate parameter.

nk-psl-gen-c

The `nk-psl-gen-c` compiler generates the C-language source code of the Kaspersky Security Module based on the solution security policy description and the IDL, CDL, and EDL descriptions. This code is used by the makekss script.

The `nk-psl-gen-c` compiler can also generate the C-language source code of solution security policy tests based on solution security policy tests in PAL.

Syntax of the shell command for starting the `nk-psl-gen-c` compiler:

```
nk-psl-gen-c [{-I|--include-dir} <DIR>]... [{-o|--output} <FILE>] [--out-tests <FILE>]
[{-t|--tests} <ARG>] [{-a|--audit} <FILE>] [-h|--help] [--version] <INPUT>
```

Parameters:

- `INPUT`

  Path to the top-level file of the solution security policy description. This is normally the `security.psl` file.

- `{-I|--include-dir} <DIR>`

  These parameters are used to define the paths to directories containing IDL, CDL, and EDL files pertaining to the solution, and the paths to directories containing auxiliary files from the KasperskyOS SDK (`common`, `sysroot-*-kos/include`, `toolchain/include`).

- `{-o|--output} <FILE>`

  Path to the file that will save the source code of the Kaspersky Security Module and (optionally) the source code of solution security policy tests. The path must include existing directories.

- `--out-tests <FILE>`

  Path to the file that will save the source code of the solution security policy tests.

- `{-t|--tests} <ARG>`

  Defines whether the source code of solution security policy tests must be generated. `ARG` can take the following values:

  - `skip:` – source code of tests is not generated. This value is used by default if the `-t, --tests <ARG>` parameter is not specified.
  - `generate:` – source code of tests is generated. If the source code of tests is generated, you are advised to use the `--out-tests <FILE>` parameter. Otherwise, the source code of tests will be saved in the same file containing the source code of the Kaspersky Security Module, which may lead to errors during the build.

- `{-a|--audit} <FILE>`

  Path to the file that will save the C-language source code of the audit decoder.

- `-h|--help`

  Prints the Help text.

- `--version`

  Prints the version of the `nk-psl-gen-c` compiler.

einit

The `einit` tool automates the creation of code for the Einit initializing program.

The `einit` tool receives the solution initialization description (the `init.yaml` file by default) and EDL, CDL and IDL descriptions, and creates a file containing the source code of the `Einit` initializing program. Then the `Einit` program must be built using the C-language cross compiler that is provided in KasperskyOS Community Edition.

Syntax for using the `einit` tool:

```
einit -I PATH -o PATH [--help] FILE
```

Parameters:

- `FILE`

  Path to the `init.yaml` file.

- `-I PATH`

  Path to the directory containing the auxiliary files (including EDL, CDL and IDL descriptions) required for generating the initializing program. By default, these files are located in the directory `/opt/KasperskyOS-Community-Edition-<version>/sysroot-aarch64-kos/include`.

- `-o, --out-file PATH`

  Path to the created .c file containing the code of the initializing program.

- `-h, --help`

  Displays the Help text.

makekss

The `makekss` script creates the Kaspersky Security Module.

The script calls the nk-psl-gen-c compiler to generate the source code of the security module, then compiles the resulting code by calling the C compiler that is provided in KasperskyOS Community Edition.

The script creates the security module from the solution security policy description.

Syntax for using the `makekss` script:

```
makekss --target=ARCH --module=PATH --with-nk="PATH" --with-nktype="TYPE" --with-
nkflags="FLAGS" [--output="PATH"][--help][--with-cc="PATH"][--with-cflags="FLAGS"]
FILE
```

Parameters:

- `FILE`

  Path to the top-level file of the solution security policy description.

- `--target=ARCH`

  Processor architecture for which the build is intended.

- `--module=-lPATH`

  Path to the `ksm_kss` library. This key is passed to the C compiler for linking to this library.

- `--with-nk=PATH`

  Path to the `nk-psl-gen-c` compiler that will be used to generate the source code of the security module. By default, the compiler is located in `/opt/KasperskyOS-Community-Edition-<version>/toolchain/bin/nk-psl-gen-c`.

- `--with-nktype="TYPE"`

  Indicates the type of NK compiler that will be used. To use the `nk-psl-gen-c` compiler, indicate the `psl` type.

- `--with-nkflags="FLAGS"`

  Parameters used when calling the `nk-psl-gen-c` compiler.

  The `nk-psl-gen-c` compiler will require access to all EDL, CDL and IDL descriptions. To enable the `nk-psl-gen-c` compiler to find these descriptions, you need to pass the paths to these descriptions in the `--with-nkflags` parameter by using the `-I` switch of the `nk-psl-gen-c` compiler.

- `--output=PATH`

  Path to the created security module file.

- `--with-cc=PATH`

  Path to the C compiler that will be used to build the security module. The compiler provided in KasperskyOS Community Edition is used by default.

- `--with-cflags=FLAGS`

  Parameters used when calling the C compiler.

- `-h, --help`

  Displays the Help text.

makeimg

The `makeimg` script creates the final boot image of the KasperskyOS-based solution with all executable files of programs and the Kaspersky Security Module.

The script receives a list of files, including the executable files of all applications that need to be added to ROMFS of the loaded image, and creates the following files:

- Solution image
- Solution image without character tables (`.stripped`)
- Solution image with debug character tables (`.dbg.syms`)

Syntax for using the makeimg script:

```
makeimg --target=ARCH --sys-root=PATH --with-toolchain=PATH --ldscript=PATH --img-
src=PATH --img-dst=PATH --with-init=PATH [--with-extra-asflags=FLAGS][--with-extra-
ldflags=FLAGS][--help] FILES
```

Parameters:

- `FILES`

  List of paths to files, including the executable files of all applications that need to be added to ROMFS.

  The security module (`ksm.module`) must be explicitly specified, or else it will not be included in the solution image. The `Einit` application does not need to be indicated because it will be automatically included in the solution image.

- `--target=ARCH`

  Architecture for which the build is intended.

- `--sys-root=PATH`

  Path to the root directory sysroot. By default, this directory is located in `/opt/KasperskyOS-Community-Edition-version/sysroot-aarch64-kos/`.

- `--with-toolchain=PATH`

  Path to the set of auxiliary tools required for the solution build. By default, these tools are located in `/opt/KasperskyOS-Community-Edition-<version>/toolchain/`.

- `--ldscript=PATH`

  Path to the linker script required for the solution build. By default, this script is located in `/opt/KasperskyOS-Community-Edition-<version>/libexec/aarch64-kos/`.

- `--img-src=PATH`

  Path to the precompiled KasperskyOS kernel. By default, the kernel is located in `/opt/KasperskyOS-Community-Edition-<version>/libexec/aarch64-kos/`.

- `--img-dst=PATH`

  Path to the created image file.

- `--with-init=PATH`

  Path to the executable file of the `Einit` initializing program.

- `--with-extra-asflags=FLAGS`

  Additional flags for the AS Assembler.

- `--with-extra-ldflags=FLAGS`

  Additional flags for the LD Linker.

- `-h, --help`

  Displays the Help text.

Cross compilers

The toolchain provided in the KasperskyOS SDK includes one or more GCC compilers. The `toolchain/bin` directory contains the following files:

- Executable files of compilers (for example, `x86_64-pc-kos-gcc`, `arm-kos-g++`)

- Executable files of linkers (for example, `x86_64-pc-kos-ld`, `arm-kos-ld`)
- Executable files of assemblers (for example, `x86_64-pc-kos-as`, `arm-kos-as`)

In addition to standard macros, an additional macro `__KOS__=1` is defined in GCC. Use of this macro lets you simplify porting of the software code to KasperskyOS, and also simplifies development of platform-independent programs.

To view the list of standard macros of GCC, run the following command:

```
echo '' | aarch64-kos-gcc -dM -E -
```

Linker operation specifics

When building the executable file of an application, by default the linker links the following libraries in the specified order:

1. libc is the standard C library.
2. libm is the library that implements the mathematical functions of the standard C language library.
3. libvfs_stubs is the library that contains stubs of I/O functions (for example, `open`, `socket`, `read`, `write`).
4. libkos is the library for accessing the KasperskyOS core endpoints.
5. libenv is the library of the subsystem for configuring the environment of applications (environment variables, arguments of the `main` function, and custom configurations).
6. libsrvtransport-u is the library that supports IPC between processes and the kernel.

Example build without using CMake

Below is an example of a script for building a basic example. This example contains a single application called `Hello`, which does not provide any endpoints.

> The provided script is intended only for demonstrating the build commands being used.

build.sh

```
#!/bin/sh

# The SDK variable should specify the path to the KasperskyOS Community Edition
installation directory.
SDK=/opt/KasperskyOS-Community-Edition-<version>
TOOLCHAIN=$SDK/toolchain
SYSROOT=$SDK/sysroot-aarch64-kos

PATH=$TOOLCHAIN/bin:$PATH

# Create the Hello.edl.h file from Hello.edl
```

```
# (The Hello program does not implement any endpoints, so there are no CDL or IDL
files.)
nk-gen-c -I $SYSROOT/include Hello.edl

# Compile and build the Hello program
aarch64-kos-gcc -o hello hello.c

# Create the Kaspersky Security Module (ksm.module)
makekss --target=aarch64-kos                                  \
        --module=-lksm_kss                                              \
        --with-nkflags="-I $SDK/examples/common -I $SYSROOT/include" \
        security.psl

# Create code of the Einit initializing program
einit -I $SYSROOT/include -I . init.yaml -o einit.c

# Compile and build the Einit program
aarch64-kos-gcc -I . -o einit einit.c

# Create loadable solution image (kos-qemu-image)
makeimg --target=aarch64-kos                                  \
        --sys-root=$SYSROOT                                     \
        --with-toolchain=$TOOLCHAIN                             \
        --ldscript=$SDK/libexec/aarch64-kos/kos-qemu.ld   \
        --img-src=$SDK/libexec/aarch64-kos/kos-qemu       \
        --img-dst=kos-qemu-image                                \
        Hello ksm.module

# Run solution under QEMU
qemu-system-aarch64 -m 1024 -serial stdio -kernel kos-qemu-image
```

Using dynamic libraries

Dynamic libraries (`*.so` files) can be used in a KasperskyOS-based solution. Compared to static libraries (`*.a` files), dynamic libraries provide the following advantages:

- Efficient use of RAM.

  Multiple processes can use the same instance of a dynamic library. Also, a program and dynamic libraries in one process can use the same instance of a dynamic library.

  Dynamic libraries can be loaded into memory and unloaded from memory on the initiative of the programs that use them.

- Convenient software updates.

  A dynamic library update is applied to all programs and dynamic libraries dependent on this dynamic library without having to rebuild them.

- Capability to implement a mechanism for plug-ins.

  Plug-ins for solution components consist of dynamic libraries.

- Shared use of code and data.

  One instance of a dynamic library can be concurrently used by multiple processes, and by a program and dynamic libraries in one process. This enables centralized management of multi-access to resources or storage of shared data, for example.

Dynamic libraries are provided in the KasperskyOS SDK, and can also be created by a KasperskyOS-based solution developer. Normal operation of third-party dynamic libraries cannot be guaranteed.
Due to current technical limitations, `libc.so` and `libpthread.so` cannot be used in a KasperskyOS-based solution.

Prerequisites for using dynamic libraries

To use dynamic libraries in a KasperskyOS-based solution, the following conditions must be met:

1. Processes that use dynamic libraries must have access to the file systems in which the files of the dynamic libraries are stored. Access to file systems is provided by VFS, which may be implemented in the context of the processes using the dynamic libraries, or may be a separate process. The dynamic libraries must not be used by VFS or other software that is used by VFS to work with storage (such as a storage driver).

2. The toolchain must support dynamic linking.

   The KasperskyOS SDK comes with a separate toolchain for each supported processor architecture. A required toolchain may not support dynamic linking. To check whether dynamic linking is supported, you need to use the `CMake` `get_property()` command in the `CMakeLists.txt` root file as follows:

   ```
   get_property(CAN_SHARED GLOBAL PROPERTY TARGET_SUPPORTS_SHARED_LIBS)
   if(CAN_SHARED)
       message(STATUS "Dynamic linking is supported.")
   endif()
   ```

3. The executable code of programs that use dynamic libraries must be built with the `-rdynamic` flag (with dynamic linking).

   If the toolchain supports dynamic linking, the `CMake` `initialize_platform()` command causes this flag to be used automatically for building all executable files defined via `CMake` `add_executable()` commands.

If the `CMake` `initialize_platform(FORCE_STATIC)` command is called in the `CMakeLists.txt` root file, the toolchain supporting dynamic linking performs static linking of executable files.
The `CMake` `project_static_executable_header_default()` command affects the build of executable files defined via subsequent `CMake` `add_executable()` commands in one `CMakeLists.txt` file. The toolchain that supports dynamic linking performs static linking of these executable files.
The `CMake` `platform_target_force_static()` command affects the build of one executable file defined via the `CMake` `add_executable()` command. The toolchain that supports dynamic linking performs static linking of this executable file.
The executable code of programs that is built with the `-rdynamic` flag is linked to a static library if a dynamic library is not found. For example, if the `CMake` `target_link_libraries(client -lm)` command is being used, the `client` program is linked to the static library `libm.a` if the dynamic library `libm.so` is not found.

Life cycle of a dynamic library

The life cycle of a dynamic library includes the following phases:

1. Loading into memory.

A dynamic library linked to a program is loaded into memory upon startup of the process in whose context this program is executed. A running process can load a dynamic library into memory by calling the `dlopen()` function of the POSIX interface. A dynamic library may be linked to other dynamic libraries, so a program depends not only on the dynamic library directly linked to it, but also depends on the entire dependency graph of this library. A dynamic library is loaded into memory together with all of the dynamic libraries that it depends on.

If the `BlobContainer` system program is included in a KasperskyOS-based solution, one instance of a dynamic library is loaded into shared memory regardless of how many processes are using this library. (More specifically, only the part of the dynamic library that includes code and read-only data is loaded into shared memory. The other part of the dynamic library is loaded into the memory of each process that uses this library.) If the `BlobContainer` system program is not included in a solution, separate instances of a dynamic library are loaded into the memory of processes that are using this library. A dynamic library on which several other dynamic libraries depend is loaded into shared memory or into the memory of a process in a single instance.

If a list of dynamic libraries is defined through the `LD_PRELOAD` environment variable, these dynamic libraries will be loaded into memory even if the program is not dependent on them. (List items must be absolute or relative paths to dynamic libraries separated by a colon, for example: `LD_PRELOAD=libmalloc.so:libfree.so:/usr/somepath/lib/libfoo.so`.) The functions that are exported by the dynamic libraries specified in `LD_PRELOAD` replace the identically named functions that are exported by other dynamic libraries loaded into shared memory or process memory. This can be used for debugging purposes if you need to replace functions imported from dynamic libraries.

The dynamic library loader searches for program-dependent dynamic libraries in the following order:

1. Absolute paths defined through the `LD_LIBRARY_PATH` environment variable.

   Paths must be separated by a colon, for example: `LD_LIBRARY_PATH=/usr/lib:/home/user/lib`.

2. Absolute paths defined in the `DT_RUNPATH` or `DT_RPATH` field of the `.dynamic` section of executable files and dynamic libraries.

   Linking of executable files and dynamic libraries may include defined paths that the dynamic library loader will search. (For example, this can be done through the `INSTALL_RPATH` property in the `CMake` command `set_target_properties()`.) Paths used to search for dynamic libraries are stored in the `DT_RUNPATH` or `DT_RPATH` field of the `.dynamic` section. This field may be in executable files linked to dynamic libraries and in dynamic libraries linked to other dynamic libraries.

3. Path `/lib`.

The dynamic library loader searches in this same order if a relative path to a dynamic library is specified in the `filename` parameter of the `dlopen()` function or in the `LD_PRELOAD` environment variable. If the absolute path is specified, the loader puts the dynamic library into memory without performing a search.

2. Use by a process (or processes).

3. Unloading from memory.

   A dynamic library is unloaded from shared memory when all processes using this library have terminated or called the `dlclose()` function of the POSIX interface. A dynamic library that was loaded into process memory by calling the `dlopen()` function is unloaded by calling the `dlclose()` function. A dynamic library that is linked to a program cannot be unloaded from memory until termination of the process in whose context this program is executed. A dynamic library that is linked to other dynamic libraries is unloaded from memory after all libraries that depend on it are unloaded, or after the process is terminated.

Including the BlobContainer system program in a KasperskyOS-based solution

> If the `BlobContainer` program is provided in the KasperskyOS SDK, it must be included into a solution in which dynamic libraries are used. To check whether the `BlobContainer` program is included in the KasperskyOS SDK, you need to make sure that the `sysroot-*-kos/bin/BlobContainer` executable file is available.

The `BlobContainer` program can be included in a solution either automatically or manually. This program is automatically included in a solution by running the `CMake` commands `build_kos_qemu_image()` and `build_kos_hw_image()` if at least one program in the solution is linked to a dynamic library. (To disable automatic inclusion of the `BlobContainer` program in a solution, you need to add the `NO_AUTO_BLOB_CONTAINER` value to the parameters of the `CMake` commands `build_kos_qemu_image()` and `build_kos_hw_image()`.) If programs in a solution work with dynamic libraries using only a POSIX interface (the `dlopen()`, `dlsym()`, `dlerror()`, and `dlclose()` functions), the `BlobContainer` program needs to be manually included in the solution.

When using the `BlobContainer` program, you must create IPC channels from the processes using dynamic libraries to the process of the `BlobContainer` program. These IPC channels can be created statically or dynamically. If a statically created IPC channel is not available, the client and server parts of the `BlobContainer` program attempt to dynamically create an IPC channel using the name server.

If the `BlobContainer` program is automatically included in a solution, the `@INIT_EXTERNAL_ENTITIES@`, `@INIT_<program name>_ENTITY_CONNECTIONS@` and `@INIT_<program name>_ENTITY_CONNECTIONS+@` macros used in the `init.yaml.in` file automatically create within the init description dictionaries of IPC channels that enable static creation of IPC channels between processes of programs linked to dynamic libraries and the process of the `BlobContainer` program. (The process of the `BlobContainer` program receives the name `kl.bc.BlobContainer`, while the IPC channels receive the name `kl.BlobContainer`.) However, dictionaries of IPC channels to the `BlobContainer` program process are not automatically created for processes that work with dynamic libraries using only a POSIX interface. To ensure that the required IPC channels are statically created, these dictionaries must be manually created (these IPC channels must have the name `kl.BlobContainer`).

If the `BlobContainer` program is manually included in the solution and you need to statically create IPC channels from processes using dynamic libraries to the `BlobContainer` program process, you must manually create dictionaries of the required IPC channels in the init description. By default, the IPC channel to the `BlobContainer` program process has the name `kl.BlobContainer`. However, this name can be changed through the environment variable `_BLOB_CONTAINER_BACKEND`. This variable must be defined for the `BlobContainer` process and for processes using dynamic libraries.

The environment variable `_BLOB_CONTAINER_BACKEND` defines not only the name of statically created IPC channels to the `BlobContainer` program process, but also defines the endpoint name that is published on the name server and used to dynamically create IPC channels to the `BlobContainer` program process. This is convenient when multiple processes of the `BlobContainer` program are running simultaneously (for example, to isolate its own dynamic libraries from external ones), and when different processes using dynamic libraries must interact over IPC with different processes of the `BlobContainer` program. In this case, you need to define different values for the environment variable `_BLOB_CONTAINER_BACKEND` for different processes of the `BlobContainer` program, and then use these values for the environment variable `_BLOB_CONTAINER_BACKEND` for processes using dynamic libraries. The specific value must be selected depending on the specific process of the `BlobContainer` program that requires the dynamically created IPC channel.

Example use of the environment variable `_BLOB_CONTAINER_BACKEND` in the `init.yaml.in` file:

```
entities:

- name: example.BlobContainer
  path: example_blob_container
  args:
  - "-v"
  env:
    _BLOB_CONTAINER_BACKEND: kl.custombc
@INIT_example_blob_container_ENTITY_CONNECTIONS@
```

```
- name: client.Client
  path: client
  env:
    _BLOB_CONTAINER_BACKEND: kl.custombc
@INIT_client_ENTITY_CONNECTIONS@

@INIT_EXTERNAL_ENTITIES@
```

Example use of the environment variable `_BLOB_CONTAINER_BACKEND` in `CMake` commands:

```
set_target_properties (ExecMgrEntity PROPERTIES
EXTRA_ENV
"    _BLOB_CONTAINER_BACKEND: kl.custombc")

set_target_properties (dump_collector::entity PROPERTIES
EXTRA_ENV
"    _BLOB_CONTAINER_BACKEND: kl.custombc")
```

If the `BlobContainer` program is being used, the VFS working with files of dynamic libraries must be a separate process. An IPC channel must also be created from the process of the `BlobContainer` program to the VFS process.

Building dynamic libraries

When building dynamic libraries, you must use a toolchain that supports dynamic linking.

To build a dynamic library, you need to use the following `CMake` command:

```
add_library(<build target name> SHARED [list of paths to files of the library source
code])
```

Use of this `CMake` command results in an error if the toolchain does not support dynamic linking.

You can also build a dynamic library by using the following `CMake` command:

```
add_library(<build target name> [list of paths to files of the library source code])
```

The `cmake` shell command must be called with the `-D BUILD_SHARED_LIBS=YES` parameter. (If the `cmake` shell command is called without the `-D BUILD_SHARED_LIBS=YES` parameter, a static library will be built.)

Example:

```
#!/bin/bash
...
cmake -G "Unix Makefiles" \
      -D CMAKE_BUILD_TYPE:STRING=Debug \
      -D CMAKE_TOOLCHAIN_FILE=$SDK_PREFIX/toolchain/share/toolchain-$TARGET.cmake \
      -D BUILD_SHARED_LIBS=YES \
```

```
    -B build \
    && cmake --build build --target kos-image
```

By default, the library file name matches the name of the build target defined via the parameter of the `CMake add_library()` command. The library file name can be changed by using the `CMake set_target_properties()` command. This can be done to make the library file name identical for its dynamic and static variants.

Example:

```
# Build the static library
add_library(somelib_static STATIC src/somesrc.cpp)
set_target_properties(somelib_static PROPERTIES OUTPUT_NAME "somelib")
# The PLATFORM_SUPPORTS_DYNAMIC_LINKING variable has the
# value "true" when using dynamic
# linking. If initialize_platform(FORCE_STATIC) is called,
# this variable has the value "false".
if(PLATFORM_SUPPORTS_DYNAMIC_LINKING)
#   Build the dynamic library
    add_library(somelib_shared SHARED src/somesrc.cpp)
    set_target_properties(somelib_shared PROPERTIES OUTPUT_NAME "somelib")
endif()
```

A dynamic library can be linked to other static and dynamic libraries by using the `CMake target_link_libraries()` command. In this case, static libraries must be built with the `-fPIC` flag. This flag is applied when building a static library if the following `CMake` command is used:

```
set_property(TARGET <list of names of build targets> PROPERTY
POSITION_INDEPENDENT_CODE ON)
```

Adding dynamic libraries to a KasperskyOS-based solution image

To add dynamic libraries to the KasperskyOS-based solution image, use `PACK_DEPS_COPY_ONLY ON`, `PACK_DEPS_LIBS_PATH`, and `PACK_DEPS_COPY_TARGET` parameters in the `CMake` commands `build_kos_qemu_image()` and `build_kos_hw_image()`.

Example:

```
set(RESOURCES ${CMAKE_SOURCE_DIR}/resources)
set(FSTAB ${RESOURCES}/fstab)
set(DISK_IMG ${CMAKE_CURRENT_BINARY_DIR}/ramdisk0.img)
set(RESOURCES_DIR ${CMAKE_CURRENT_SOURCE_DIR}/../resources)
set(EXT4_PART_DIR ${CMAKE_CURRENT_BINARY_DIR}/../system_hdd)

set_target_properties(${vfs_ENTITY} PROPERTIES
EXTRA_ARGS
"   - \"-f\"
  - \"fstab\""
EXTRA_ENV
"    ROOTFS: ramdisk0 / ext4 0"
${blkdev_ENTITY}_REPLACEMENT "${ramdisk_ENTITY};${sdcard_ENTITY}")
```

```
add_custom_target(copy-so)

add_custom_command(OUTPUT ${DISK_IMG}
       COMMAND ${CMAKE_COMMAND} -E copy_directory ${RESOURCES_DIR}/rootdir
${EXT4_PART_DIR}
       COMMAND mke2fs -v -d ${EXT4_PART_DIR} -t ext4 ${DISK_IMG} 40M
       DEPENDS copy-so
       COMMENT "Creating disk image '${DISK_IMG}' from files in '${EXT4_PART_DIR}'
...")

build_kos_hw_image(kos-image
                   ...
                   IMAGE_FILES ${ENTITIES_LIST} ${FSTAB} ${DISK_IMG}
                   PACK_DEPS_COPY_ONLY ON
                   PACK_DEPS_LIBS_PATH ${EXT4_PART_DIR}/lib
                   PACK_DEPS_COPY_TARGET copylibs)

if(PLATFORM_SUPPORTS_DYNAMIC_LINKING)
    add_dependencies(copy-so copylibs)
endif()
```

The solution program-dependent dynamic libraries are added to a storage device image (for example, one with an ext4 file system) that will be included into the solution image.

> Dynamic libraries that are loaded into memory by calling the `dlopen()` function of the POSIX interface are not added to the solution image.

The build system does the following:

- Searches for dynamic libraries and copies these libraries to the directory whose path is specified in the `PACK_DEPS_LIBS_PATH` parameter of the `CMake` commands `build_kos_qemu_image()` and `build_kos_hw_image()`. (To ensure that the found dynamic libraries are included in the storage device image, this directory must reside in the file system that will be put into the storage device image.)

- Creates a storage device image that includes the directory containing the dynamic libraries.

  To create a storage device image, use the `CMake` command `add_custom_command()`. The target specified in the `DEPENDS` parameter of the `CMake` command `add_custom_command()`, indicates that a storage device image is created. The target specified in the `PACK_DEPS_COPY_TARGET` parameter of the `CMake` commands `build_kos_qemu_image()` and `build_kos_hw_image()`, indicates that dynamic libraries are copied. To make sure that the storage device image is created only after the dynamic libraries are fully copied, use the `CMake` command `add_dependencies()`.

- Adds the storage device image to the solution image.

  To add the storage device image to the solution image, specify the full path to the storage device image in the `IMAGE_FILES` parameter of the `CMake` commands `build_kos_qemu_image()` and `build_kos_hw_image()`.

Formal specifications of KasperskyOS-based solution components

Solution development includes the creation of formal specifications for its components that form a global picture for the Kaspersky Security Module. A *formal specification of a KasperskyOS-based solution component* (hereinafter referred to as the *formal specification of the solution component*) is comprised of a system of IDL, CDL and EDL descriptions (IDL and CDL descriptions are optional) for this component. These descriptions are used to automatically generate transport code of solution components, and source code of the security module and the initializing program. The formal specifications of solution components are also used as source data for the solution security policy description.

> Just like solution components, the KasperskyOS kernel also has a formal specification (for details, see "Methods of KasperskyOS core endpoints").

Each solution component corresponds to an EDL description. In terms of a formal specification, a solution component is a container for components that provide endpoints. Multiple instances of one solution component may be used at the same time, which means that multiple processes can be started from the same executable file. Processes that correspond to the same EDL description are processes of the same class. An EDL description defines the process class name and the top-level component parameters, such as the provided endpoints with one or multiple interfaces, the security interface, and embedded components.

Each embedded component corresponds to a CDL description. This description defines the component name, provided endpoints, security interface, and embedded components. Embedded components can simultaneously provide endpoints, support a security interface, and serve as containers for other components. Each embedded component can provide multiple endpoints with one or more interfaces.

Each interface (including the security interface) is defined in an IDL description. This description defines the interface name, signatures of interface methods, and data types for the parameters of interface methods. The data comprising signatures of interface methods and definitions of data types for parameters of interface methods is referred to as a package.

Processes that do not provide endpoints may only act as clients. Processes that provide endpoints are servers, but they can also act as clients at the same time.

> The formal specification of a solution component does not define how this component will be implemented. In other words, the presence of components in a formal specification of a solution component does not mean that these components will be present in the architecture of this solution component.

Names of process classes, components, packages and interfaces

Process classes, components, packages and interfaces are identified by their names in IDL, CDL and EDL descriptions. Within one KasperskyOS-based solution, the names of process classes and the names of components form one set of names, while the names of packages form a different set of names. These two sets may overlap. A set of package names includes a set of interface names.

The name of a process class, component, package or interface is a link to the IDL, CDL or EDL file in which this name is defined. This link is a path to the IDL, CDL or EDL file (without the extension and dot before it) relative to the directory that is included in the set of directories where the source code generators search for IDL, CDL and EDL files. (This set of directories is defined by parameters `-I <path to the directory>`.) A dot is used as a separator in a path description.

For example, the `kl.core.NameServer` process class name is a link to the EDL file named `NameServer.edl`, which is located in the KasperskyOS SDK at the following path:

`sysroot-*-kos/include/kl/core`

However, source code generators must be configured to search for IDL, CDL and EDL files in the following directory:

`sysroot-*-kos/include`

> The name of an IDL, CDL or EDL file begins with an uppercase letter and must not contain any underscores `_`.

EDL description

EDL descriptions are placed into separate `*.edl` files and contain declarations in the Entity Definition Language (EDL):

1. **Process class name.** The following declaration is used:

   ```
   entity <process class name>
   ```

2. [Optional] **List of instances of components.** The following declaration is used:

   ```
   components {
       <component instance name : component name>
       [...]
   }
   ```

   Each component instance is indicated in a separate line. The component instance name must not contain any underscores `_`. The list can contain multiple instances of one component. Each component instance in the list has a unique name.

3. [Optional] **Security interface.** The following declaration is used:

   ```
   security <interface name>
   ```

4. [Optional] **List of endpoints.** The following declaration is used:

   ```
   endpoints {
       <endpoint name : interface name>
   ```

```
    [...]
}
```

Each endpoint is indicated in a separate line. The endpoint name must not contain any underscores `_`. The list can contain multiple endpoints with the same interface. Each endpoint in the list has a unique name.

The EDL language is case sensitive.

Single-line comments and multi-line comments can be used in an EDL description.

> A security interface and provided endpoints can be defined in an EDL description and in a CDL description. If solution component development is utilizing already prepared constituent parts (such as libraries) that are accompanied by CDL descriptions, it is advisable to refer to them from the EDL description by using the `components` declaration. Otherwise, you can describe all provided endpoints in the EDL description. In addition, you can separately define the security interface in the EDL description and in each CDL description.

Examples of EDL files

Hello.edl

```
// Class of processes that do not contain components.
entity Hello
```

Signald.edl

```
/* Class of processes that contain
 * one instance of one component. */
entity kl.Signald

components {
    signals : kl.Signals
}
```

LIGHTCRAFT.edl

```
/* Class of processes that contain
 * two instances of different components. */
entity kl.drivers.LIGHTCRAFT

components {
    KUSB : kl.drivers.KUSB
    KIDF : kl.drivers.KIDF
}
```

Downloader.edl

```
/* Class of processes that do not contain
 * components and provide one endpoint. */
entity updater.Downloader

endpoints {
    download : updater.Download
}
```

CDL description

CDL descriptions are placed into individual `*.cdl` files and contain declarations in the Component Definition Language (CDL):

1. **The name of the component.** The following declaration is used:

   ```
   component <component name>
   ```

2. [Optional] **Security interface.** The following declaration is used:

   ```
   security <interface name>
   ```

3. [Optional] **List of endpoints.** The following declaration is used:

   ```
   endpoints {
       <endpoint name : interface name>
       [...]
   }
   ```

   Each endpoint is indicated in a separate line. The endpoint name must not contain any underscores `_`. The list can contain multiple endpoints with the same interface. Each endpoint in the list has a unique name.

4. [Optional] **List of instances of embedded components.** The following declaration is used:

   ```
   components {
       <component instance name : component name>
       [...]
   }
   ```

   Each component instance is indicated in a separate line. The component instance name must not contain any underscores `_`. The list can contain multiple instances of one component. Each component instance in the list has a unique name.

The CDL language is case sensitive.

Single-line comments and multi-line comments can be used in a CDL description.

> At least one optional declaration is used in a CDL description. If a CDL description does not use at least one optional declaration, this description will correspond to an "empty" component that does not provide endpoints, does not contain embedded components, and does not support a security interface.

Examples of CDL files

`KscProductEventsProvider.cdl`

```
// Component provides one endpoint.
component kl.KscProductEventsProvider

endpoints {
    eventProvider : kl.IKscProductEventsProvider
}
```

KscConnectorComponent.cdl

```
// Component provides multiple endpoints.
component kl.KscConnectorComponent

endpoints {
    KscConnCommandSender : kl.IKscConnCommandSender
    KscConnController : kl.IKscConnController
    KscConnSettingsHolder : kl.IKscConnSettingsHolder
    KscDataProvider : kl.IKscDataProvider
    ProductDataHolder : kl.IProductDataHolder
    KscDataNotifier : kl.IKscDataNotifier
    KscConnectorStateNotifier : kl.IKscConnectorStateNotifier
}
```

FsVerifier.cdl

```
/* Component does not provide endpoints, supports
 * a security interface, and contains one instance
 * of another component. */
component FsVerifier

security Approve

components {
    verifyComp : Verify
}
```

IDL description

IDL descriptions are placed into separate `*.idl` files and contain declarations in the Interface Definition Language (IDL):

1. **Package name.** The following declaration is used:

   ```
   package <package name>
   ```

2. [Optional] **Packages from which the data types for interface method parameters are imported.** The following declaration is used:

   ```
   import <package name>
   ```

3. [Optional] Definitions of data types for parameters of interface methods.

4. [Optional] **Signatures of interface methods.** The following declaration is used:

```
interface {
    <interface method name([parameters])>;
    [...]
}
```

Each method signature is indicated in a separate line. The method name must not contain any underscores `_`. Each method in the list has a unique name. The parameters of methods are divided into input parameters (`in`), output parameters (`out`), and parameters for transmitting error information (`error`). The order of parameters in the description is important: first input parameters, then output parameters, then error parameters. Methods of the security interface cannot have output parameters and error parameters.

Input parameters and output parameters are transmitted in IPC requests and IPC responses, respectively. Error parameters are transmitted in IPC responses if the server cannot correctly handle the corresponding IPC requests.

The server can inform a client about IPC request processing errors via error parameters as well as through output parameters of interface methods. If the server sets the error flag in an IPC response when an error occurs, this IPC response will contain the error parameters without any output parameters. Otherwise this IPC response will contain output parameters just like when requests are correctly processed. (The error flag is set in IPC responses by using the `nk_err_reset()` macro defined in the `nk/types.h` header file from the KasperskyOS SDK.)

An IPC response sent with the error flag set and an IPC response with the error flag not set are considered to be different types of events for the Kaspersky Security Module. When describing a solution security policy, this difference lets you conveniently distinguish between the processing of events associated with the correct execution of IPC requests and the processing of events associated with incorrect execution of IPC requests. If the server does not set the error flag in IPC responses, the security module must check the values of output parameters indicating errors to properly process events related to the incorrect execution of IPC requests. (A client can check the state of the error flag in an IPC response even if the corresponding interface method does not contain error parameters. To do so, the client uses the `nk_msg_check_err()` macro defined in the `nk/types.h` header file from the KasperskyOS SDK.)

Signatures of interface methods cannot be imported from other IDL files.

The IDL language is case sensitive.

Single-line comments and multi-line comments can be used in an IDL description.

> At least one optional declaration is used in a IDL description. If an IDL description does not use at least one optional declaration, this description will correspond to an "empty" package that does not assign any interface methods or data types (including from other IDL descriptions).
> Some IDL files from the KasperskyOS SDK do not describe interface methods, but instead only contain definitions of data types. These IDL files are used only as exporters of data types.
> If a package contains a description of interface methods, the interface name matches the package name.

Examples of IDL files

Env.idl

```
package kl.Env

// Definitions of data types for interface method parameters
typedef string<128> Name;
typedef string<256> Arg;
typedef sequence<Arg,256> Args;
```

```
// Interface includes one method.
interface {
    Read(in Name name, out Args args, out Args envs);
}
```

Kpm.idl

```
package kl.Kpm

// Import data types for parameters of interface methods
import kl.core.Types

// Definition of data type for parameters of interface methods
typedef string<64> String;

/* Interface includes multiple methods.
 * Some methods do not have any parameters. */
interface {
    Shutdown();
    Reboot();
    PowerButtonPressedWait();
    TerminationSignalWait(in UInt32 entityId, in String entityName);
    EntityTerminated(in UInt32 entityId);
    Terminate(in UInt32 callingEntityId);
}
```

MessageBusSubs.idl

```
package kl.MessageBusSubs

// Import data types for interface method parameters
import kl.MessageBusTypes

/* Interface includes a method that has
 * input and output parameters, and
 * an error parameter.*/
interface {
    Wait(in ClientId id,
         out Message topic,
         out BundleId dataId,
         error ResultCode result);
}
```

WaylandTypes.idl

```
// Package contains only definitions of data types.
package kl.WaylandTypes

typedef UInt32                  ClientId;
typedef bytes<8192>             Buffer;
typedef string<4096>            ConnectionId;
typedef SInt32                  SsizeT;
typedef UInt32                  SizeT;
typedef SInt32                  ShmFd;
typedef SInt32                  ShmId;
typedef bytes<16384000>         ShmBuffer;
```

IDL data types

IDL supports primitive data types as well as composite data types. The set of supported composite types includes unions, structures, arrays, and sequences.

Primitive types

IDL supports the following primitive types:

- `SInt8`, `SInt16`, `SInt32`, `SInt64` – signed integer.
- `UInt8`, `UInt16`, `UInt32`, `UInt64` – unsigned integer.
- `Handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field.
- `bytes<<size in bytes>>` – byte buffer consisting of a memory area with a size that does not exceed the defined number of bytes.
- `string<<size in bytes>>` – string buffer consisting of a byte buffer whose last byte is a terminating zero. The maximum size of a string buffer is a unit larger than the defined size due to the additional byte with the terminating zero.

Integer literals can be specified in decimal format, hexadecimal format (for example, `0x2f`, `0X2f`, `0x2F`, `0X2F`) or octal format (for example, `0O123`, `0o123`).

You can use the reserved word `const` to define the named integer constants by assigning their values using integer literals or integer expressions.

Example definitions of named integer constants:

```
const UInt32 DeviceNameMax          = 0o100;
const UInt32 HandleTypeUserLast     = 0x0001FFFF;
const UInt32 MaxLogMessageSize = (2 << 3) ** 2;
const UInt32 MaxLogMessageCount = 100;
const UInt64 MaxLen = (MaxLogMessageSize + 4) * MaxLogMessageCount;
```

Named integer constants can be used to avoid problems associated with so-called "magic numbers". For example, if an IDL description defines named integer constants for return codes of an interface method, you can interpret these codes without additional information when describing a policy. Named integer constants and integer expressions can also be applied in definitions of byte buffers, string buffers, and composite types to define the size of data or the number of data elements.

The `bytes<<size in bytes>>` and `string<<size in bytes>>` constructs are used in definitions of composite types, signatures of interface methods, and when creating type aliases because they define anonymous types (types without a name).

Unions

A union stores different types of data in one memory area. In an IPC message, a union is provided with an additional `tag` field that defines which specific member of the union is used.

The following construct is used to define a union:

```
union <type name> {
    <member type> <member name>;
    [...]
}
```

Example of a union definition:

```
union ExitInfo {
    UInt32        code;
    ExceptionInfo exc;
}
```

Structures

The following construct is used to define a structure:

```
struct <type name> {
    <field type> <field name>;
    [...]
}
```

Example of a structure definition:

```
struct SessionEvqParams {
    UInt32 count;
    UInt32 align;
    UInt32 size;
}
```

Arrays

The following construct is used to define an array:

```
array<<type of elements, number of elements>>
```

This construct is used in definitions of other composite types, signatures of interface methods, and when creating type aliases because it defines an anonymous type.

> The `Handle` type can be used as the type of array elements if this array is not included in another composite data type. However, the total number of handles in an IPC message cannot exceed 255.

Sequences

A sequence is a variable-sized array. When defining a sequence, the maximum number of elements of the sequence is specified.

The following construct is used to define a sequence:

```
sequence<<type of elements, number of elements>>
```

This construct is used in definitions of other composite types, signatures of interface methods, and when creating type aliases because it defines an anonymous type.

> The `Handle` type cannot be used as the type of sequence elements.

Variable-size and fixed-size types

The `bytes`, `string` and `sequence` types are variable-size types. In other words, the maximum number of elements is assigned when defining these types, but less elements (or none) may actually be used. Data of the `bytes`, `string` and `sequence` types are stored in the IPC message arena. All other types are fixed-size types. Data of fixed-size types are stored in the constant part of IPC messages.

Types based on composite types

Composite types can be used to define other composite types. The definition of an array or sequence can also be included in the definition of another type.

Example definition of a structure with embedded definitions of an array and sequence:

```
const UInt32 MessageSize = 64;

struct BazInfo {
    array<UInt8, 100> a;
    sequence<sequence<UInt32, MessageSize>, ((2 << 2) + 2 ** 2) * MessageSize> b;
    string<100> c;
    bytes<4096> d;
    UInt64 e;
}
```

The definition of a union or structure cannot be included in the definition of another type. However, a type definition may include already defined unions and structures. This is done by indicating the names of the included types in the type definition.

Example definition of a structure that includes a union and structure:

```
union foo {
    UInt32 value1;
    UInt8 value2;
}

struct bar {
```

```
    UInt32 a;
    UInt8 b;
}

struct BazInfo {
    foo x;
    bar y;
}
```

Creating aliases of types

Type aliases make it more convenient to work with types. For example, type aliases can be used to assign mnemonic names to types that have abstract names. Assigned aliases for anonymous types also let you receive named types.

The following construct is used to create a type alias:

```
typedef <type name/anonymous type definition> <type alias>
```

Example of creating mnemonic aliases:

```
typedef UInt64 ApplicationId;
typedef Handle PortHandle;
```

Example of creating an alias for an array definition:

```
typedef array<UInt8, 4> IP4;
```

Example of creating an alias for a sequence definition:

```
const UInt32 MaxDevices = 8;
struct Device {
    string<32> DeviceName;
    UInt8 DeviceID;
}
typedef sequence<Device, MaxDevices> Devices;
```

Example of creating an alias for a union definition:

```
union foo {
    UInt32 value1;
    UInt8 value2;
}

typedef foo bar;
```

Defining anonymous types in signatures of interface methods

Anonymous types can be defined in signatures of interface methods.

Example of defining a sequence in an interface method signature:

```
const UInt8 DeviceCount = 8;

interface {
    Poll(in UInt32 timeout,
         out sequence<UInt32, DeviceCount / 2> report,
         out UInt32 count,
         out UInt32 rc);
}
```

Integer expressions in IDL

Integer expressions in IDL are composed of named integer constants, integer literals, operators (see the table below), and grouping parentheses.

Example use of integer expressions:

```
const UInt8 itemHeaderLen = 2;
const UInt8 itemBlockLen = 4;
const UInt8 maxItemCount = 0X10;
const UInt64 maxLen = (2 << 3) + (itemHeaderLen + itemBlockLen * 4) * maxItemCount;

interface {
    CopyPage(in array<UInt8, 4 * maxLen> page);
}
```

If an integer overflow occurs when computing an expression, the source code generator using the IDL file will terminate with an error.

Details on operators of integer expressions in IDL

Syntax	Operation	Precedence	Associativity	Special considerations
`-a`	Sign change	1	No	N/A
`~a`	Bitwise negation	1	No	N/A

`a ** b`	Exponentiation	2	No	Special considerations:
				• Due to the lack of associativity, you must use parentheses when specifying multiple consecutive operators to define the order of operations.
				Example:
				`(a ** b) ** c`
				`a ** (b ** c)`
				• The power exponent cannot be negative.

`a * b`	Multiplication	3	Left	N/A
`a / b`	Integer division	3	Left	Special considerations: • The result of the operation is a value obtained by rounding the real quotient down to the next lower integer. For example, *4 / 3 = 1*, *-4 / 3 = -2*. • The divisor cannot be zero.
`a % b`	Modulo	3	Left	Special considerations: • The sign of the operation result matches the sign of the divisor. For example, *-5 % 2 = 1*, *5 % -2 = -1*. • The divisor cannot be zero.
`a + b`	Addition	4	Left	N/A
`a - b`	Subtraction	4	Left	N/A

`a << b`	Bit shift left	2*	No	Special considerations:
				• The precedence is lower than with unary operations but incomparable to the precedences of binary arithmetic operations. Therefore, in expressions with binary arithmetic operations, you must use parentheses to define the order of operations.
				Example:
				`a << (b + c)`
				`(a << b) ** c`
				• Due to the lack of associativity, you must use parentheses when specifying multiple consecutive operators to define the order of operations.
				Example:
				`(a << b) << c`
				`a << (b << c)`
				• The shift value must be within the interval *[0; 63]*.

`a >> b`	Bit shift right	2*	No	Special considerations: • The precedence is lower than with unary operations but incomparable to the precedences of binary arithmetic operations. Therefore, in expressions with binary arithmetic operations, you must use parentheses to define the order of operations. Example:

				`a >> (b * c)`
				`(a >> b) / c`
				• Due to the lack of associativity, you must use parentheses when specifying multiple consecutive operators to define the order of operations.
				Example:
				`(a >> b) >> c`
				`a >> (b >> c)`
				• The shift value must be within the interval *[0; 63]*.

Describing a security policy for a KasperskyOS-based solution

A *KasperskyOS-based solution security policy description* (hereinafter also referred to as a *solution security policy description* or *policy description*) provides a set of interrelated text files with the `psl` extension that contain declarations in the PSL language (Policy Specification Language). Some files reference other files through an inclusion declaration, which results in a hierarchy of files with one top-level file. The top-level file is specific to the solution. Files of lower and intermediate levels contain parts of the solution security policy description that may be specific to the solution or may be re-used in other solutions.

Some of the files of the lower and intermediate levels are provided in the KasperskyOS SDK. These files contain definitions of the basic data types and formal descriptions of KasperskyOS security models. *KasperskyOS security models* (hereinafter referred to as *security models*) serve as the framework for implementing security policies for KasperskyOS-based solutions. Files containing formal descriptions of security models reference a file containing definitions of the basic data types that are used in the descriptions of models.

The other files of lower and intermediate levels are created by the policy description developer if any parts of the policy description need to be re-used in other solutions. A policy description developer can also put parts of the policy description into separate files for convenient editing.

The top-level file references files containing definitions of basic data types and descriptions of security models that are applied in the part of the solution security policy that is described in this file. The top-level file also references all files of the lower and intermediate levels that were created by the policy description developer.

> The top-level file is normally named `security.psl`, but it can have any other name in the `*.psl` format.

General information about a KasperskyOS-based solution security policy description

In simplified terms, a KasperskyOS-based solution security policy description consists of bindings that associate descriptions of security events with calls of methods provided by security model objects. A *security model object* is an instance of a class whose definition is a formal description of a security model (in a PSL file). Formal descriptions of security models contain signatures of *methods of security models* that determine the permissibility of interactions between different processes and between processes and the KasperskyOS kernel. These methods are divided into two types:

- *Security model rules* are methods of security models that return a "granted" or "denied" result. Security model rules can change security contexts (for information about a security context, see "Resource Access Control").

- *Security model expressions* are methods of security models that return values that can be used as input data for other methods of security models.

A security model object provides methods that are specific to one security model and stores the parameters used by these methods (for example, the initial state of a finite-state machine or the size of a container for specific data). The same object can be used to work with multiple resources. (In other words, you do not need to create a separate object for each resource.) However, the security contexts of these resources will be independent of each other. Likewise, multiple objects of one or more different security models can be used to work with the same resource. In this case, different objects will use the security context of the same resource without any reciprocal influence.

Security events serve as signals indicating the initiation of interaction between different processes and between processes and the KasperskyOS kernel. Security events include the following events:

- Clients send IPC requests.

- Servers or the kernel send IPC responses.

- The kernel or processes initialize the startup of processes.

- The kernel starts.

- Processes query the Kaspersky Security Module via the security interface.

Security events are processed by the security module.

Security models

The KasperskyOS SDK provides PSL files that describe the following security models:

- Base – methods that implement basic logic.

- Pred – methods that implement comparison operations.

- Bool – methods that implement logical operations.

- Math – methods that implement integer arithmetic operations.

- Struct – methods that provide access to structural data elements (for example, access to parameters of interface methods transmitted in IPC messages).

- Regex – methods for text data validation based on regular expressions.

- HashSet – methods for working with one-dimensional tables associated with resources.

- StaticMap – methods for working with two-dimensional "key–value" tables associated with resources.

- Flow – methods for working with finite-state machines associated with resources.

- Mic – methods for implementing *Mandatory Integrity Control* (MIC).

Security event handling by the Kaspersky Security Module

The Kaspersky Security Module calls all methods (rules and expressions) of security models related to an occurring security event. If all rules returned the "granted" result, the security module returns the "granted" decision. If even one rule returned the "denied" result, the security module returns the "denied" decision.

If even one method related to an occurring security event cannot be correctly performed, the security module returns the "denied" decision.

If no rule is related to an occurring security event, the security module returns the "denied" decision. In other words, all interactions between solution components and between those components and the KasperskyOS kernel are denied by default (Default Deny principle) unless those interactions are explicitly allowed by the solution security policy.

PSL language syntax

Basic rules

1. Declarations can be listed in any sequence in a file.
2. One declaration can be written to one or multiple lines.
3. The PSL language is case sensitive.
4. Single-line comments and multi-line comments are supported:

```
/* This is a comment
 * And this, too */
// Another comment
```

Types of declarations

The PSL language has declarations for the following purposes:

- Setting the global parameters of a solution security policy
- Including PSL files in a solution security policy description
- Including EDL files in a solution security policy description
- Create security model objects
- Bind methods of security models to security events
- Creating security audit profiles
- Creating solution security policy tests

Setting the global parameters of a KasperskyOS-based solution security policy

Global parameters include the following parameters of a solution security policy:

- *Execute interface* used by the KasperskyOS kernel when querying the Kaspersky Security Module to notify it about kernel startup or about initiating the startup of a process by the kernel or by other processes. To define this interface, use the following declaration:

  ```
  execute: kl.core.Execute
  ```

  KasperskyOS currently supports only one execute interface (`Execute`) defined in the file named `kl/core/Execute.idl`. (This interface consists of one `main` method, which has no parameters and does not perform any actions. The `main` method is reserved for potential future use.)

- [Optional] Global security audit profile and initial security audit run-time level. (For more details about profiles and the security audit run-time level, see "Creating security audit profiles".) To define these parameters, use the following declaration:

  ```
  audit default = <security audit profile name> <security audit runtime-level>
  ```

  Example:

  ```
  audit default = global 0
  ```

  The default global profile is the `empty` security audit profile described in the file named `toolchain/include/nk/base.psl` from the KasperskyOS SDK, and the default security audit runtime-level is 0. When the `empty` security audit profile is applied, a security audit is not conducted.

Including PSL files in a KasperskyOS-based solution security policy description

To include a PSL file in a policy description, use the following declaration:

```
use <link to PSL file._>
```

The link to the PSL file is the file path (without the extension and dot before it) relative to the directory that is included in the set of directories where the `nk-psl-gen-c` compiler searches for PSL, IDL, CDL, and EDL files. (This set of directories is defined by the parameters `-I <path to the directory>` when starting the `makekss` script or the `nk-psl-gen-c` compiler.) A dot is used as a separator in a path description. A declaration is ended by the `._` character sequence.

Example:

```
use policy_parts.flow_part._
```

This declaration includes the `flow_part.psl` file, which is located in the `policy_parts` directory. The `policy_parts` directory must reside in one of the directories where the `nk-psl-gen-c` compiler searches for PSL, IDL, CDL, and EDL files. For example, the `policy_parts` directory may reside in the same directory as the PSL file containing this declaration.

Including a PSL file containing a formal description of a security model

To use the methods of a required security model, the policy description must include a PSL file containing a formal description of this model. PSL files containing formal descriptions of security models are located in the KasperskyOS SDK at the following path:

`toolchain/include/nk`

Example:

```
/* Include the base.psl file containing a formal description of the
 * Base security model */
use nk.base._

/* Include the flow.psl file containing a formal description of the
 * Flow security model */
use nk.flow._
/* The nk-psl-gen-c compiler must be configured to search for
 * PSL, IDL, CDL, and EDL files in the toolchain/include directory. */
```

Including EDL files in a KasperskyOS-based solution security policy description

To include an EDL file for the KasperskyOS kernel in a policy description, use the following declaration:

```
use EDL kl.core.Core
```

To include an EDL file for a program (such as a driver or application) into a policy description, use the following declaration:

```
use EDL <link to EDL file>
```

The link to the EDL file is the EDL file path (without the extension and dot before it) relative to the directory that is included in the set of directories where the `nk-psl-gen-c` compiler searches for PSL, IDL, CDL, and EDL files. (This set of directories is defined by the parameters `-I <path to the directory>` when starting the `makekss` script or the `nk-psl-gen-c` compiler.) A dot is used as a separator in a path description.

Example:

```
/* Include the UART.edl file, which is located
 * in the KasperskyOS SDK at the path sysroot-*-kos/include/kl/drivers. */
use EDL kl.drivers.UART
/* The nk-psl-gen-c compiler must be configured to search for
 * PSL, IDL, CDL, and EDL files in the sysroot-*-kos/include directory. */
```

The `nk-psl-gen-c` compiler finds IDL and CDL files through EDL files because EDL files contain links to the corresponding CDL and IDL files, and the CDL files contain links to the corresponding CDL and IDL files.

Creating security model objects

To call the methods of a required security model, create an object for this security model.

To create a security model object, use the following declaration:

```
policy object <security model object name : security model name> {
    [security model object parameters]
}
```

The security model object name must begin with a lowercase letter. The parameters of a security model object are specific to the security model. A description of parameters and examples of creating objects of various security models are provided in the "KasperskyOS security models" section.

Binding methods of security models to security events

To create an attachment between methods of security models and a security event, use the following declaration:

```
<security event type> [security event selectors] {
    [security audit profile]
    <called security model methods>
}
```

Security event type

To define the security event type, use the following specifiers:

- `request` – sending IPC requests.
- `response` – sending IPC responses.
- `error` – sending IPC responses containing information about errors.
- `security` – processes querying the Kaspersky Security Module via the security interface.
- `execute` – initializing the startups of processes or the startup of the KasperskyOS kernel.

When processes interact with the security module, they use a mechanism that is different from IPC. However, when describing a policy, queries sent by processes to the security module can be viewed as the transfer of IPC messages because processes actually transmit messages to the security module (the recipient is not indicated in these messages).
The IPC mechanism is not used to start processes. However, when the startup of a process is initiated, the kernel queries the security module and provides information about the initiator of the startup and the started process. For this reason, the policy description developer can consider the startup of a process to be analogous to sending an IPC message from the startup initiator to the started process. When the kernel is started, this is analogous to the kernel sending an IPC message to itself.

Security event selectors

Security event selectors let you clarify the description of the defined type of security event. You can use the following selectors:

- `src=<kernel/process class name>` – processes of the defined class or the KasperskyOS kernel are the sources of IPC messages.
- `dst=<kernel/process class name>` – processes of the defined class or the kernel are the recipients of IPC messages.
- `interface=<interface name>` – describes the following security events:
  - Clients attempt to use the endpoints of servers or the kernel with the defined interface.
  - Processes query the Kaspersky Security Module via the defined security interface.
  - The kernel or servers send clients the results from using the endpoints with the defined interface.
- `component=<component name>` – describes the following security events:
  - Clients attempt to use the core or server endpoints provided by the defined component.
  - The kernel or servers send clients the results from using the endpoints provided by the defined component.
- `endpoint=<qualified endpoint name>` – describes the following security events:
  - Clients attempt to use the defined core or server endpoints.
  - The kernel or servers send clients the results from using the defined endpoint.
- `method=<method name>` – describes the following security events:
  - Clients attempt to query servers or the kernel by calling the defined method of the endpoint.
  - Processes query the security module by calling the defined method of the security interface.
  - The kernel or servers send clients the results from calling the defined method of the endpoint.
  - The kernel notifies the security module about its startup by calling the defined method of the execute interface.
  - The kernel initiates the startup of processes by calling the defined method of the execute interface.

- Processes initiate the startup of other processes, which results in the kernel calling the defined method of the execute interface.

Process classes, components, instances of components, interfaces, endpoints, and methods must be named the same as they are in the IDL, CDL, and EDL descriptions. The kernel must be named `kl.core.Core`.

The qualified name of the endpoint has the format `<path to endpoint.endpoint name>`. The path to the endpoint is a sequence of component instance names separated by dots. Among these component instances, each subsequent component instance is embedded into the previous one, and the last one provides the endpoint with the defined name.

For `security` events, specify the qualified name of the security interface method if you need to use the security interface defined in a CDL description. (If you need to use a security interface defined in an EDL description, it is not necessary to specify the qualified name of the method.) The qualified name of a security interface method is a construct in the format `<path to security interface.method name>`. The path to the security interface is a sequence of component instance names separated by dots. Among these component instances, each subsequent component instance is embedded into the previous one, and the last one supports the security interface that includes the method with the defined name.

If selectors are not specified, the participants of a security event may be any process and the kernel (except `security` events in which the kernel cannot participate).

You can use combinations of selectors. Selectors can be separated by commas.

There are restrictions on the use of selectors. The `interface`, `component`, and `endpoint` selectors cannot be used for security events of the `execute` type. The `dst`, `component`, and `endpoint` selectors cannot be used for security events of the `security` type.

There are also restrictions on combinations of selectors. For security events of the `request`, `response` and `error` types, the `method` selector can only be used together with one of the `endpoint`, `interface`, or `component` selectors or a combination of them. (The `method`, `endpoint`, `interface` and `component` selectors must be coordinated. In other words, the method, endpoint, interface, and component must be interconnected.) For security events of the `request` type, the `endpoint` selector can be used only together with the `dst` selector. For security events of the `response` and `error` types, the `endpoint` selector can be used only together with the `src` selector.

> The type and selectors of a security event form the security event description. It is recommended to describe security events with maximum precision to allow only the required interactions between different processes and between processes and the kernel. If IPC messages of the same type are always verified when processing the defined event, the description of this event is maximally precise.

To ensure that IPC messages of the same type correspond to a security event description, one of the following conditions must be fulfilled for this description:

- For events of the `request`, `response` and `error` type, the "interface method-endpoint-server class or kernel" chain is unequivocally defined. For example, the security event description `request dst=Server endpoint=net.Net method=Send` corresponds to IPC messages of the same type, and the security event description `request dst=Server` corresponds to any IPC message sent to the `Server`.

- For `security` events, the security interface method is specified.

- The execute-interface method is indicated for `execute` events.

  There is currently support for only one fictitious method of the `main` execute-interface. This method is used by default, so it does not have to be defined through the `method` selector. This way, any description of an `execute` security event corresponds to IPC messages of the same type.

Security audit profile

To define a security audit profile, use the following construct:

```
audit <security audit profile name>
```

If a security audit profile is not defined, the global security audit profile is used.

Called security model methods

To call a security model method, use the following construct:

```
[security model object name.]<security model method name> <parameter>
```

Data of PSL-supported types can be used as the parameter. However, the following special considerations should be taken into account:

- If a security model method does not actually have a parameter, this method formally has a Unit-type parameter designated as `()`.
- If a security model method parameter is a dictionary `{name of field 1 : value of field 1[, name of field 2 : value of field 2]...}`, this parameter does not need to be enclosed in parentheses.
- If the security model method parameter is not a dictionary and does not have the Unit type, this parameter must be enclosed in parentheses.

You can call one or more methods by using the same or different security model objects. Security model rules can use the parameter to receive values returned by expressions of security models.

> When a security event is processed by the Kaspersky Security Module, expressions are called before rules. Therefore, expressions do not receive the changes made by rules. For example, if a declaration of attachment between StaticMap security model methods and security events first specifies the `set` rule and then specifies the `get_uncommited` expression for the same resource, the `get_uncommited` expression will return the key value that was defined before the current security event was processed instead of the key value that is defined by the `set` rule when processing the current security event. The key value defined by the `set` rule when processing the current security event can be returned by the `get_uncommited` expression only when processing subsequent security events if the security module returns the "allowed" decision as a result of processing the current security event. If the security module returns a "denied" decision as a result of processing the current security event, all changes made by rules and expressions invoked during processing of the current security event will be discarded.

A security model method (rule or expression) can use the parameter to receive the parameters of interface methods. (For details about obtaining access to parameters of interface methods, see "Struct security model"). A security model method can also use the parameter to receive the SID values of processes and the KasperskyOS kernel that are defined by the reserved words `src_sid` and `dst_sid`. The first reserved word refers to the SID of the process (or kernel) that is the source of the IPC message. The second reserved word refers to the SID of the process (or kernel) that is the recipient of the IPC message (`dst_sid` cannot be used for queries to the Kaspersky Security Module).

You do not have to indicate the security model object name to call certain security model methods. Also, some of the security model methods must be called using operators instead of the call construct. For details about the methods of security models, see KasperskyOS Security models.

Embedded constructs for binding methods of security models to security events

In one declaration, you can bind methods of security models to different security events of the same type. To do so, use the match sections that consist of the following types of constructs:

```
    match <security event selectors> {
        [security audit profile]
        <called security model methods>
    }
```

Match sections can be embedded into another match section. A match section simultaneously uses its own security event selectors and the security event selectors at the level of the declaration and all match sections in which this match section is "wrapped". By default, a match section applies the security audit profile of its own container (match section of the preceding level or the declaration level), but you can define a separate security audit profile for the match section.

In one declaration, you can define different variants for processing a security event depending on the conditions in which this event occurred (for example, depending on the state of the finite-state machine associated with the resource). To do so, use the conditional sections that are elements of the following construct:

```
    choice <call of the security model expression that verifies fulfillment of
conditions> {
        "<condition 1>" : [{] // Conditional section 1
            <called security model methods>
        [}]
        "<condition 2>" : ... // Conditional section 2
    ...
        _             : ... // Conditional section, if no condition is fulfilled.
    }
```

The `choice` construct can be used within a match section. A conditional section uses the security event selectors and security audit profile of its own container.

If multiple conditions described in the `choice` construct are simultaneously fulfilled when a security event is processed, only the one conditional section corresponding to the first true condition on the list is triggered.

You can verify the fulfillment of conditions in the `choice` construct only by using the expressions that are specially intended for this purpose. Some security models contain these expressions (for more details, see KasperskyOS Security models).
Only text and integer literals, logical values and the `_` character designating an always true condition can be used as conditions.

Examples of binding security model methods to security events

See "Examples of binding security model methods to security events", "Example descriptions of basic security policies for KasperskyOS-based solutions", and "KasperskyOS security models".

Creating security audit profiles

A *security audit* (hereinafter also referred to as an *audit*) is the following sequence of actions. The Kaspersky Security Module notifies the KasperskyOS kernel about decisions made by this module. Then the kernel forwards this data to the system program `Klog`, which decodes this data and forwards it to the system program `KlogStorage` (data is transmitted via IPC). The latter sends the received audit data to standard output (or standard error) or writes it to a file.

Security audit data (hereinafter referred to as *audit data*) refers to information about decisions made by the Kaspersky Security Module, which includes the actual decisions ("granted" or "denied"), descriptions of security events, results from calling methods of security models, and data on incorrect IPC messages. Data on calls of security model expressions is included in the audit data just like data on calls of security model rules.

To perform a security audit, you need to associate security model objects with security audit profile(s). A *security audit profile* (hereinafter also referred to as an *audit profile*) combines *security audit configurations* (hereinafter also referred to as *audit configurations*), each of which defines the security model objects covered by the audit, and specifies the conditions for conducting the audit. You can define a global audit profile (for more details, see "Setting the global parameters of a KasperskyOS-based solution security policy") and/or assign an audit profile(s) at the level of binding security model methods to security events, and/or assign an audit profile(s) at the level of match sections (for more details, see "Binding methods of security models to security events").

> Regardless of whether or not audit profiles are being used, audit data contains information about "denied" decisions that were made by the Kaspersky Security Module when IPC messages were invalid and when handling security events that are not associated with any security model rule.

To create a security audit profile, use the following declaration:

```
audit profile <security audit profile name> =
  { <security audit runtime-level> :
      // Security audit configuration
      { <security model object name> :
          { kss: <security audit conditions linked to the results
                  from calls of security model methods>
         [, security audit conditions specific to the security model]
          }
    [ ,...]
      }
[ ,...]
  }
```

Security audit runtime-level

The *security audit runtime-level* (hereinafter referred to as the *audit runtime-level*) is a global parameter of a solution security policy and consists of an unsigned integer that defines the active security audit configuration. (The word "runtime-level" here refers to the configuration variant and does not necessarily involve a hierarchy.) The audit runtime-level can be changed during operation of the Kaspersky Security Module. To do so, use a specialized method of the `Base` security model that is called when processes query the security module through the security interface (for more details, see "Base security model"). The initial audit runtime-level is assigned together with the global audit profile (for more details, see "Setting the global parameters of a KasperskyOS-based solution security policy"). An `empty` audit profile can be explicitly assigned as the global audit profile.

You can define multiple audit configurations in an audit profile. In different configurations, different security model objects can be covered by the audit and different conditions for conducting the audit can be applied. Audit configurations in a profile correspond to different audit runtime-levels. If a profile does not have an audit configuration corresponding to the current audit runtime-level, the security module will activate the configuration that corresponds to the next-lowest audit runtime-level. If a profile does not have an audit configuration for an audit runtime-level equal to or less than the current level, the security module will not use this profile (in other words, an audit will not be performed for this profile).

The capability to change the audit runtime-level lets you regulate the level of detail of an audit, for example. The higher the audit runtime-level, the higher the level of detail. In other words, a higher audit runtime-level activates audit configurations in which more security model objects are covered by the audit and/or less restrictions are applied in the audit conditions. In addition, you can change the audit runtime-level to switch the audit from one set of logically connected security model objects to another set. For example, a low audit runtime-level activates audit configurations in which the audit covers security model objects related to drivers, a medium audit runtime-level activates audit configurations in which the audit covers security model objects related to the network subsystem, and a high audit runtime-level activates audit configurations in which the audit covers security model objects related to applications.

Name of the security model object

The security model object name is indicated so that the methods provided by this object can be covered by the audit. These methods will be covered by the audit whenever they are called, provided that the conditions for conducting the audit are observed.

> Information about the decisions of the Kaspersky Security Module contained in audit data includes the overall decision of the security module as well as the results from calling individual methods of security modules covered by the audit. To ensure that information about a security module decision is included in audit data, at least one method called during security event handling must be covered by the audit.
> The names of security model objects and the names of methods provided by these objects are included in the audit data.

Security audit conditions

Security audit conditions must be defined separately for each object of a security model.

To define the audit conditions related to the results from calling security model methods, use the following constructs:

- `["granted"]` – the audit is performed if the rules return the "granted" result; the expressions are correctly executed.
- `["denied"]` – the audit is performed if the rules return the "denied" result; the expressions are incorrectly executed.
- `["granted", "denied"]` – the audit is performed regardless of the result returned by rules, and regardless of whether or not rules are correctly fulfilled.
- `[]` – the audit is not performed.

Audit conditions specific to security models are defined by constructs specific to these models (for more details, see KasperskyOS Security models). These conditions apply to rules and expressions. For example, one of these conditions can be the state of a finite-state machine.

Security audit profile for a security audit route

A security audit route includes the kernel and the `Klog` and `KlogStorage` processes, which are connected by IPC channels based on the "kernel – `Klog` – `KlogStorage`" scheme. Security model methods that are associated with transmission of audit data via this route must not be covered by the audit. Otherwise, this will lead to an avalanche of audit data because any data transmission will give rise to new data.

To "suppress" an audit that was defined by a profile with a wider scope (for example, by a global profile or a profile at the level of binding security model methods to a security event), assign an `empty` audit profile at the level of binding security model methods to security events or at the level of the match section.

Examples of security audit profiles

See "Examples of security audit profiles".

Creating and performing tests for a KasperskyOS-based solution security policy

A solution security policy is tested to verify whether or not the policy actually allows what should be allowed and denies what should be denied.

To create a set of tests for a solution security policy, use the following declaration:

```
assert ["name of test set"] {
// Constructs in PAL (Policy Assertion Language)
    [setup {<initial part of tests>}]
    sequence ["test name"] {<main part of test>}
    [...]
    [finally {<final part of tests>}]
}
```

You can create multiple sets of tests by using several of these declarations.

A set of tests can optionally include the initial part of the tests and/or the final part of the tests. The execution of each test from the set begins with whatever is described in the initial part of the test and ends with whatever is described in the final part of the test. This lets you describe the repeated initial and/or final parts of tests in each test.

> After completing each test, all modifications in the Kaspersky Security Module related to the execution of this test are rolled back.

Each test includes one or more test cases.

Test cases

A test case associates a security event description and values of interface method parameters with an expected decision of the Kaspersky Security Module. If the actual security module decision matches the expected decision, the test case passes. Otherwise it fails.

When a test is run, the test cases are executed in the same sequence in which they are described. In other words, the test demonstrates how the security module handles a sequence of security events.

If all test cases within a test pass, the test passes. If even one test case fails to pass, the test fails. A test is terminated on the first failing test case. Each test from the set is run regardless of whether the previous test passed or failed.

A test case description in the PAL language is comprised of the following construct:

```
[<expected decision of security module> ["test case name"]] <security event type>
<security event selectors> [{interface method parameter values}]
```

The expected decision of the security module can be indicated as `grant` ("granted"), `deny` ("denied") or `any` ("any decision"). You are not required to indicate the expected decision of the security module. The "granted" decision is expected by default. If the `any` value is specified, the security module decision does not have any influence on whether or not the test case passes. In this case, the test case may fail due to errors that occur when the security module processes an IPC message (for example, when the IPC message has an invalid structure).

The name of the test case can be specified if only the expected decision of the security module is specified.

For information about the types and selectors of security events, and about the limitations when using selectors, see Binding methods of security models to security events. Selectors must ensure that the security event description corresponds to IPC messages of the same type. (When security model methods are bound to security events, selectors may not ensure this.)

In security event descriptions, you need to specify the SID instead of the process class name (and the KasperskyOS kernel). However, this requirement does not apply to `execute` events for which the SID of the started process (or kernel) is unknown. To save the SID of the process or kernel to a variable, you need to use the `<-` operator in the test case description in the following format:

```
<variable name> <- execute dst=<kernel/process class name> ...
```

The SID value will be assigned to the variable even if startup of the process of the defined class (or kernel) is denied by the tested policy but the "denied" decision is expected.

The PAL language supports abbreviated forms of security event descriptions:

- `security: <Process SID> ! <qualified name of security interface method>` corresponds to `security src=<process SID> method=<qualified name of security interface method>`.
- `request: <client SID> ~> <kernel/server SID> : <qualified name of endpoint.method name>` corresponds to `request src=<client SID> dst=<kernel/server SID> endpoint=<qualified name of endpoint> method=<method name>`.
- `response: <client SID> <~ <kernel/server SID> : <qualified name of endpoint.method name>` corresponds to `response src=<kernel/server SID> dst=<client SID> endpoint=<qualified name of endpoint> method=<method name>`.

The values of interface method parameters must be defined for all types of security events except `execute`. If the interface method has no parameters, specify `{}`. You cannot specify `{}` for security events of the `execute` type.

Interface method parameters and their values must be defined by comma-separated constructs that look as follows:

```
<parameter name> : <value>
```

The names and types of parameters must comply with the IDL description. The sequence order of parameters is not important.

Example definition of parameter values:

```
{ param1 : 23, param2 : "bar", param3 : { collection : [5,7,12], filehandle : 15 },
param4 : { name : ["foo", "baz" } }
```

In this example, the number is passed through the `param1` parameter. The string buffer is passed through the `param2` parameter. A structure consisting of two fields is passed through the `param3` parameter. The `collection` field contains an array or sequence of three numeric elements. The `filehandle` field contains the SID. A union or structure containing one field is passed through the `param4` parameter. The `name` field contains an array or sequence of two string buffers.

> Currently, only an SID can be indicated as the value of a `Handle` parameter, and there is no capability to indicate the SID together with a handle permissions mask. For this reason, it is not possible to properly test a solution security policy when the permissions masks of handles influence the security module decisions.

The values of parameters (or elements of parameters) do not have to be specified. If they are not specified, the system automatically applies the default values corresponding to the IDL types of parameters (and elements of parameters):

- The default values for numerical types and the `Handle` type are zero.
- A zero-sized byte- or string buffer is the default value for byte- or string buffers.
- The default value for sequences is a sequence with zero elements.
- The default value for arrays is an array of elements with the default values.
- The default value for structures is a structure consisting of fields with the default values.
- For unions, the default value of the first member of the union is applied by default.

Example of applying the default value for a parameter and parameter element:

```
/* Parameter is specified. */
request src=x dst=y endpoint=e method=m { name : { firstname: "a", lastname: "b" } }
/* Parameter is not specified. The applied value of the name parameter will be a
structure
 * consisting of two zero-sized string buffers.*/
request src=x dst=y endpoint=e method=m {}
/* Parameter element is not specified. The applied value of the lastname parameter
element will be
 * a zero-sized string buffer.*/
request src=x dst=y endpoint=e method=m { name : { firstname: "a"} }
```

Example tests

See "Examples of tests for KasperskyOS-based solution security policies".

Test procedure

The test procedure includes the following steps:

1. Save the tests in one or multiple PSL files (`*.psl` or `*.psl.in`).

2. Add the `CMake` command `add_kss_pal_qemu_tests()` to one of the `CMakeLists.txt` files of the project.

   Use the `PSL_FILES` parameter to define the paths to PSL files containing tests. Use the `DEPENDS` parameter to define the `CMake` targets whose execution will cause the PSL file-dependent IDL, CDL, and EDL files to be put into the directories where the `nk-psl-gen-c` compiler can find them. If `*.psl.in` files are utilized, use the `ENTITIES` parameter to define the names of process classes of system programs. (These system programs are included in a KasperskyOS-based solution that requires security policy testing.)

   Example use of the `CMake` command `add_kss_pal_qemu_tests()` in the file `einit/CMakeLists.txt`:

   ```
   add_kss_pal_qemu_tests (
     PSL_FILES src/security.psl.in
     DEPENDS kos-qemu-image
     ENTITIES ${ENTITIES})
   ```

3. Build and run the tests.

   You must run the Bash build script `cross-build.sh` with the parameter `--target pal-test<N>` (*N* is the index of the PSL file in the list of PSL files defined through the `PSL_FILES` parameter of the `CMake` command `add_kss_pal_qemu_tests()` at step 2. For example, `--target pal-test0` will create a KasperskyOS-based solution image corresponding to the first PSL file defined through the `PSL_FILES` parameter of the `CMake` command `add_kss_pal_qemu_tests()` and then run that image in QEMU. (Instead of applications and system programs, this solution will contain the program that runs tests.)

   Example:

   ```
   ./cross-build.sh --target pal-test0
   ```

Example test results:

```
[==========] Running 4 tests from 1 test suite.
[----------] Global test environment set-up.
[----------] 4 tests from KSS
[ RUN      ] KSS.KssUnitTest_flow_normal
[       OK ] KSS.KssUnitTest_flow_normal (6 ms)
[ RUN      ] KSS.KssUnitTest_flow_ping_must_be_first
/home/work/build/stat/build/install/examples/ping/build/einit/
pal-test/gen_security.psl.test.c:9742: Failure
Expected equality of these values:
  rc
    Which is: -1
  NK_EOK
    Which is: 0
gen_security.psl:116: expect grant

[  FAILED  ] KSS.KssUnitTest_flow_ping_must_be_first (8 ms)
[ RUN      ] KSS.KssUnitTest_flow_ping_ping_is_deny
[       OK ] KSS.KssUnitTest_flow_ping_ping_is_deny (4 ms)
```

```
[ RUN      ] KSS.KssUnitTest_flow_test_deny
[       OK ] KSS.KssUnitTest_flow_test_deny (1 ms)
[----------] 4 tests from KSS (29 ms total)

[----------] Global test environment tear-down
[==========] 4 tests from 1 test suite ran. (42 ms total)
[  PASSED  ] 3 tests.
[  FAILED  ] KSS.KssUnitTest_flow_ping_must_be_first (8 ms)
```

The test results contain information about whether or not each test passed or failed. If a test failed, information indicating the location of the description of the failed test example will be displayed in the PSL file.

PSL data types

The data types supported in the PSL language are presented in the table below.

PSL data types

Designations of types	Description of types
`UInt8`, `UInt16`, `UInt32`, `UInt64`	Unsigned integer
`SInt8`, `SInt16`, `SInt32`, `SInt64`	Signed integer
`Boolean`	Boolean type The Boolean type includes two values: `true` and `false`.
`Text`	Text type
`()`	`Unit` type The `Unit` type includes one immutable value. It is used as a stub value in cases when PSL language syntax requires certain data formulation but this data is not actually required. For example, the Unit type can be used to declare a method that does not have any parameters (similar to how the `void` type is used in C/C++).

`"[type]"`	Text literal
	A text literal includes one immutable text value.
	Example definitions of text literals:
	`""`
	`"granted"`

`<type>`	Integer literal
	An integer literal includes one immutable integer value.
	Example definitions of integer literals:
	`12`
	`-5`
	`0xFFFF`

`<type 1 | type 2> [| ...]`	Variant type A variant type combines two or more types and may perform the role of either of them. Examples of definitions of variant types:

	`Boolean | ()`
	`UInt8 | UInt16 | UInt32 | UInt64`
	`"granted" | "denied"`

`{ [field name : field type]`
`[, ...]`
`}`
	Dictionary
	A dictionary consists of one or more types of fields. A dictionary can be empty.
	Examples of dictionary definitions:
	`{}`
	`{ handle : Handle`
	`, rights : UInt32`
	`}`

`[[type] [, ...]]`	Tuple
	A tuple consists of fields of one or more types in the order in which the types are listed. A tuple can be empty.
	Examples of tuple definitions:
	`[]`
	`["granted"]`
	`[Boolean, Boolean]`

`Set<<type of elements>>`	Set
	A set includes zero or more unique elements of the same type.
	Examples of set definitions:
	`Set<"granted" | "denied">`
	`Set<Text>`

`List<<type of elements>>`	List
	A list includes zero or more elements of the same type.
	Examples of list definitions:
	`List<Boolean>`
	`List<Text | ()>`

`Map<<key type, value type>>`	Associative array An associative array includes zero or more entries of the "key-value" type with unique keys. Example of defining an associative array: `Map<UInt32, UInt32>`
`Array<<type of elements, number of elements>>`	Array An array includes a defined number of elements of the same type. Example of defining an array: `Array<UInt8, 42>`
`Sequence<<type of elements, number of elements>>`	Sequence A sequence includes from zero to the defined number of elements of the same type. Example of defining a sequence: `Sequence<SInt64, 58>`

Aliases of certain PSL types

The `nk/base.psl` file from the KasperskyOS SDK defines the data types that are used as the types of parameters (or structural elements of parameters) and returned values for methods of various security models. Aliases and definitions of these types are presented in the table below.

Aliases and definitions of certain data types in PSL

Type alias	Type definition
`Unsigned`	Unsigned integer `UInt8 | UInt16 | UInt32 | UInt64`
`Signed`	Signed integer `SInt8 | SInt16 | SInt32 | SInt64`
`Number`	Integer `Unsigned | Signed`
`ScalarLiteral`	Scalar literal `() | Boolean | Number`
`Literal`	Literal `ScalarLiteral | Text`
`Sid`	Type of security ID (SID) `UInt32`
`Handle`	Type of security ID (SID) `Sid`

`HandleDesc`	Dictionary containing fields for the SID and handle permissions mask
	`{ handle : Handle`
	`, rights : UInt32`
	`}`

`Cases`	Type of data received by expressions of security models called in the `choice` construct for verifying fulfillment of conditions `List<Text | ()>`
`KSSAudit`	Type of data defining the conditions for conducting the security audit `Set<"granted" | "denied">`

Mapping IDL types to PSL types

Data types of the IDL language are used to describe the parameters of interface methods. The input data for security model methods have types from the PSL language. The set of data types in the IDL language differs from the set of data types in the PSL language. Parameters of interface methods transmitted in IPC messages can be used as input data for methods of security models, so the policy description developer needs to understand how IDL types are mapped to PSL types.

Integer types of IDL are mapped to integer types of PSL and to variant types of PSL that combine these integer types (including with other types). For example, signed integer types of IDL are mapped to the `Signed` type in PSL, and integer types of IDL are mapped to the `ScalarLiteral` type in PSL.

The `Handle` type in IDL is mapped to the `HandleDesc` type in PSL.

Unions and structures of IDL are mapped to PSL dictionaries.

Arrays and sequences of IDL are mapped to arrays and sequences of PSL, respectively.

String buffers in IDL are mapped to the text type in PSL.

Byte buffers in IDL are not currently mapped to PSL types, so the data contained in byte buffers cannot be used as inputs for security model methods.

Examples of binding security model methods to security events

> Before analyzing examples, you need to become familiar with the Base security model.

Processing the initiation of process startups

```
/* The KasperskyOS kernel and any process
 * in the solution is allowed to start any
 * process. */
execute { grant () }

/* The kernel is allowed to start a process
 * of the Einit class. */
execute src=kl.core.Core, dst=Einit { grant () }

/* An Einit-class process is allowed
 * to start any process in the solution. */
execute src=Einit { grant () }
```

Handling the startup of the KasperskyOS kernel

```
/* The KasperskyOS kernel is allowed to start.
 * (This binding is necessary so that the security
 * module can be notified of the kernel SID. The kernel starts irrespective
 * of whether this is allowed by the solution security policy
 * or denied. If the solution security policy denies the
 * startup of the kernel, after startup the kernel will terminate its
 * execution.) */
execute src=kl.core.Core, dst=kl.core.Core { grant () }
```

Handling IPC request forwarding

```
/* Any client in the solution is allowed to query
 * any server and the KasperskyOS kernel. */
request { grant () }

/* A client of the Client class is allowed to query
```

```
 * any server in the solution and the kernel. */
request src=Client { grant () }

/* Any client in the solution is allowed to query
 * a server of the Server class. */
request dst=Server { grant () }

/* A client of the Client class is not allowed to
 * query a server of the Server class. */
request src=Client dst=Server { deny () }

/* A client of the Client class is allowed to
 * query a server of the Server class
 * by calling the Ping method of the net.Net endpoint. */
request src=Client dst=Server endpoint=net.Net method=Ping {
    grant ()
}

/* Any client in the solution is allowed to query
 * a server of the Server class by calling the Send method
 * of the endpoint with the MessExch interface. */
request dst=Server interface=MessExch method=Send {
    grant ()
}
```

Handling IPC response forwarding

```
/* A server of the Server class is allowed to respond to
 * queries of a Client-class client that
 * calls the Ping method of the net.Net endpoint. */
response src=Server, dst=Client, endpoint=net.Net, method=Ping {
    grant ()
}

/* The server containing the kl.drivers.KIDF component
 * that provide endpoints with the monitor interface is allowed to
 * respond to queries of a DriverManager-class client
 * that uses these endpoints. */
response dst=DriverManager component=kl.drivers.KIDF interface=monitor {
    grant ()
}
```

Handling the transmission of IPC responses containing error information

```
/* A server of the Server class is not allowed to notify a client
 * of the Client class regarding errors that occur
 * when the client queries the server by calling the
 * Ping method of the net.Net endpoint. */
error src=Server, dst=Client, endpoint=net.Net, method=Ping {
    deny ()
}
```

Handling queries sent by processes to the Kaspersky Security Module

```
/* A process of the Sdcard class will receive the
 * "granted" decision from the Kaspersky Security Module
 /* by calling the Register method of the security interface.
 * (Using the security interface defined
 * in the EDL description.) */
security src=Sdcard, method=Register {
    grant ()
}

/* A process of the Sdcard class will receive the "denied" decision
 * from the security module when calling the Comp.Register method
 * of the security interface. (Using the security interface
 * defined in the CDL description.) */
security src=Sdcard, method=Comp.Register {
    deny ()
}
```

Using match sections

```
/* A client of the Client class is allowed to query
 * a server of the Server class by calling the Send
 * and Receive methods of the net endpoint. */
request src=Client, dst=Server, endpoint=net {
    match method=Send { grant () }
    match method=Receive { grant () }
}

/* A client of the Client class is allowed to query
 * a server of the Server class by calling the Send
 * and Receive methods of the sn.Net endpoint and the Write and
 * Read methods of the sn.Storage endpoint. */
request src=Client, dst=Server {
    match endpoint=sn.Net {
        match method=Send { grant () }
        match method=Receive { grant () }
    }
    match endpoint=sn.Storage {
        match method=Write { grant () }
        match method=Read { grant () }
    }
}
```

Setting audit profiles

```
/* Set the default global audit profile
 * and initial audit runtime-level of 0 */
audit default = global 0
request src=Client, dst=Server {
    /* Set the parent audit profile at the level of
     * binding methods of security models to
     * security events */
    audit parent
    match endpoint=net.Net, method=Send {
        /* Set a child audit profile at the
```

```
         * match section level */
        audit child
        grant ()
        }
    /* This match section applies a
     * parent audit profile. */
    match endpoint=net.Net, method=Receive {
        grant ()
        }
}
/* This binding of the security model method
 * to the security event utilizes the
 * global audit profile. */
response src=Client, dst=Server {
     grant ()
}
```

Example descriptions of basic security policies for KasperskyOS-based solutions

> Before analyzing examples, you need to become familiar with the Struct, Base and Flow security models.

Example 1

The solution security policy in this example allows any interaction between different processes of the `Client`, `Server` and `Einit` classes, and between these processes and the KasperskyOS kernel. The "granted" decision will always be received when these processes query the Kaspersky Security Module. This policy can be used only as a stub during the early stages of development of a KasperskyOS-based solution so that the Kaspersky Security Module does not interfere with interactions. It would be unacceptable to apply such a policy in a real-world KasperskyOS-based solution.

security.psl

```
execute: kl.core.Execute

use nk.base._
use EDL Einit
use EDL Client
use EDL Server
use EDL kl.core.Core

execute { grant () }

request { grant () }

response { grant () }

error { grant () }

security { grant () }
```

Example 2

The solution security policy in this example imposes limitations on queries sent from clients of the `FsClient` class to servers of the `FsDriver` class. When a client opens a resource controlled by a server of the `FsDriver` class, a finite-state machine in the `unverified` state is associated with this resource. A client of the `FsClient` class is allowed to read data from a resource controlled by a server of the `FsDriver` class only if the finite-state machine associated with this resource is in the `verified` state. To switch a resource-associated finite-state machine from the `unverified` state to the `verified` state, a process of the `FsVerifier` class needs to query the Kaspersky Security Module.

In a real-world KasperskyOS-based solution, this policy cannot be applied because it allows an excessive variety of interactions between different processes and between processes and the KasperskyOS kernel.

security.psl

```
execute: kl.core.Execute

use nk.base._
use nk.flow._
use nk.basic._

policy object file_state : Flow {
    type States = "unverified" | "verified"
    config = {
        states      : ["unverified" , "verified"],
        initial     : "unverified",
        transitions : {
            "unverified" : ["verified"],
            "verified" : []
        }
    }
}


execute { grant () }

request { grant () }

response { grant () }

use EDL kl.core.Core
use EDL Einit
use EDL FsClient
use EDL FsDriver
use EDL FsVerifier

response src=FsDriver, endpoint=operationsComp.operationsImpl, method=Open {
    file_state.init {sid: message.handle.handle}
}

request src=FsClient, dst=FsDriver, endpoint=operationsComp.operationsImpl,
method=Read {
    file_state.allow {sid: message.handle.handle, states: ["verified"]}
}

security src=FsVerifier, method=Approve {
    file_state.enter {sid: message.handle.handle, state: "verified"}
}
```

Examples of security audit profiles

> Before analyzing examples, you need to become familiar with the Base, Regex and Flow security models.

Example 1

```
// Describing a trace security audit profile
// base - Base security model object
// session - Flow security model object
audit profile trace =
/* If the audit runtime-level is equal to 0, the audit covers
 * base object rules when these rules return
 * the "denied" result. */
  { 0 :
      { base :
          { kss : ["denied"]
          }
      }
/* If the audit runtime-level is equal to 1, the audit covers methods
 * of the session object in the following cases:
 * 1. Rules of the session object return any result, and
 * the finite-state machine is in a state other than closed.
 * 2. A query expression of the session object is executed, and the
 * finite-state machine is in a state other than closed. */
  , 1 :
      { session :
          { kss : ["granted", "denied"]
          , omit : ["closed"]
          }
      }
/* If the audit runtime-level is equal to 2, the audit covers methods
 * of the session object in the following cases:
 * 1. Rules of the session object return any result.
 * 2. A query expression of the session object is executed. */
  , 2 :
      { session :
          { kss : ["granted", "denied"]
          }
      }
  }
```

Example 2

```
// Describing a test security audit profile
// base - Base security model object
// re - Regex security model object
audit profile test =
/* If the audit runtime-level is equal to 0, rules of the base object
 * and expressions of the re object are not covered by the audit. */
  { 0 :
      { base :
```

```
        { kss : []
        }
      , re :
        { kss : []
        , emit : []
        }
      }
/* If the audit runtime-level is equal to 1, rules of the
 * base object are not covered by the audit, and expressions of the
 * re object are covered by the audit.*/
  , 1 :
      { base :
        { kss : []
        }
      , re :
        { kss : ["granted"]
        , emit : ["match", "select"]
        }
      }
/* If the audit runtime-level is equal to 2, rules of the base object
 * and expressions of the re object are covered by the audit. Rules
 * of the base object are covered by the audit irrespective of the
 * result that they return.*/
  , 2 :
      { base :
        { kss : ["granted", "denied"]
        }
      , re :
        { kss : ["granted"]
        , emit : ["match", "select"]
        }
      }
  }
```

Examples of tests for KasperskyOS-based solution security policies

Example 1

```
/* Test set that includes only one test. */
assert "some tests" {
    /* Test that includes four test cases. */
    sequence "first sequence" {
        /* It is expected that startup of a Server-class process is allowed.
         * If this is true, the s variable will be assigned the SID value
         * of the started Server-class process. */
        s <- execute dst=Server
        /* It is expected that startup of a Client-class process is allowed.
         * If this is true, the c variable will be assigned the SID value
         * of the started Client-class process. */
        c <- execute dst=Client
        /* It is expected that a client of the Client class is allowed to query
         * a server of the Server class by calling the Ping method of the
pingComp.pingImpl endpoint
         * with the value parameter equal to 100. */
        grant "Client calls Ping" request src=c dst=s endpoint=pingComp.pingImpl
                                          method=Ping { value : 100 }
```

```
        /* It is expected that a server of the Server class is not allowed to respond
to a client
         * of the Client class if the client calls the Ping method of the
pingComp.pingImpl endpoint.
         * (The IPC response does not contain any parameters because the Ping
interface method
         * has no output parameters.) */
        deny "Server cannot respond" response src=s dst=c endpoint=pingComp.pingImpl
                                                    method=Ping {}
    }
}
```

Example 2

```
/* Test set that includes two tests. */
assert "ping tests"{
    /* Initial part of each of the two tests
     that includes two test cases. */
    setup {
        /* It is expected that startup of a Server-class process is allowed.
         * If this is true, the s variable will be assigned the SID value
         * of the started Server-class process. */
        s <- execute dst=Server
        /* It is expected that startup of a Client-class process is allowed.
         * If this is true, the c variable will be assigned the SID value
         * of the started Client-class process. */
        c <- execute dst=Client
    }
    /* Test that includes four test cases: two test cases
     * in the initial part and two test cases in the main part.*/
    sequence "ping-ping is denied" {
        /* It is expected that a client of the Client class is allowed to query
         * a server of the Server class by calling the Ping method of the
pingComp.pingImpl endpoint
         * with the value parameter equal to 100. */
        c ~> s : pingComp.pingImpl.Ping { value : 100 }
        /* It is expected that a client of the Client class is not allowed to query
         * a server of the Server class by once again calling the Ping method of the
pingComp.pingImpl endpoint
         * with the value parameter equal to 100. */
        deny c ~> s : pingComp.pingImpl.Ping { value : 100 }
    }
    /* Test that includes four test cases: two test cases
     * in the initial part and two test cases in the main part. */
    sequence "ping-pong is granted" {
        /* It is expected that a client of the Client class is allowed to query
         * a server of the Server class by calling the Ping method of the
pingComp.pingImpl endpoint
         * with the value parameter equal to 100. */
        c ~> s : pingComp.pingImpl.Ping { value: 100 }
        /* It is expected that a client of the Client class is allowed to query
         * a server of the Server class by calling the Pong method of the
pingComp.pingImpl endpoint
         * with the value parameter equal to 100. */
        c ~> s : pingComp.pingImpl.Pong { value: 100 }
    }
}
```

Example 3

```
/* Test set that includes only one test. */
assert {
    /* Test that includes eight test cases. */
    sequence {
        storage <- execute dst=test.kl.UpdateStorage
        manager <- execute dst=test.kl.UpdateManager
        deployer <- execute dst=test.kl.UpdateDeployer
        downloader <- execute dst=test.kl.UpdateDownloader
        grant manager ~>
              downloader:UpdateDownloader.Downloader.LoadPackage { url :
”url012345678” }
        grant response src=downloader dst=manager endpoint=UpdateDownloader.Downloader
                      method=LoadPackage { handle : 29, result : 1 }
        deny manager ~> deployer:UpdateDeployer.Deployer.Start { handle : 29 }
        deny request src=manager dst=deployer endpoint=UpdateDeployer.Deployer
                     method=Start { handle : 29 }
    }
}
```

KasperskyOS Security models

Pred security model

The Pred security model performs comparison operations.

A PSL file containing a description of the Pred security model is located in the KasperskyOS SDK at the following path:

`toolchain/include/nk/basic.psl`

Pred security model object

The `basic.psl` file contains a declaration that creates a Pred security model object named `pred`. Consequently, inclusion of the `basic.psl` file into the solution security policy description will create a Pred security model object by default.

A Pred security model object does not have any parameters and cannot be covered by a security audit.

It is not necessary to create additional Pred security model objects.

Pred security model methods

A Pred security model contains expressions that perform comparison operations and return values of the `Boolean` type. To call these expressions, use the following comparison operators:

- `<ScalarLiteral> == <ScalarLiteral>` – "equals".

- `<ScalarLiteral> != <ScalarLiteral>` – "does not equal".
- `<Number> < <Number>` – "is less than".
- `<Number> <= <Number>` – "is less than or equal to".
- `<Number> > <Number>` – "is greater than".
- `<Number> >= <Number>` – "is greater than or equal to".

The Pred security model also contains the `empty` expression that determines whether data contains its own structural elements. This expression returns values of the `Boolean` type. If data does not contain its own structural elements (for example, a set is empty), the expression returns `true`, otherwise it returns `false`. To call the expression, use the following construct:

```
pred.empty (<Text | Set | List | Map>) | ()
```

Bool security model

The Bool security model performs logical operations.

A PSL file containing a description of the Bool security model is located in the KasperskyOS SDK at the following path:

`toolchain/include/nk/basic.psl`

Bool security model object

The `basic.psl` file contains a declaration that creates a Bool security model object named `bool`. Consequently, inclusion of the `basic.psl` file into the solution security policy description will create a Bool security model object by default.

A Bool security model object does not have any parameters and cannot be covered by a security audit.

It is not necessary to create additional Bool security model objects.

Bool security model methods

The Bool security model contains expressions that perform logical operations and return values of the `Boolean` type. To call these expressions, use the following logical operators:

- `! <Boolean>` – "logical NOT".
- `<Boolean> && <Boolean>` – "logical AND".
- `<Boolean> || <Boolean>` – "logical OR".
- `<Boolean> ==> <Boolean>` – "implication" (`! <Boolean> || <Boolean>`).

The Bool security model also contains the `all`, `any` and `cond` expressions.

The expression `all` performs a "logical AND" for an arbitrary number of values of `Boolean` type. It returns values of the `Boolean` type. It returns `true` if an empty list of values (`[]`) is passed via the parameter. To call the expression, use the following construct:

```
bool.all (<List<Boolean>>)
```

The expression `any` performs a "logical OR" for an arbitrary number of values of `Boolean` type. It returns values of the `Boolean` type. It returns `false` if an empty list of values (`[]`) is passed via the parameter. To call the expression, use the following construct:

```
bool.any (<List<Boolean>>)
```

`cond` expression performs a ternary conditional operation. Returns values of the `ScalarLiteral` type. To call the expression, use the following construct:

```
bool.cond
  { if   : <Boolean> // Condition
  , then : <ScalarLiteral> // Value returned when the condition is true
  , else : <ScalarLiteral> // Value returned when the condition is false
  }
```

In addition to expressions, the Bool security model includes the `assert` rule that works the same as the rule of the same name included in the Base security model.

Math security model

The Math security model performs integer arithmetic operations.

A PSL file containing a description of the Math security model is located in the KasperskyOS SDK at the following path:

`toolchain/include/nk/basic.psl`

Math security model object

The `basic.psl` file contains a declaration that creates a Math security model object named `math`. Consequently, inclusion of the `basic.psl` file into the solution security policy description will create a Math security model object by default.

A Math security model object does not have any parameters and cannot be covered by a security audit.

It is not necessary to create additional Math security model objects.

Math security model methods

The Math security model contains expressions that perform integer arithmetic operations. To call a part of these expressions, use the following arithmetic operators:

- `<Number> + <Number>` – "addition". Returns values of the `Number` type.
- `<Number> - <Number>` – "subtraction". Returns values of the `Number` type.
- `<Number> * <Number>` – "multiplication". Returns values of the `Number` type.

The other expressions are as follows:

- `neg (<Signed>)` – "change number sign". Returns values of the `Signed` type.
- `abs (<Signed> )` – "get module of number". Returns values of the `Signed` type.
- `sum (<List<Number>>)` – "add numbers from list". Returns values of the `Number` type. It returns `0` if an empty list of values (`[]`) is passed via the parameter.
- `product (<List<Number>>)` – "multiple numbers from list". Returns values of the `Number` type. It returns `1` if an empty list of values (`[]`) is passed via the parameter.

To call these expressions, use the following construct:

```
math.<expression name> (<parameter>)
```

Struct security model

The Struct security model obtains access to structural data elements.

A PSL file containing a description of the Struct security model is located in the KasperskyOS SDK at the following path:

`toolchain/include/nk/basic.psl`

Struct security model object

The `basic.psl` file contains a declaration that creates a Struct security model object named `struct`. Consequently, inclusion of the `basic.psl` file into the solution security policy description will create a Struct security model object by default.

A Struct security model object does not have any parameters and cannot be covered by a security audit.

It is not necessary to create additional Struct security model objects.

Struct security model methods

The Struct security model contains expressions that provide access to structural data elements. To call these expressions, use the following constructs:

- `<dictionary>.<field name>` – "get access to dictionary field". The type of returned data corresponds to the type of dictionary field.
- `<List | Set | Sequence | Array>.[<element number>]` – "get access to data element". The type of returned data corresponds to the type of elements. The numbering of elements starts with zero. When out of bounds of dataset, the expression terminates with an error and the Kaspersky Security Module returns the "denied" decision.
- `<HandleDesc>.handle` – "get SID". Returns values of the `Handle` type. (For details on the correlation between handles and SID values, see "Resource Access Control").
- `<HandleDesc>.rights` – "get handle permissions mask". Returns values of the `UInt32` type.

Parameters of interface methods are saved in a special dictionary named `message`. To obtain access to an interface method parameter, use the following construct:

```
message.<interface method parameter name>
```

The parameter name is specified in accordance with the IDL description.

To obtain access to structural elements of parameters, use the constructs corresponding to expressions of the Struct security model.

> To use expressions of the Struct security model, the security event description must be sufficiently precise so that it corresponds to IPC messages of the same type (for more details, see "Binding methods of security models to security events"). IPC messages of this type must contain the defined parameters of the interface method, and the interface method parameters must contain the defined structural elements.

Base security model

The Base security model implements basic logic.

A PSL file containing a description of the Base security model is located in the KasperskyOS SDK at the following path:

`toolchain/include/nk/base.psl`

Base security model object

The `base.psl` file contains a declaration that creates a Base security model object named `base`. Consequently, inclusion of the `base.psl` file into the solution security policy description will create a Base security model object by default. Methods of this object can be called without indicating the object name.

A Base security model object does not have any parameters.

A Base security model object can be covered by a security audit. There are no audit conditions specific to the Base security model.

It is necessary to create additional objects of the Base security model in the following cases:

- You need to configure a security audit differently for different objects of the Base security model (for example, you can apply different audit profiles or different audit configurations of the same profile for different objects).
- You need to distinguish between calls of methods provided by different objects of the Base security model (audit data includes the name of the security model method and the name of the object that provides this method, so you can verify that the method of a specific object was called).

Base security model methods

The Base security model contains the following rules:

- `grant ()`

  It has a parameter of the `()` type. It returns the "granted" result.

  Example:

  ```
  /* A client of the foo class is allowed
   * to query a server of the bar class. */
  request src=foo dst=bar { grant () }
  ```

- `assert (<Boolean>)`

  It returns the "granted" result if the `true` value is passed via the parameter. Otherwise it returns the "denied" result.

  Example:

  ```
  /* Any client in the solution will be allowed to query a server of the foo class
   * by calling the Send method of the net.Net endpoint if the port parameter
   * of the Send method will be used to pass a value greater than 80. Otherwise any
   * client in the solution will be prohibited from querying a server of the
   * foo class by calling the Send method of the net.Net endpoint. */
  request dst=foo endpoint=net.Net method=Send { assert (message.port > 80) }
  ```

- `deny (<Boolean>) | ()`

  It returns the "denied" result if the `true` or `()` value is passed via the parameter. Otherwise it returns the "granted" result.

  Example:

  ```
  /* A server of the foo class is not allowed to
   * respond to a client of the bar class. */
  response src=foo dst=bar { deny () }
  ```

- `set_level (<UInt8>)`

  It sets the security audit runtime-level equal to the value passed via this parameter. It returns the "granted" result. (For more details about the security audit runtime-level, see "Describing security audit profiles".)

  Example:

  ```
  /* A process of the foo class will receive the "allowed" decision from the
   * Kaspersky Security Module if it calls the
   * SetAuditLevel security interface method to change the security audit runtime-
  ```

```
level. */
security src=foo method=SetAuditLevel { set_level (message.audit_level) }
```

Regex security model

The Regex security model implements text data validation based on statically defined regular expressions.

A PSL file containing a description of the Regex security model is located in the KasperskyOS SDK at the following path:

`toolchain/include/nk/regex.psl`

Regex security model object

The `regex.psl` file contains a declaration that creates a Regex security model object named `re`. Consequently, inclusion of the `regex.psl` file into the solution security policy description will create a Regex security model object by default.

A Regex security model object does not have any parameters.

A Regex security model object can be covered by a security audit. In this case, you also need to define the audit conditions specific to the Regex security model. To do so, use the following constructs in the audit configuration description:

- `emit : ["match"]` – the audit is performed if the `match` method is called.
- `emit : ["select"]` – the audit is performed if the `select` method is called.
- `emit : ["match", "select"]` – the audit is performed if the `match` or `select` method is called.
- `emit : []` – the audit is not performed.

It is necessary to create additional objects of the Regex security model in the following cases:

- You need to configure a security audit differently for different objects of the Regex security model (for example, you can apply different audit profiles or different audit configurations of the same profile for different objects).
- You need to distinguish between calls of methods provided by different objects of the Regex security model (audit data includes the name of the security model method and the name of the object that provides this method, so you can verify that the method of a specific object was called).

Regex security model methods

The `Regex` security model contains the following expressions:

- `match {text : <Text>, pattern : <Text>}`

  Returns a value of the `Boolean` type. If the specified `text` matches the `pattern` regular expression, it returns `true`. Otherwise it returns `false`.

  Example:

```
assert (re.match {text : message.text, pattern : "[0-9]*"})
```

- `select {text : <Text>}`

  It is intended to be used as an expression that verifies fulfillment of the conditions in the `choice` construct (for details on the `choice` construct, see "Binding methods of security models to security events"). It checks whether the specified `text` matches regular expressions. Depending on the results of this check, various options for security event handling can be performed.

  Example:

```
choice (re.select {text : "hello world"}) {
    "hello\ .*": grant ()
    ".*world" : grant ()
    _         : deny ()
   }
```

Syntax of regular expressions of the Regex security model

A regular expression for the `match` method of the Regex security model can be written in two ways: within the multi-line `regex` block or as a text literal.

> When writing a regular expression as a text literal, all backslash instances must be doubled.

For example, the following two regular expressions are identical:

```
// Regular expression within the multi-line regex block
{ pattern:
    ```regex
    Hello\ world\!
    ```
, text: "Hello world!"
}
// Regular expression as a text literal (doubled backslash)
{ pattern: "Hello\\ world\\!"
, text: "Hello world!"
}
```

Regular expressions for the `select` method of the Regex security model are written as text literals with a double backslash.

A regular expression is defined as a template string and may contain the following:

- Literals (ordinary characters)
- Metacharacters (characters with special meanings)
- White-space characters
- Character sets

- Character groups
- Operators for working with characters

Regular expressions are case sensitive.

Literals and metacharacters in regular expressions

- A literal can be any ASCII character except the metacharacters `.()*&|!?+[]\` and a white-space character. (Unicode characters are not supported.)

  For example, the regular expression `KasperskyOS` corresponds to the text `KasperskyOS`.

- Metacharacters have special meanings that are presented in the table below.

  Special meanings of metacharacters

Metacharacter	Special meaning
`[]`	Square brackets (braces) denote the beginning and end of a set of characters.
`()`	Round brackets (parentheses) denote the beginning and end of a group of characters.
*	An asterisk denotes an operator indicating that the character preceding it can repeat zero or more times.
+	A plus sign denotes an operator indicating that the character preceding it can repeat one or more times.
?	A question mark denotes an operator indicating that the character preceding it can repeat zero or one time.
!	An exclamation mark denotes an operator excluding the subsequent character from the list of valid characters.
|	A vertical line denotes an operator for selection between characters (logically close to the "OR" conjunction).
&	An ampersand denotes an operator for overlapping of multiple conditions (logically close to the "AND" conjunction).
.	A dot denotes any character. For example, the regular expression `K.S` corresponds to the sequences of characters `KOS`, `KoS`, `KES` and a multitude of other sequences consisting of three characters that begin with `K` and end with `S`, and in which the second character can be any character: literal, metacharacter, or dot.
\	`\<metaSymbol>` A backslash indicates that the metacharacter that follows it will lose its special meaning and instead be interpreted as a literal. A backslash placed before a metacharacter is known as an escape character. For example, a regular expression that consists of a dot metacharacter (`.`) corresponds to any character. However, a regular expression that consists of a backslash with a dot (`\.`) corresponds to only a dot character. Accordingly, a backslash also escapes another subsequent backslash. For example, the regular expression `C:\\Users` corresponds to the sequence of characters `C:\Users`.

- The `^` and `$` characters are not used to designate the start and end of a line.

White-space characters in regular expressions

- A space character has an ASCII code of `20` in a hexadecimal number system and has an ASCII code of `40` in an octal number system. Although a space character does not infer any special meaning, it must be escaped to avoid any ambiguous interpretation by the regular expression interpreter.

  For example, the regular expression `Hello\ world` corresponds to the sequence of characters `Hello world`.

- `\r`

  Carriage return character.

- `\n`

  Line break character.

- `\t`

  Horizontal tab character.

Definition of a character based on its octal or hexadecimal code in regular expressions

- `\x{<hex>}`

  Definition of a character using its `hex` code from the ASCII character table. The character code must be less than `0x100`.

  For example, the regular expression `Hello\x{20}world` corresponds to the sequence of characters `Hello world`.

- `\o{<octal>}`

  Definition of a character using its `octal` code from the ASCII character table. The character code must be less than `0o400`.

  For example, the regular expression `\o{75}` corresponds to the `=` character.

Sets of characters in regular expressions

A character set is defined within square brackets `[]` as a list or range of characters. A character set tells the regular expression interpreter that only one of the characters listed in the set or range of characters can be at this specific location in a sequence of characters. A character set cannot be left blank.

- `[<BracketSpec>]` – character set.

  One character corresponds to any character from the `BracketSpec` character set.

  For example, the regular expression `K[OE]S` corresponds to the sequences of characters `KOS` and `KES`.

- `[^<BracketSpec>]` – inverted character set.

  One character corresponds to any character that is not in the `BracketSpec` character set.

  For example, the regular expression `K[^OE]S` corresponds to the sequences of characters `KAS`, `K8S` and any other sequences consisting of three characters that begin with `K` and end with `S`, excluding `KOS` and `KES`.

The `BracketSpec` character set can be listed explicitly or can be defined as a range of characters. When defining a range of characters, the first and last character in the set must be separated with a hyphen.

- `[<Digit1>-<DigitN>]`

  Any number from the range `Digit1`, `Digit2`, … ,`DigitN`.

For example, the regular expression `[0-9]` corresponds to any numerical digit. The regular expressions `[0-9]` and `[0123456789]` are identical.

Please note that a range is defined by one character before a hyphen and one character after the hyphen. The regular expression `[1-35]` corresponds only to the characters `1`, `2`, `3` and `5`, and does not represent the range of numbers from `1` to `35`.

- `[<Letter1>-<LetterN>]`

  Any English letter from the range `Letter1`, `Letter2`, … , `LetterN` (these letters must be in the same case).

  For example, the regular expression `[a-zA-Z]` corresponds to all letters in uppercase and lowercase from the ASCII character table.

The ASCII code for the upper boundary character of a range must be higher than the ASCII code for the lower boundary character of the range.

For example, the regular expressions `[5-2]` or `[z-a]` are invalid.

The hyphen (minus) `-` character is interpreted as a special character only within a set of characters. Outside of a character set, a hyphen is a literal. For this reason, the `\` metacharacter does not have to precede a hyphen. To use a hyphen as a literal within a character set, it must be indicated first or last in the set.

Examples:

The regular expressions `[-az]` and `[az-]` correspond to the characters `a`, `z` and `-`.

The regular expression `[a-z]` corresponds to any of the 26 English letters from `a` to `z` in lowercase.

The regular expression `[-a-z]` corresponds to any of the 26 English letters from `a` to `z` in lowercase and `-`.

The circumflex (caret character) `^` is interpreted as a special character only within a character set when it is located directly after an opening square bracket. Outside of a character set, a circumflex is a literal. For this reason, the `\` metacharacter does not have to precede a circumflex. To use a circumflex as a literal within a character set, it must be indicated in a location other than first in the set.

Examples:

The regular expression `[0^9]` correspond to the characters `0`, `9` and `^`.

The regular expression `[^09]` corresponds to any character except `0` and `9`.

Within a character set, the metacharacters `*.&|!?+` lose their special meaning and are instead interpreted as literals. Therefore, they do not have to be preceded by the `\` metacharacter. The backslash `\` retains its special meaning within a character set.

For example, the regular expressions `[a.]` and `[a\.]` are identical and correspond to the character `a` and a dot interpreted as a literal.

Groups of characters and operators in regular expressions

A character group uses parentheses `()` to distinguish its portion (subexpression) within a regular expression. Groups are normally used to allocate subexpressions as operands. Groups can be embedded into each other.

> Operators are applied to more than one character in a regular expression only if they are immediately before or after the definition of a set or group of characters. If this is the case, the operator is applied to the entire group or set of characters.

The syntax contains definitions of the following operators (listed in descending order of their priority):

- `!<Expression>`, where `Expression` can be a character, set or group of characters.

  This operator excludes the `Expression` from the list of valid expressions.

  Examples:

  The regular expression `K!OS` corresponds to the sequences of characters `KoS`, `KES`, and a multitude of other sequences that consist of three characters and begin with `K` and end with `S`, excluding `KOS`.

  The regular expression `K!(OS)` corresponds to the sequences of characters `Kos`, `KES`, `KOT`, and a multitude of other sequences that consist of three characters and begin with `K`, excluding `KOS`.

  The regular expression `K![OE]S` corresponds to the sequences of characters `KoS`, `KeS`, `K;S`, and a multitude of other sequences that consist of three characters and begin with `K` and end with `S`, excluding `KOS` and `KES`.

- `<Expression>*`, where `Expression` can be a character, set or group of characters.

  This operator means that the `Expression` may occur in the specific position zero or more times.

  Examples:

  The regular expression `0-9*` corresponds to the sequences of characters `0-`, `0-9`, `0-99`, … .

  The regular expression `(0-9)*` corresponds to the empty sequence `""` and the sequences of characters `0-9`, `0-90-9`, … .

  The regular expression `[0-9]*` corresponds to the empty sequence `""` and any non-empty sequence of numbers.

- `<Expression>+`, where `Expression` can be a character, set or group of characters.

  This operator means that the `Expression` may occur in the specific position one or more times.

  Examples:

  The regular expression `0-9+` corresponds to the sequences of characters `0-9`, `0-99`, `0-999`, … .

  The regular expression `(0-9)+` corresponds to the sequences of characters `0-9`, `0-90-9`, … .

  The regular expression `[0-9]+` corresponds to any non-empty sequence of numbers.

- `<Expression>?`, where `Expression` can be a character, set or group of characters.

  This operator means that the `Expression` may occur in the specific position zero or one time.

  Examples:

  The regular expression `https?://` corresponds to the sequences of characters `http://` and `https://`.

  The regular expression `K(aspersky)?OS` corresponds to the sequences of characters `KOS` and `KasperskyOS`.

- `<Expression1><Expression2>` – concatenation. `Expression1` and `Expression2` can be characters, sets or groups of characters.

  This operator does not have a specific designation. In the resulting expression, `Expression2` follows `Expression1`.

  For example, concatenation of the sequences of characters `micro` and `kernel` will result in the sequence of characters `microkernel`.

- `<Expression1>|<Expression2>` – disjunction. `Expression1` and `Expression2` can be characters, sets or groups of characters.

  This operator selects either `Expression1` or `Expression2`.

Examples:

The regular expression `KO|ES` corresponds to the sequences of characters `KO` and `ES`, but not `KOS` or `KES` because the concatenation operator has a higher priority than the disjunction operator.

The regular expression `Press (OK|Cancel)` corresponds to the sequences of characters `Press OK` or `Press Cancel`.

The regular expression `[0-9]|()` corresponds to numbers from `0` to `9` or an empty string.

- `<Expression1>&<Expression2>` – conjunction. `Expression1` and `Expression2` can be characters, sets or groups of characters.

  This operator intersects the result of `Expression1` with the result of `Expression2`.

  Examples:

  The regular expression `[0-9]&[^3]` corresponds to numbers from `0` to `9`, excluding `3`.

  The regular expression `[a-zA-Z]&()` corresponds to all English letters and an empty string.

HashSet security model

The HashSet security model associates resources with one-dimensional tables of unique values of the same type, adds or deletes these values, and checks whether a defined value is in the table. For example, a process of the network server can be associated with the set of ports that this server is allowed to open. This association can be used to check whether the server is allowed to initiate the opening of a port.

A PSL file containing a description of the HashSet security model is located in the KasperskyOS SDK at the following path:

`toolchain/include/nk/hashmap.psl`

HashSet security model object

To use the HashSet security model, you need to create an object or objects of this model.

A HashSet security model object contains a pool of one-dimensional tables of the same size intended for storing the values of one type. A resource can be associated with only one table from the tables pool of each HashSet security model object.

A HashSet security model object has the following parameters:

- `type Entry` – type of values in tables (these can be integer types, `Boolean` type, and dictionaries and tuples based on integer types and the `Boolean` type).
- `config` – configuration of the pool of tables:
  - `set_size` – size of the table.
  - `pool_size` – number of tables in the pool.

All parameters of a HashSet security model object are required.

Example:

```
policy object s : HashSet {
    type Entry = UInt32

    config =
      { set_size : 5
      , pool_size : 2
      }
}
```

A HashSet security model object can be covered by a security audit. There are no audit conditions specific to the HashSet security model.

It is necessary to create multiple objects of the HashSet security model in the following cases:

- You need to configure a security audit differently for different objects of the HashSet security model (for example, you can apply different audit profiles or different audit configurations of the same profile for different objects).
- You need to distinguish between calls of methods provided by different objects of the HashSet security model (audit data includes the name of the security model method and the name of the object that provides this method, so you can verify that the method of a specific object was called).
- You need to use tables of different sizes and/or with different types of values.

HashSet security model init rule

```
init {sid : <Sid>}
```

It associates a free table from the tables pool with the `sid` resource. If the free table contains values after its previous use, these values are deleted.

It returns the "allowed" result if an association was created between the table and the `sid` resource.

It returns the "denied" result in the following cases:

- There are no free tables in the pool.
- The `sid` resource is already associated with a table from the tables pool of the HashSet security model object being used.
- The `sid` value is outside of the permissible range.

Example:

```
/* A process of the Server class will be allowed to start if,
 * at startup initiation, an association will be created
 * between this process and the table. Otherwise the startup of a process of the
 * Server class will be denied. */
execute dst=Server {
    s.init {sid : dst_sid}
}
```

HashSet security model fini rule

```
fini {sid : <Sid>}
```

It deletes the association between the table and the `sid` resource (the table becomes free).

It returns the "allowed" result if the association between the table and the `sid` resource was deleted.

It returns the "denied" result in the following cases:

- The `sid` resource is not associated with a table from the tables pool of the HashSet security model object being used.
- The `sid` value is outside of the permissible range.

HashSet security model add rule

```
add {sid : <Sid>, entry : <Entry>}
```

It adds the `entry` value to the table associated with the `sid` resource.

It returns the "allowed" result in the following cases:

- The rule added the `entry` value to the table associated with the `sid` resource.
- The table associated with the `sid` resource already contains the `entry` value.

It returns the "denied" result in the following cases:

- The table associated with the `sid` resource is completely full.
- The `sid` resource is not associated with a table from the tables pool of the HashSet security model object being used.
- The `sid` value is outside of the permissible range.

Example:

```
/* A process of the Server class will receive the "allowed" decision from
 * the Kaspersky Security Module by calling the
 * Add security interface method if, when this method is called, the value
 * 5 will be added to the table associated with this
 * process, or is already in the table. Otherwise
 * a process of the Server class will receive the "denied" decision from the
 * security module by calling the
 * Add security interface method. */
security src=Server, method=Add {
```

```
    s.add {sid : src_sid, entry : 5}
}
```

HashSet security model remove rule

```
remove {sid : <Sid>, entry : <Entry>}
```

It deletes the `entry` value from the table associated with the `sid` resource.

It returns the "allowed" result in the following cases:

- The rule deleted the `entry` value from the table associated with the `sid` resource.
- The table associated with the `sid` resource does not contain the `entry` value.

It returns the "denied" result in the following cases:

- The `sid` resource is not associated with a table from the tables pool of the HashSet security model object being used.
- The `sid` value is outside of the permissible range.

HashSet security model contains expression

```
contains {sid : <Sid>, entry : <Entry>}
```

It checks whether the `entry` value is in the table associated with the `sid` resource.

It returns a value of the `Boolean` type. If the `entry` value is in the table associated with the `sid` resource, it returns `true`. Otherwise it returns `false`.

It runs incorrectly in the following cases:

- The `sid` resource is not associated with a table from the tables pool of the HashSet security model object being used.
- The `sid` value is outside of the permissible range.

When the expression runs incorrectly, the Kaspersky Security Module returns the "denied" decision.

Example:

```
/* A process of the Server class will receive the "allowed" decision from
 * the Kaspersky Security Module by calling the
 * Check security interface method if the value 42 is in the table
 * associated with this process. Otherwise a process of the
 * Server class will receive the "denied" decision from the security module
```

```
 /* by calling the Check security interface method. */
security src=Server, method=Check {
    assert(s.contains {sid : src_sid, entry : 42})
}
```

StaticMap security model

The StaticMap security model associates resources with two-dimensional "key–value" tables, reads and modifies the values of keys. For example, a process of the driver can be associated with the MMIO memory region that this driver is allowed to use. This will require two keys whose values define the base address and the size of the MMIO memory region. This association can be used to check whether the driver can query the MMIO memory region that it is attempting to access.

Keys in the table have the same type but are unique and immutable. The values of keys in the table have the same type.

There are two simultaneous instances of the table: base instance and working instance. Both instances are initialized by the same data. Changes are made first to the working instance and then can be added to the base instance, or vice versa: the working instance can be changed by using previous values from the base instance. The values of keys can be read from the base instance or working instance of the table.

A PSL file containing a description of the StaticMap security model is located in the KasperskyOS SDK at the following path:

`toolchain/include/nk/staticmap.psl`

StaticMap security model object

To use the StaticMap security model, you need to create an object or objects of this model.

A StaticMap security model object contains a pool of two-dimensional "key–value" tables that have the same size. A resource can be associated with only one table from the tables pool of each StaticMap security model object.

A StaticMap security model object has the following parameters:

- `type Value` – type of values of keys in tables (integer types are supported).
- `config` – configuration of the pool of tables:
  - `keys` – table containing keys and their default values (keys have the `Key = Text | List<UInt8>` type).
  - `pool_size` – number of tables in the pool.

All parameters of a StaticMap security model object are required.

Example:

```
policy object m : StaticMap {
    type Value = UInt16

    config =
```

```
      { keys:
        { "k1" : 0
        , "k2" : 1
        }
      , pool_size : 2
      }
}
```

A StaticMap security model object can be covered by a security audit. There are no audit conditions specific to the StaticMap security model.

It is necessary to create multiple objects of the StaticMap security model in the following cases:

- You need to configure a security audit differently for different objects of the StaticMap security model (for example, you can apply different audit profiles or different audit configurations of the same profile for different objects).
- You need to distinguish between calls of methods provided by different objects of the StaticMap security model (audit data includes the name of the security model method and the name of the object that provides this method, so you can verify that the method of a specific object was called).
- You need to use tables with different sets of keys and/or different types of key values.

StaticMap security model init rule

```
init {sid : <Sid>}
```

It associates a free table from the tables pool with the `sid` resource. Keys are initialized by the default values.

It returns the "allowed" result if an association was created between the table and the `sid` resource.

It returns the "denied" result in the following cases:

- There are no free tables in the pool.
- The `sid` resource is already associated with a table from the tables pool of the StaticMap security model object being used.
- The `sid` value is outside of the permissible range.

Example:

```
/* A process of the Server class will be allowed to start if,
 * at startup initiation, an association will be created
 * between this process and the table. Otherwise the startup of a process of the
 * Server class will be denied. */
execute dst=Server {
    m.init {sid : dst_sid}
}
```

StaticMap security model fini rule

```
fini {sid : <Sid>}
```

It deletes the association between the table and the `sid` resource (the table becomes free).

It returns the "allowed" result if the association between the table and the `sid` resource was deleted.

It returns the "denied" result in the following cases:

- The `sid` resource is not associated with a table from the tables pool of the StaticMap security model object being used.
- The `sid` value is outside of the permissible range.

StaticMap security model set rule

```
set {sid : <Sid>, key : <Key>, value : <Value>}
```

It assigns the specified `value` to the specified `key` in the working instance of the table associated with the `sid` resource.

It returns the "allowed" result if the specified `value` was assigned to the specified `key` in the working instance of the table associated with the `sid` resource. (The current value of the key will be overwritten even if it is equal to the new value.)

It returns the "denied" result in the following cases:

- The specified `key` is not in the table associated with the `sid` resource.
- The `sid` resource is not associated with a table from the tables pool of the StaticMap security model object being used.
- The `sid` value is outside of the permissible range.

Example:

```
/* A process of the Server class will receive the "allowed" decision from
 * the Kaspersky Security Module by calling the
 * Set security interface method if, when this method is called, the value 2
 * will be assigned to key k1 in the working instance of the table
 * associated with this process. Otherwise a process of the
 * Server class will receive the "denied" decision from the security module
 /* by calling the Set security interface method. */
security src=Server, method=Set {
    m.set {sid : src_sid, key : "k1", value : 2}
}
```

StaticMap security model commit rule

```
commit {sid : <Sid>}
```

It copies the values of keys from the working instance to the base instance of the table associated with the `sid` resource.

It returns the "allowed" result if the values of keys were copied from the working instance to the base instance of the table associated with the `sid` resource.

It returns the "denied" result in the following cases:

- The `sid` resource is not associated with a table from the tables pool of the StaticMap security model object being used.
- The `sid` value is outside of the permissible range.

StaticMap security model rollback rule

```
rollback {sid : <Sid>}
```

It copies the values of keys from the base instance to the working instance of the table associated with the `sid` resource.

It returns the "allowed" result if the values of keys were copied from the base instance to the working instance of the table associated with the `sid` resource.

It returns the "denied" result in the following cases:

- The `sid` resource is not associated with a table from the tables pool of the StaticMap security model object being used.
- The `sid` value is outside of the permissible range.

StaticMap security model get expression

```
get {sid : <Sid>, key : <Key>}
```

It returns the value of the specified `key` from the base instance of the table associated with the `sid` resource.

It returns a value of the `Value` type.

It runs incorrectly in the following cases:

- The specified `key` is not in the table associated with the `sid` resource.
- The `sid` resource is not associated with a table from the tables pool of the StaticMap security model object being used.
- The `sid` value is outside of the permissible range.

When the expression runs incorrectly, the Kaspersky Security Module returns the "denied" decision.

Example:

```
/* A process of the Server class will receive the "allowed" decision from
 * the Kaspersky Security Module by calling the
 * Get security interface method if the value of key k1 in the base
 * instance of the table associated with this process
 * is not zero. Otherwise a process of the Server class will receive
 * the "denied" decision from the security module
 * by calling the Get security interface method. */
security src=Server, method=Get {
    assert(m.get {sid : src_sid, key : "k1"} != 0)
}
```

StaticMap security model get_uncommitted expression

```
get_uncommitted {sid: <Sid>, key: <Key>}
```

It returns the value of the specified `key` from the working instance of the table associated with the `sid` resource.

It returns a value of the `Value` type.

It runs incorrectly in the following cases:

- The specified `key` is not in the table associated with the `sid` resource.
- The `sid` resource is not associated with a table from the tables pool of the StaticMap security model object being used.
- The `sid` value is outside of the permissible range.

When the expression runs incorrectly, the Kaspersky Security Module returns the "denied" decision.

Flow security model

The Flow security model associates resources with finite-state machines, receives and modifies the states of finite-state machines, and checks whether the state of the finite-state machine is within the defined set of states. For example, a process can be associated with a finite-state machine to allow or prohibit this process from using storage and/or the network depending on the state of the finite-state machine.

A PSL file containing a description of the Flow security model is located in the KasperskyOS SDK at the following path:

`toolchain/include/nk/flow.psl`

Flow security model object

To use the Flow security model, you need to create an object or objects of this model.

One Flow security model object associates a set of resources with a set of finite-state machines that have the same configuration. A resource can be associated with only one finite-state machine of each Flow security model object.

A Flow security model object has the following parameters:

- `type State` – type that determines the set of states of the finite-state machine (variant type that combines text literals).
- `config` – configuration of the finite-state machine:
  - `states` – set of states of the finite-state machine (must match the set of states defined by the `State` type).
  - `initial` – initial state of the finite-state machine.
  - `transitions` – description of the permissible transitions between states of the finite-state machine.

All parameters of a Flow security model object are required.

Example:

```
policy object service_flow : Flow {
    type State = "sleep" | "started" | "stopped" | "finished"

    config = { states      : ["sleep", "started", "stopped", "finished"]
             , initial     : "sleep"
             , transitions : { "sleep"   : ["started"]
                             , "started" : ["stopped", "finished"]
                             , "stopped" : ["started", "finished"]
                             }
             }
}
```

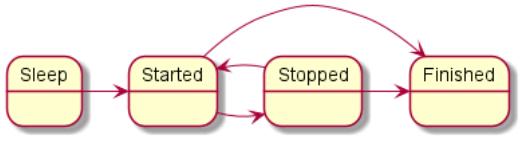


Diagram of finite-state machine states in the example

A Flow security model object can be covered by a security audit. You can also define the audit conditions specific to the Flow security model. To do so, use the following construct in the audit configuration description:

`omit : [<"state 1">[, ...]]` – the audit is not performed if the finite-state machine is in one of the listed states.

It is necessary to create multiple objects of the Flow security model in the following cases:

- You need to configure a security audit differently for different objects of the Flow security model (for example, you can apply different audit profiles or different audit configurations of the same profile for different objects).
- You need to distinguish between calls of methods provided by different objects of the Flow security model (audit data includes the name of the security model method and the name of the object that provides this method, so you can verify that the method of a specific object was called).
- You need to use finite-state machines with different configurations.

Flow security model init rule

```
init {sid : <Sid>}
```

It creates a finite-state machine and associates it with the `sid` resource. The created finite-state machine has the configuration defined in the settings of the Flow security model object being used.

It returns the "granted" result if an association was created between the finite-state machine and the `sid` resource.

It returns the "denied" result in the following cases:

- The `sid` resource is already associated with a finite-state machine of the Flow security model object being used.
- The `sid` value is outside of the permissible range.

Example:

```
/* A process of the Server class will be allowed to start
 * if, at startup initiation, an association will be created
 * between this process and the finite-state machine.
 * Otherwise the startup of the Server-class process will be denied. */
execute dst=Server {
    service_flow.init {sid : dst_sid}
}
```

Flow security model fini rule

```
fini {sid : <Sid>}
```

It deletes the association between the finite-state machine and the `sid` resource. The finite-state machine that is no longer associated with the resource is destroyed.

It returns the "granted" result if the association between the finite-state machine and the `sid` resource was deleted.

It returns the "denied" result in the following cases:

- The `sid` resource is not associated with a finite-state machine of the Flow security model object being used.
- The `sid` value is outside of the permissible range.

Flow security model enter rule

```
enter {sid : <Sid>, state : <State>}
```

It switches the finite-state machine associated with the `sid` resource to the specified `state`.

It returns the "granted" result if the finite-state machine associated with the `sid` resource was switched to the specified `state`.

It returns the "denied" result in the following cases:

- The transition to the specified `state` from the current state is not permitted by the configuration of the finite-state machine associated with the `sid` resource.
- The `sid` resource is not associated with a finite-state machine of the Flow security model object being used.
- The `sid` value is outside of the permissible range.

Example:

```
/* Any client in the solution will be allowed to query
 * a server of the Server class if the finite-state machine
 * associated with this server will be switched to
 * the "started" state when initiating the query. Otherwise
 * any client in the solution will be denied to query
 * a server of the Server class. */
request dst=Server {
    service_flow.enter {sid : dst_sid, state : "started"}
}
```

Flow security model allow rule

```
allow {sid : <Sid>, states : <Set<State>>}
```

It verifies that the state of the finite-state machine associated with the `sid` is in the set of defined `states`.

It returns the "granted" result if the state of the finite-state machine associated with the `sid` resource is in the set of defined `states`.

It returns the "denied" result in the following cases:

- The state of the finite-state machine associated with the `sid` resource is not in the set of defined `states`.

- The `sid` resource is not associated with a finite-state machine of the Flow security model object being used.
- The `sid` value is outside of the permissible range.

Example:

```
/* Any client in the solution is allowed to query a server
 * of the Server class if the finite-state machine associated with this server
 * is in the started or stopped state. Otherwise any client
 * in the solution will be prohibited from querying a server of the Server class. */
request dst=Server {
    service_flow.allow {sid : dst_sid, states : ["started", "stopped"]}
}
```

Flow security model query expression

```
query {sid : <Sid>}
```

It is intended to be used as an expression that verifies fulfillment of the conditions in the `choice` construct (for details on the `choice` construct, see "Binding methods of security models to security events"). It checks the state of the finite-state machine associated with the `sid` resource. Depending on the results of this check, various options for security event handling can be performed.

It runs incorrectly in the following cases:

- The `sid` resource is not associated with a finite-state machine of the Flow security model object being used.
- The `sid` value is outside of the permissible range.

When the expression runs incorrectly, the Kaspersky Security Module returns the "denied" decision.

Example:

```
/* Any client in the solution is allowed to query
 * a server of the ResourceDriver class if the finite-state machine
 * associated with this server is in the
 * "started" or "stopped" state. Otherwise any client in the solution
 * is prohibited from querying a server of the ResourceDriver class. */
request dst=ResourceDriver {
    choice (service_flow.query {sid : dst_sid}) {
        "started"   : grant ()
        "stopped"   : grant ()
        _           : deny ()
    }
}
```

Mic security model

The Mic security model implements mandatory integrity control. In other words, this security model provides the capability to manage data streams between different processes and between processes and the KasperskyOS kernel by controlling the integrity levels of processes, the kernel, and resources that are used via IPC.

> In Mic security model terminology, processes and the kernel are called subjects while resources are called objects. However, the information provided in this section slightly deviates from the terminology of the Mic security model. In this section, the term "object" is not used to refer to a "resource".

Data streams are generated between subjects when the subjects interact via IPC.

The *integrity level of a subject/resource* is the level of trust afforded to the subject/resource. The degree of trust in a subject depends on whether the subject interacts with untrusted external software/hardware systems or whether the subject has a proven quality level, for example. (The kernel has a high level of integrity.) The degree of trust in a resource depends on whether this resource was created by a trusted subject within a software/hardware system running KasperskyOS or if it was received from an untrusted external software/hardware system, for example.

The Mic security model is characterized by the following provisions:

- By default, data streams from subjects with less integrity to subjects with higher integrity are prohibited. You have the option of permitting such data streams if you can guarantee that the subjects with higher integrity will not be compromised.
- A resource consumer is prohibited from writing data to a resource if the integrity level of the resource is higher than the integrity level of the resource consumer.
- By default, a resource consumer is prohibited from reading data from a resource if the integrity level of the resource is lower than the integrity level of the resource consumer. You have the option to allow the resource consumer to perform such an operation if you can guarantee that the resource consumer will not be compromised.

Methods of a Mic security model let you perform the following operations:

- Assign integrity levels to subjects and resources.
- Unassign the integrity level from resources.
- Verify the permissibility of data streams based on a comparison of integrity levels.
- Increase the integrity levels of resources.

A PSL file containing a description of the Mic security model is located in the KasperskyOS SDK at the following path:

`toolchain/include/nk/mic.psl`

For an example of using the Mic security model, we can examine a secure software update for a software/hardware system running KasperskyOS. Four processes are involved in the update:

- `Downloader` is a low-integrity process that downloads a low-integrity update image from a remote server on the Internet.
- `Verifier` is a high-integrity process that verifies the digital signature of the low-integrity update image (high-integrity process that can read data from a low-integrity resource).

- `FileSystem` is a high-integrity process that manages the file system.
- `Updater` is a high-integrity process that applies an update.

A software update is performed according to the following scenario:

1. The `Downloader` downloads an update image and saves it to a file by transferring the contents of the image to the `FileSystem`. A low integrity level is assigned to this file.
2. The `Verifier` receives the update image from the `FileSystem` by reading the high-integrity file, and verifies its digital signature. If the signature is correct, the `Verifier` queries the `FileSystem` so that the `FileSystem` creates a copy of the file containing the update image. A high integrity level is assigned to the new file.
3. The `Updater` receives the update image from the `FileSystem` by reading the high-integrity file, and applies the update.

In this example, the Mic security model ensures that the high-integrity `Updater` process can read data only from a high-integrity update image. As a result, the update can be applied only after the digital signature of the update image is verified.

Mic security model object

To use the Mic security model, you need to create an object or objects of this model. You also need to assign a set of integrity levels for subjects and resources.

A Mic security model object has the following parameters:

- `config` – set of integrity levels or configuration of a set of integrity levels:
  - `degrees` – set of gradations for generating a set of integrity levels.
  - `categories` – set of categories for generating a set of integrity levels.

Examples:

```
policy object mic : Mic {
    config = ["LOW", "MEDIUM", "HIGH"]
}

policy object mic_po : Mic {
    config =
      { degrees    : ["low", "high"]
      , categories : ["net", "log"]
      }
}
```

A set of integrity levels is a partially ordered set that is linearly ordered or contains incomparable elements. The set {LOW, MEDIUM, HIGH} is linearly ordered because all of its elements are comparable to each other. Incomparable elements arise when a set of integrity levels is defined through a set of gradations and a set of categories. In this case, the set of integrity levels L is a Cartesian product of the Boolean set of categories C multiplied by the set of gradations D:

$$L = 2^C \times D.$$

The `degrees` and `categories` parameters in this example define the following set:

{

{}/low, {}/high,

{net}/low, {net}/high,

{log}/low, {log}/high,

{net,log}/low, {net,log}/high

}

In this set, {} means an empty set.

The order relation between elements of the set of integrity levels *L* is defined as follows:

$$l_i = A/B,$$
$$l_j = E/F,$$
$$l_i \prec l_j \Leftrightarrow \begin{cases} A \subseteq E, \\ B \leq F. \end{cases}$$

According to this order relation, the *j*th element exceeds the *i*th element if the subset of categories *E* includes the subset of categories *A*, and gradation *F* is greater than or equal to gradation *A*. Examples of comparing elements of the set of integrity levels *L*:

- The {net,log}/high element exceeds the {log}/low element because the "high" gradation is greater than the "low" gradation, and the subset of categories {net,log} includes the subset of categories {log}.
- The {net,log}/low element exceeds the {log}/low element because the levels of gradations for these elements are equal, and the subset of categories {net,log} includes the subset of categories {log}.
- The {net,log}/high element is the highest because it exceeds all other elements.
- The {}/low element is the lowest because all other elements exceed this element.
- The {net}/low and {log}/high elements are incomparable because the "high" gradation is greater than the "low" gradation but the subset of categories {log} does not include the subset of categories {net}.
- The {net,log}/low and {log}/high elements are incomparable because the "high" gradation is greater than the "low" gradation but the subset of categories {log} does not include the subset of categories {net,log}.

> For subjects and resources that have incomparable integrity levels, the Mic security model provides conditions that are analogous to the conditions that the security model provides for subjects and resources that have comparable integrity levels.
> By default, data streams between subjects that have incomparable integrity levels are prohibited. However, you have the option to allow such data streams if you can guarantee that the subjects receiving data will not be compromised. A resource consumer is prohibited from writing data to a resource and read data from a resource if the integrity level of the resource is incomparable to the integrity level of the resource consumer. You have the option to allow the resource consumer to read data from a resource if you can guarantee that the resource consumer will not be compromised.

A Mic security model object can be covered by a security audit. There are no audit conditions specific to the Mic security model.

It is necessary to create multiple objects of the Mic security model in the following cases:

- You need to configure a security audit differently for different objects of the Mic security model (for example, you can apply different audit profiles or different audit configurations of the same profile for different objects).
- You need to distinguish between calls of methods provided by different objects of the Mic security model (audit data includes the name of the security model method and the name of the object that provides this method, so you can verify that the method of a specific object was called).
- You need to use multiple variants of mandatory integrity control that may have different sets of integrity levels for subjects and resources, for example.

Mic security model create rule

```
create { source    : <Sid>
       , target    : <Sid>
       , container : <Sid | ()>
       , driver    : <Sid>
       , level     : <Level | ... | ()>
       }
```

Assign the specified integrity `level` to the `target` resource in the following situation:

- The `source` process initiates creation of the `target` resource.
- The `target` resource is managed by the `driver` subject, which is the resource provider or the KasperskyOS kernel.
- The `container` resource is a container for the `target` resource (for example, a directory is a container for files and/or other directories).

If the `container` field has the value `()`, the `target` resource is considered to be the root resource, which means that it has no container.

To define the integrity `level`, values of the `Level` type are used:

```
type Level = LevelFull | LevelNoCategory

type LevelFull =
  { degree     : Text | ()
  , categories : List<Text> | ()
  }

type LevelNoCategory = Text
```

The rule returns the "granted" result if a specific integrity `level` was assigned to the `target` resource.

The rule returns the "denied" result in the following cases:

- The `level` value exceeds the integrity level of the `source` process, `driver` subject or `container` resource.

- The `level` value is incomparable to the integrity level of the `source` process, `driver` subject or `container` resource.
- An integrity level was not assigned to the `source` process, `driver` subject, or `container` resource.
- The value of `source`, `target`, `container` or `driver` is outside of the permissible range.

Example:

```
/* A server of the updater.Realmserv class will be allowed to respond to
 * queries of any client in the solution calling the resolve method
 * of the realm.Reader endpoint if the resource whose creation is requested
 * by the client will be assigned the LOW integrity level during response initiation.
 * Otherwise a server of the updater.Realmserv class will be prohibited from
responding to
 * queries of any client calling the resolve method of the realm.Reader endpoint. */
response src=updater.Realmserv,
         endpoint=realm.Reader {
             match method=resolve {
                 mic.create { source : dst_sid
                            , target : message.handle.handle
                            , container : ()
                            , driver : src_sid
                            , level : "LOW"
                            }
             }
}
```

Mic security model delete rule

```
delete { source    : <Sid>
       , target    : <Sid>
       , container : <Sid | ()>
       , driver    : <Sid>
       }
```

Unassigns the integrity level from the `target` resource in the following situation:

- The `source` process initiates deletion of the `target` resource.
- The `target` resource is managed by the `driver` subject, which is the resource provider or the KasperskyOS kernel.
- The `container` resource is a container for the `target` resource (for example, a directory is a container for files and/or other directories).

If the `container` field has the value `()`, the `target` resource is considered to be the root resource, which means that it has no container.

The rule returns the "granted" result if it unassigned the integrity level from the `target` resource.

The rule returns the "denied" result in the following cases:

- The integrity level of the `target` resource exceeds the integrity level of the `source` process or `driver` subject.
- The integrity level of the `target` resource is incomparable to the integrity level of the `source` process or `driver` subject.
- An integrity level was not assigned to the `source` process, `driver` subject, `target` resource or `container` resource.
- The value of `source`, `target`, `container` or `driver` is outside of the permissible range.

Example:

```
/* Any client in the solution will be allowed to query a server of the foo class
 * updater.Realmserv class by calling the del method of the realm.Reader endpoint if
the
 * integrity level will be unassigned from the resource whose deletion is requested by
the client.
 * Otherwise, any client in the solution will be prohibited from querying a server of
the
 * updater.Realmserv class by calling the del method of the realm.Reader endpoint. */
request dst=updater.Realmserv,
        endpoint=realm.Reader {
            match method=del {
                mic.delete { source : src_sid
                           , target : message.handle.handle
                           , container : ()
                           , driver : dst_sid
                           }
               }
}
```

Mic security model execute rule

```
execute <ExecuteImage | ExecuteLevel>

type ExecuteImage =
  { image  : Sid
  , target : Sid
  , level  : Level | ... | ()
  , levelR : Level | ... | ()
  }

type ExecuteLevel =
  { image  : Sid | ()
  , target : Sid
  , level  : Level | ...
  , levelR : Level | ... | ()
  }
```

This assigns the specified integrity `level` to the `target` subject and defines the minimum integrity level of subjects and resources from which this subject can receive data (`levelR`). The code of the `target` subject is in the `image` executable file.

If the `level` field has the value `()`, the integrity level of the `image` executable file is assigned to the `target` subject. If the `image` field has the value `()`, the `level` field must have a value other than `()`.

If the `levelR` field has the value `()`, the `levelR` integrity level is assumed to be equal to the integrity level of the `target` subject.

To define the integrity `level` and `levelR`, values of the `Level` type are used. For the definition of the `Level` type, see "Mic security model create rule".

The rule returns the "granted" result if it assigned the specified integrity `level` to the `target` subject and defined the minimum integrity level of subjects and resources from which this subject can receive data (`levelR`).

The rule returns the "denied" result in the following cases:

- The `level` value exceeds the integrity level of the `image` executable file.
- The `level` value is incomparable to the integrity level of the `image` executable file.
- The value of `levelR` exceeds the value of `level`.
- The `level` and `levelR` values are incomparable.
- An integrity level was not assigned to the `image` executable file.
- The `image` or `target` value is outside of the permissible range.

Example:

```
/* A process of the updater.Manager class will be allowed to start
 * if, at startup initiation, this process will be assigned
 * the integrity level LOW, and the minimum
 * integrity level will be defined for the processes and resources from which this
 * process can received data (LOW). Otherwise the startup of a process
 * of the updater.Manager class will be denied. */
execute src=Einit, dst=updater.Manager, method=main {
    mic.execute { target : dst_sid
                , image : ()
                , level : "LOW"
                , levelR : "LOW"
                }
}
```

Mic security model upgrade rule

```
upgrade { source    : <Sid>
        , target    : <Sid>
        , container : <Sid | ()>
        , driver    : <Sid>
        , level     : <Level | ...>
        }
```

This elevates the previously assigned integrity level of the `target` resource to the specified `level` in the following situation:

- The `source` process initiates elevation of the integrity level of the `target` resource.
- The `target` resource is managed by the `driver` subject, which is the resource provider or the KasperskyOS kernel.
- The `container` resource is a container for the `target` resource (for example, a directory is a container for files and/or other directories).

If the `container` field has the value `()`, the `target` resource is considered to be the root resource, which means that it has no container.

To define the integrity `level`, values of the `Level` type are used. For the definition of the `Level` type, see "Mic security model create rule".

The rule returns the "granted" result if it elevated the previously assigned integrity level of the `target` resource to the `level` value.

The rule returns the "denied" result in the following cases:

- The `level` value does not exceed the integrity level of the `target` resource.
- The `level` value exceeds the integrity level of the `source` process, `driver` subject or `container` resource.
- The integrity level of the `target` resource exceeds the integrity level of the `source` process.
- An integrity level was not assigned to the `source` process, `driver` subject, or `container` resource.
- The value of `source`, `target`, `container` or `driver` is outside of the permissible range.

Mic security model call rule

```
call {source : <Sid>, target : <Sid>}
```

This verifies the permissibility of data streams from the `target` subject to the `source` subject.

It returns the "allowed" result in the following cases:

- The integrity level of the `source` subject does not exceed the integrity level of the `target` subject.
- The integrity level of the `source` subject exceeds the integrity level of the `target` subject, but the minimum integrity level of subjects and resources from which the `source` subject can receive data does not exceed the integrity level of the `target` subject.
- The integrity level of the `source` subject is incomparable to the integrity level of the `target` subject, but the minimum integrity level of subjects and resources from which the `source` subject can receive data does not exceed the integrity level of the `target` subject.

It returns the "denied" result in the following cases:

- The integrity level of the `source` subject exceeds the integrity level of the `target` subject, and the minimum integrity level of subjects and resources from which the `source` subject can receive data exceeds the integrity level of the `target` subject.
- The integrity level of the `source` subject exceeds the integrity level of the `target` subject, and the minimum integrity level of subjects and resources from which the `source` subject can read data is incomparable to the integrity level of the `target` subject.
- The integrity level of the `source` subject is incomparable to the integrity level of the `target` subject, and the minimum integrity level of subjects and resources from which the `source` subject can receive data exceeds the integrity level of the `target` subject.
- The integrity level of the `source` subject is incomparable to the integrity level of the `target` subject, and the minimum integrity level of subjects and resources from which the `source` subject can receive data is incomparable to the integrity level of the `target` subject.
- An integrity level was not assigned to the `source` subject or to the `target` subject.
- The `source` or `target` value is outside of the permissible range.

Example:

```
/* Any client in the solution is allowed to query
 * any server (kernel) if data streams from
 * the server (kernel) to the client are permitted by the
 * Mic security model. Otherwise any client in the solution
 * is prohibited from querying any server (kernel). */
request {
    mic.call { source : src_sid
             , target : dst_sid
             }
}
```

Mic security model invoke rule

```
invoke {source : <Sid>, target : <Sid>}
```

This verifies the permissibility of data streams from the `source` subject to the `target` subject.

It returns the "granted" result if the integrity level of the `target` subject does not exceed the integrity level of the `source` subject.

It returns the "denied" result in the following cases:

- The integrity level of the `target` subject exceeds the integrity level of the `source` subject.
- The integrity level of the `target` subject is incomparable to the integrity level of the `source` subject.
- An integrity level was not assigned to the `source` subject or to the `target` subject.
- The `source` or `target` value is outside of the permissible range.

Mic security model read rule

```
read {source : <Sid>, target : <Sid>}
```

This verifies that the `source` resource consumer is allowed to read data from the `target` resource.

It returns the "allowed" result in the following cases:

- The integrity level of the `source` resource consumer does not exceed the integrity level of the `target` resource.
- The integrity level of the `source` resource consumer exceeds the integrity level of the `target` resource, but the minimum integrity level of subjects and resources from which the `source` resource consumer can receive data does not exceed the integrity level of the `target` resource.
- The integrity level of the `source` resource consumer is incomparable to the integrity level of the `target` resource, but the minimum integrity level of subjects and resources from which the `source` resource consumer can receive data does not exceed the integrity level of the `target` resource.

It returns the "denied" result in the following cases:

- The integrity level of the `source` resource consumer exceeds the integrity level of the `target` resource, and the minimum integrity level of subjects and resources from which the `source` resource consumer can receive data exceeds the integrity level of the `target` resource.
- The integrity level of the `source` resource consumer exceeds the integrity level of the `target` resource, and the minimum integrity level of subjects and resources from which the `source` resource consumer can receive data is incomparable to the integrity level of the `target` resource.
- The integrity level of the `source` resource consumer is incomparable to the integrity level of the `target` resource, and the minimum integrity level of subjects and resources from which the `source` resource consumer can receive data exceeds the integrity level of the `target` resource.
- The integrity level of the `source` resource consumer is incomparable to the integrity level of the `target` resource, and the minimum integrity level of subjects and resources from which the `source` resource consumer can receive data is incomparable to the integrity level of the `target` resource.
- An integrity level was not assigned to the `source` resource consumer or to the `target` resource.
- The `source` or `target` value is outside of the permissible range.

Example:

```
/* Any client in the solution is allowed to query a server of
 * the updater.Realmserv class by calling the read method of the
 * realm.Reader service if the Mic security model permits
 * this client to read data from the resource needed by
 * this client. Otherwise any client in the solution is prohibited from
 * querying a server of the updater.Realmserv class by calling
 * the read method of the realm.Reader endpoint. */
request dst=updater.Realmserv,
        endpoint=realm.Reader {
```

```
            match method=read {
                mic.read { source : src_sid
                         , target : message.handle.handle
                         }
               }
}
```

Mic security model write rule

```
write {source : <Sid>, target : <Sid>}
```

This verifies that the `source` resource consumer is allowed to write data to the `target` resource.

It returns the "granted" result if the integrity level of the `target` resource does not exceed the integrity level of the `source` resource consumer.

It returns the "denied" result in the following cases:

- The integrity level of the `target` resource exceeds the integrity level of the `source` resource consumer.
- The integrity level of the `target` resource is incomparable to the integrity level of the `source` resource consumer.
- An integrity level was not assigned to the `source` resource consumer or to the `target` resource.
- The `source` or `target` value is outside of the permissible range.

Mic security model query_level expression

```
query_level {source : <Sid>}
```

It is intended to be used as an expression that verifies fulfillment of the conditions in the `choice` construct (for details on the `choice` construct, see "Binding methods of security models to security events"). It checks the integrity level of the `source` resource or subject. Depending on the results of this check, various options for security event handling can be performed.

It runs incorrectly in the following cases:

- An integrity level was not assigned to the subject or `source` resource.
- The `source` value is outside of the permissible range.

When the expression runs incorrectly, the Kaspersky Security Module returns the "denied" decision.

Methods of KasperskyOS core endpoints

From the perspective of the Kaspersky Security Module, the KasperskyOS kernel is a container of components that provide endpoints. The list of kernel components is provided in the `Core.edl` file located in the `sysroot-*-kos/include/kl/core` directory of the KasperskyOS SDK. This directory also contains the CDL and IDL files for the formal specification of the kernel.

Methods of core endpoints can be divided into secure methods and potentially dangerous methods. Potentially dangerous methods could be used by a cybercriminal in a compromised solution component to cause a denial of service, set up covert data transfer, or hijack an I/O device. Secure methods cannot be used for these purposes.

Access to methods of core endpoints must be restricted as much as possible by the solution security policy (according to the Least Privilege principle). For that, the following requirements must be fulfilled:

1. Access to a secure method must be granted only to the solution components that require this method.
2. Access to a potentially dangerous method must be granted only to the trusted solution components that require this method.
3. Access to a potentially dangerous method must be granted to untrusted solution components that require this method only if the verifiable access conditions limit the possibilities of malicious use of this method, or if the impact from malicious use of this method is acceptable from a security perspective.

   For example, an untrusted component may be allowed to use a limited set of I/O ports that do not allow this component to take control of I/O devices. In another example, covert data transfer between untrusted components may be acceptable from a security perspective.

Virtual memory endpoint

This endpoint is intended for managing virtual memory.

Information about methods of the endpoint is provided in the table below.

Methods of the vmm.VMM endpoint (kl.core.VMM interface)

Method	Method purpose and parameters	Potential danger of the method
`Allocate`	Purpose Allocates (reserves and optionally commits) a virtual memory region. Parameters • [in] `addr` – preferred base address of the virtual memory region, or `0` for the base address to be selected automatically. • [in] `size` – size of the virtual memory region in bytes. • [in] `flags` – flags defining the parameters of the virtual memory region. • [out] `va` – base address of the allocated virtual memory region.	Allows the following: • Exhaust the kernel memory by creating a multitude of objects within it. • Exhaust the RAM.

	• [out] `rc` – return code.	
`Commit`	Purpose Commits a virtual memory region that was reserved by the `Allocate` method. Parameters • [in] `va` – base address of the virtual memory region. • [in] `size` – size of the virtual memory region in bytes. • [in] `flags` – fictitious parameter. • [out] `rc` – return code.	Exhausts RAM.
`Decommit`	Purpose Decommits a virtual memory region. Parameters • [in] `va` – base address of the virtual memory region. • [in] `size` – size of the virtual memory region in bytes. • [out] `rc` – return code.	N/A
`Protect`	Purpose Modifies the access rights to the virtual memory region. Parameters • [in] `va` – base address of the virtual memory region. • [in] `size` – size of the virtual memory region in bytes. • [in] `flags` – flags defining the access rights to the virtual memory region. • [out] `rc` – return code.	N/A
`Free`	Purpose	N/A

	Frees up the virtual memory region. Parameters • [in] `va` – base address of the virtual memory region. • [in] `size` – size of the virtual memory region in bytes. • [out] `rc` – return code.	
`Query`	Purpose Gets information about a virtual memory page. Parameters • [in] `va` – address included in the virtual memory page. • [out] `info` – sequence containing information about a virtual memory page. • [out] `rc` – return code.	N/A
`MdlCreate`	Purpose Creates an MDL buffer. Parameters • [in] `size` – size of the MDL buffer in bytes. • [in] `prot` – flags defining the access rights to the MDL buffer. • [out] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the MDL buffer. • [out] `rc` – return code.	Allows the following: • Exhaust the kernel memory by creating a multitude of objects within it. • Exhaust the RAM.
`MdlCreateFromVm`	Purpose Creates an MDL buffer from physical memory that is mapped to the defined virtual memory region and maps the created MDL buffer to this region.	Allows the following: • Exhaust the kernel memory by creating a multitude of objects within it. • Exhaust the RAM.

	Parameters • [in] `va` – base address of the virtual memory region. • [in] `size` – size of the virtual memory region in bytes. • [in] `flags` – flags defining the access rights to the MDL buffer. • [out] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the MDL buffer. • [out] `rc` – return code.	
`MdlGetSize`	Purpose Gets the size of the MDL buffer. Parameters • [in] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the MDL buffer. • [out] `size` – size of the MDL buffer in bytes. • [out] `rc` – return code.	N/A
`MdlMap`	Purpose Reserves a virtual memory region and maps the MDL buffer to it. Parameters • [in] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the MDL buffer. • [in] `offset` – offset (in bytes) in the MDL buffer where mapping should start. • [in] `length` – size (in bytes) of the part of the MDL buffer that needs to be mapped.	Allows the following: • Create shared memory for interprocess communication concealed from the security module if multiple processes own the handles of one MDL buffer (the handle permissions masks must allow mapping of the MDL buffer). • Exhaust the kernel memory by creating a multitude of objects within it.

	• [in] `hint` – preferred base address of the virtual memory region, or `0` for the base address to be selected automatically. • [in] `prot` – flags defining the parameters of the virtual memory region. • [out] `address` – base address of the virtual memory region. • [out] `rc` – return code.	
`MdlClone`	Purpose Creates an MDL buffer based on an existing one. The MDL buffer is created from the same regions of physical memory as the original buffer. Parameters • [in] `originHandle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the original MDL buffer. • [in] `offset` – offset (in bytes) in the original MDL buffer where duplication should start. • [in] `length` – size (in bytes) of the part of the original MDL buffer that needs to be duplicated. • [out] `cloneHandle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the created MDL buffer. • [out] `rc` – return code.	Allows the kernel memory to be used up by creating a multitude of objects within it.

I/O endpoint

This endpoint is intended for working with I/O ports, MMIO, DMA, and interrupts.

Information about methods of the endpoint is provided in the table below.

Methods of the io.IO endpoint (kl.core.IO interface)

Method	Method purpose and parameters	Potential danger of the method
`RegisterPort`	Purpose Registers a sequence of I/O ports. Parameters • [in] `base` – address of the first I/O port in the sequence. • [in] `size` – number of I/O ports in the sequence. • [out] `resource` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the sequence of I/O ports. • [out] `rc` – return code.	Allows the following: • Hijack I/O ports (it is recommended to monitor the address of the first I/O port and the number of I/O ports in the sequence). • Exhaust the kernel memory by creating a multitude of objects within it.
`RegisterMmio`	Purpose Registers an MMIO memory region. Parameters • [in] `base` – base address of the MMIO memory region. • [in] `size` – size of the MMIO memory region in bytes. • [out] `resource` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the MMIO memory region. • [out] `rc` – return code.	Allows the kernel memory to be used up by creating a multitude of objects within it.
`RegisterDma`	Purpose Creates a DMA buffer. Parameters • [in] `size` – size of the DMA buffer in bytes. • [in] `flags` – flags defining the DMA buffer parameters.	Allows the following: • Exhaust the kernel memory by creating a multitude of objects within it. • Exhaust the RAM.

	• [in] `order` – parameter defining the minimum number of memory pages (*2^order*) in a block. • [out] `resource` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the DMA buffer. • [out] `rc` – return code.	
`RegisterIrq`	Purpose Registers an interrupt. Parameters • [in] `irq` – interrupt number. • [out] `resource` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the interrupt. • [out] `rc` – return code.	Allows the kernel memory to be used up by creating a multitude of objects within it.
`MapMem`	Purpose Reserves the virtual memory region and maps the MMIO memory region to it. Parameters • [in] `resource` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the MMIO memory region. • [in] `prot` – flags defining the access rights to the virtual memory region. • [in] `attr` – flags defining the parameters of the virtual memory region (for example, use of caching). • [out] `address` – base address of the virtual memory region. • [out] `mapping` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle is used to free the virtual memory region. • [out] `rc` – return code.	Allows the following: • Take control of a device when mapping an MMIO memory region to a virtual memory region (it is recommended to monitor the base address and size of the MMIO memory region when the `RegisterMmio` method is called). • Create shared memory for interprocess communication concealed from the security module if multiple processes own the handles of one MMIO memory region (the handle permissions masks must allow mapping of the MMIO memory region). • Exhaust the kernel memory by creating a multitude of objects within it.
`PermitPort`	Purpose	Allows the following:

	Opens access to I/O ports. Parameters • [in] `resource` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the sequence of I/O ports. • [out] `access` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle is used to close access to I/O ports. • [out] `rc` – return code.	• Take control of a device (it is recommended to monitor the address of the first I/O port and the number of I/O ports in the sequence when the `RegisterPort` method is called). • Exhaust the kernel memory by creating a multitude of objects within it.
`AttachIrq`	Purpose Attaches the calling thread to an interrupt. Parameters • [in] `resource` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the interrupt. • [in] `flags` – flags defining the interrupt parameters. • [out] `delivery` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle is the client IPC handle that is used by the interrupt handler. • [out] `rc` – return code.	Allows the following: • Take CPU time from all other threads, including from other processes (the thread that attached to the interrupt will become a real-time thread). • Make it impossible to terminate a process from another process (the process whose thread was attached to the interrupt cannot be terminated from another process). • Stop the operating system (if an unhandled exception occurs in the thread handling an interrupt, the operating system stops). • Lock, delay, or incorrectly handle an interrupt (it is recommended to monitor the interrupt number when the `RegisterIrq` method is called). • Exhaust the kernel memory by creating a multitude of objects within it.
`DetachIrq`	Purpose Sends a request to a thread. When this request is fulfilled, the thread must detach from the interrupt.	Stops interrupt handling in another process.

	Parameters • [in] `resource` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the interrupt. • [out] `rc` – return code.	
`EnableIrq`	Purpose Allows (unmasks) an interrupt. Parameters • [in] `resource` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the interrupt. • [out] `rc` – return code.	Allows an interrupt at the system level.
`DisableIrq`	Purpose Denies (masks) an interrupt. Parameters • [in] `resource` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the interrupt. • [out] `rc` – return code.	Denies an interrupt at the system level.
`ModifyDma`	Purpose Modifies the DMA buffer cache settings. Parameters • [in] `resource` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the DMA buffer. • [in] `flags` – flags defining the DMA buffer caching parameters. • [out] `rc` – return code.	N/A
`MapDma`	Purpose Reserves a virtual memory region and maps the DMA buffer to it. Parameters	Allows the following: • Create shared memory for interprocess communication concealed from the security module if multiple processes own the handles of one DMA

	• [in] `resource` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the DMA buffer. • [in] `offset` – offset (in bytes) in the DMA buffer where mapping should start. • [in] `length` – size (in bytes) of the part of the DMA buffer that needs to be mapped. • [in] `hint` – preferred base address of the virtual memory region, or `0` for the base address to be selected automatically. • [in] `prot` – flags defining the access rights to the virtual memory region. • [out] `address` – base address of the virtual memory region. • [out] `mapping` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle is used to free the virtual memory region. • [out] `rc` – return code.	buffer (the handle permissions masks must allow mapping of the DMA buffer). • Exhaust the kernel memory by creating a multitude of objects within it.
`DmaGetInfo`	Purpose Gets information about a DMA buffer. Parameters • [in] `resource` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the DMA buffer. • [out] `flags` – flags indicating the DMA parameters. • [out] `order` – parameter indicating the minimum number of memory pages (2^order) in a block. • [out] `size` – size of the DMA buffer in bytes. • [out] `count` – number of blocks. • [out] `frames` – sequence containing the addresses and sizes of blocks. • [out] `rc` – return code.	N/A

`DmaGetPhysInfo`	Purpose Gets information about the physical memory that was used to create a DMA buffer. Parameters • [in] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the DMA buffer. • [out] `count` – number of blocks. • [out] `frames` – sequence containing the addresses and sizes of blocks. • [out] `rc` – return code.	N/A
`BeginDma`	Purpose Opens access to a DMA buffer for a device. Parameters • [in] `resource` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the DMA buffer. • [out] `iomapping` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the kernel object that contains the addresses and sizes of blocks required by the device to use the DMA buffer. The memory addresses used by the device can be physical addresses or virtual addresses depending on whether the IOMMU is enabled. • [out] `rc` – return code.	Allows the kernel memory to be used up by creating a multitude of objects within it.

Threads endpoint

This endpoint is intended for managing threads.

Information about methods of the endpoint is provided in the table below.

Methods of the thread.Thread endpoint (kl.core.Thread interface)

Method	Method purpose and parameters	Potential danger of the method
`Create`	Purpose	Allows the following:

	Creates a thread. Parameters • [out] `thread` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the thread. • [out] `tid` – thread ID (TID). • [in] `priority` – thread priority. • [in] `stackSize` – thread stack limit (in bytes), or `0` to use the default size that was defined when the process was created. • [in] `routine` – pointer to the function that is called when the thread starts. • [in] `context` – pointer to the function executed by the thread. • [in] `context2` – pointer to the parameters passed to the function defined via the `context` parameter. • [in] `flags` – flags defining the parameters for creating the thread. • [out] `rc` – return code.	• Create a real-time thread that takes up all the CPU time from other threads, including from other processes (it is recommended to monitor thread creation parameters). • Create a multitude of threads (including with high priority) to reduce the CPU time available to the threads of other processes (it is recommended to monitor thread priority). • Exhaust the RAM. • Exhaust the kernel memory by creating a multitude of objects within it.
`OpenCurrent`	Purpose Creates the handle of the calling thread. Parameters • [out] `thread` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the thread. • [out] `rc` – return code.	N/A
`Suspend`	Purpose	Locks a thread that has captured a synchronization object that was created in

	Locks the calling thread. Parameters • [out] `rc` – return code.	shared memory and is anticipated by a thread of another process. As a result, the thread of the other process may be locked indefinitely.
`Resume`	Purpose Resumes execution of a locked thread. Parameters • [in] `thread` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the thread. • [out] `rc` – return code.	N/A
`Terminate`	Purpose Terminates a thread. Parameters • [in] `thread` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the thread. • [in] `code` – thread exit code. • [out] `rc` – return code.	N/A
`Exit`	Purpose Terminates the calling thread. Parameters • [in] `code` – thread exit code. • [out] `rc` – return code.	N/A
`Wait`	Purpose Locks the calling thread until the defined thread is terminated. Parameters	N/A

	• [in] `thread` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the thread. • [in] `msec` – thread termination timeout (in milliseconds). • [out] `code` – thread exit code. • [out] `rc` – return code.	
`SetPriority`	Purpose Defines the priority of a thread. Parameters • [in] `thread` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the thread. • [in] `priority` – thread priority. • [out] `rc` – return code.	Allows the priority of a thread to be elevated to reduce the CPU time available to all other threads, including from other processes. It is recommended to monitor thread priority.
`SetTls`	Purpose Defines the base address of the Thread Local Storage (TLS) for the calling thread. Parameters • [in] `va` – pointer to the local memory of the thread. • [out] `rc` – return code.	N/A
`Sleep`	Purpose Locks the calling thread for the specified duration. Parameters • [in] `mdelay` – thread lockout duration (in milliseconds). • [out] `rc` – return code.	N/A

`GetInfo`	Purpose Gets information about a thread. Parameters • [in] `thread` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the thread. • [out] `info` is the structure containing the base address of the thread stack and its size (in bytes), and the thread identifier (TID). • [out] `rc` – return code.	N/A
`DetachIrq`	Purpose Detaches the calling thread from the interrupt handled in its context. Parameters • [out] `rc` – return code.	N/A
`GetAffinity`	Purpose Gets a thread affinity mask. Parameters • [in] `thread` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the thread. • [out] `mask` – thread affinity mask. • [out] `rc` – return code.	N/A
`SetAffinity`	Purpose Defines a thread affinity mask. Parameters • [in] `thread` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the thread.	N/A

	• [in] `mask` – thread affinity mask. • [out] `rc` – return code.	
`SetSchedPolicy`	Purpose Defines the scheduler class and priority of the thread. Parameters • [in] `thread` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the thread. • [in] `policy` – thread scheduler class. • [in] `priority` – thread priority. • [in] `param` – union containing parameters of a thread scheduler class. • [out] `rc` – return code.	Allows the following: • Convert a thread into a real-time thread that takes up all the CPU time from all other threads, including from other processes (it is recommended to monitor the thread scheduler class). • Elevate the priority of a thread to reduce the CPU time available to all other threads, including from other processes (it is recommended to monitor thread priority).
`GetSchedPolicy`	Purpose Gets information about the scheduler class and priority of a thread. Parameters • [in] `thread` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the thread. • [out] `policy` – thread scheduler class. • [out] `priority` – thread priority. • [out] `param` – union containing parameters of a thread scheduler class. • [out] `rc` – return code.	N/A

Handles endpoint

This endpoint is intended for performing operations with handles.

Information about methods of the endpoint is provided in the table below.

Methods of the handle.Handle endpoint (kl.core.Handle interface)

Method	Method purpose and parameters	Potential danger of the method
`Copy`	Purpose Duplicates a handle. As a result of duplication, the calling process receives the handle descendant. Parameters • [in] `inHandle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle field contains the original handle. • [in] `newRightsMask` – permissions mask of the handle descendant. • [in] `copyBadge` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the resource transfer context object. • [out] `outHandle` – value whose binary representation consists of multiple fields, including a field for the handle descendant and a field for the permissions mask of the handle descendant. • [out] `rc` – return code.	Allows the kernel memory to be used up by creating a multitude of objects within it.
`CreateUserObject`	Purpose Creates a handle. Parameters • [in] `type` – handle type. • [in] `rights` – handle permissions mask. • [in] `context` – pointer to the data that should be associated with the handle. • [in] `ipcChannel` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle is the server IPC handle.	Allows the kernel memory to be used up by creating a multitude of objects within it.

	• [in] `riid` – endpoint ID (RIID). • [out] `handle` – value whose binary representation consists of multiple fields, including a field for the created handle and a field for the permissions mask of the created handle. • [out] `rc` – return code.	
`Close`	Purpose Closes a handle. Parameters • [in] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. • [out] `rc` – return code.	N/A
`Connect`	Purpose Creates and connects the client, server, and listener IPC handles. Parameters • [in] `server` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the server process. • [in] `srListener` – listener handle from the handle space of the server process, or the value `0xFFFFFFFF` to create it. • [in] `createSrEndpoint` – value that defines whether or not to create a server IPC handle in the handle space of the server process (`0` means no, and any other number means yes). • [in] `client` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the client process. • [out] `outSrListener` – listener handle from the handle space of the server process. • [out] `outSrEndpoint` – server IPC handle from the handle space of the server process. • [out] `outClEndpoint` – client IPC handle from the handle space of the client process. • [out] `rc` – return code.	Allows the kernel memory to be used up by creating a multitude of objects within it.
`SecurityConnect`	Purpose	Allows a multitude of possible

	Creates a client IPC handle for querying the Kaspersky Security Module through the security interface. Parameters • [out] `client` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. • [out] `rc` – return code.	kernel process handle values to be used up.
`GetSidByHandle`	Purpose Receives a security ID (SID) based on a handle. Parameters • [in] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. • [out] `sid` – security ID (SID). • [out] `rc` – return code.	N/A
`Revoke`	Purpose Closes a handle and revokes its descendants. Parameters • [in] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. • [out] `rc` – return code.	N/A
`RevokeSubtree`	Purpose Revokes the handles that make up the inheritance subtree of the specified handle. Parameters • [in] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handles forming the inheritance subtree of this handle are revoked. • [in] `badge` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the resource transfer context object that defines the inheritance subtree of the handles to revoke. The root node of this subtree is the handle that was generated by the transfer or duplication of the handle that is defined through the `handle` parameter and is associated with the resource transfer context object.	N/A

	• [out] `rc` – return code.	
`CreateBadge`	Purpose Creates a resource transfer context object and configures a notification mechanism for monitoring the life cycle of this object. Parameters • [in] `notify` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the notification receiver. • [in] `notifyContext` – ID of the "resource–event mask" entry in the notification receiver. • [in] `badgeContext` – pointer to the data that should be associated with the handle transfer. • [out] `badge` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the resource transfer context object. • [out] `rc` – return code.	Allows the kernel memory to be used up by creating a multitude of objects within it.

Processes endpoint

This endpoint is intended for managing processes.

Information about methods of the endpoint is provided in the table below.

Methods of the task.Task endpoint (kl.core.Task interface)

Method	Method purpose and parameters	Potential danger of the method
`Create`	Purpose Creates a process. Parameters • [in] `name` – process name. • [in] `eiid` – process class name. • [in] `path` – name of the executable file in ROMFS. • [in] `stackSize` – thread stack limit (in bytes) used by default when creating process threads.	Allows the following: • Create a process that will be privileged from the perspective of the solution security policy (indicating the name of the process class with privileges). • Reserve a process name so that another process with this name cannot be created. • Create a process that will cause the operating system to stop if an unhandled exception occurs.

	• [in] `priority` – priority of the initial thread. • [in] `flags` – flags defining the parameters for creating the process. • [out] `child` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the created process. • [out] `rc` – return code.	• Load code from an executable file into process memory for subsequent execution of that code. • Exhaust RAM by creating a multitude of processes. • Exhaust the kernel memory by creating a multitude of objects within it.
`LoadSeg`	Purpose Loads an ELF image segment into process memory from the MDL buffer. Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process. • [in] `mdl` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the MDL buffer containing the ELF image segment. • [in] `segAttr` – structure containing the parameters for loading the ELF image segment. • [out] `rc` – return code. • [out] `retaddr` – base address of the virtual memory region of the process where the ELF image segment is loaded.	Allows code to be loaded into process memory for subsequent execution of that code.
`VmReserve`	Purpose Reserves the virtual memory region in a process that was created as an empty process.	Allows the following: • Exhaust the kernel memory by creating a multitude of objects within it.

	Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process. • [in] `addr` – preferred base address of the virtual memory region, or `0` for the address to be selected automatically. • [in] `size` – size of the virtual memory region in bytes. • [in] `flags` – flags defining the parameters of the virtual memory region. • [out] `outAddr` – base address of the reserved virtual memory region. • [out] `rc` – return code.	• Reserve virtual memory regions in another process that was created as an empty process and has not yet been started (if its handle is available). (The handle permissions mask must allow reservation of virtual memory.)
`VmFree`	Purpose Frees the virtual memory region that was reserved by calling the `VmReserve` method in a process that was created as an empty process. Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process. • [in] `addr` – base address of the virtual memory region. • [in] `size` – size of the virtual memory region in bytes. • [out] `rc` – return code.	Frees virtual memory regions in another process that was created as an empty process and has not yet been started (if its handle is available). (The handle permissions mask must allow freeing of virtual memory.)
`SetEntry`	Purpose Defines the program entry point and the ELF image load offset.	Creates conditions for executing code loaded into process memory.

	Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process. • [in] `state` – structure containing the address of the program entry point and the ELF image load offset (in bytes). • [out] `rc` – return code.	
`LoadElfSyms`	Purpose Loads the symbol table `.symtab` and string table `.strtab` from MDL buffers into the memory of a process that was created as an empty process. Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process. • [in] `symMdl` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the MDL buffer containing the symbol table `.symtab`. • [in] `symSegAttr` – structure containing the parameters for loading the symbol table `.symtab`. • [in] `symSize` – size of the symbol table `.symtab` (in bytes). • [in] `strMdl` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the MDL buffer containing the string table `.strtab`.	N/A

	• [in] `strSegAttr` – structure containing the parameters for loading the string table `.strtab`. • [in] `strSize` – size of the string table `.strtab` (in bytes). • [out] `rc` – return code.	
`LoadElfHdr`	Purpose Writes the ELF image header to the PCB of a process that was created as an empty process. Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process. • [in] `hdrData` – sequence containing the ELF image header. • [out] `rc` – return code.	N/A
`SetEnv`	Purpose Writes data to the SCP of a child process. Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the child process. • [in] `env` – sequence containing data to be written to the SCP. • [out] `rc` – return code.	Allows the kernel memory to be used up by creating a multitude of objects within it.
`FreeSelfEnv`	Purpose Deletes the SCP of the calling process. Parameters	N/A

	• [out] `rc` – return code.	
`Resume`	Purpose Starts a process. Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process. • [out] `rc` – return code.	Allows the following: • Execute code loaded into process memory. • Start a multitude of previously created processes to reduce the computing resources available to other processes (it is recommended to monitor the priority of the initial thread when the `Create` method is called).
`Exit`	Purpose Terminates the calling process. Parameters • [in] `status` – exit code of the process. • [out] `rc` – return code.	N/A
`Terminate`	Purpose Terminates a process. Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process. • [out] `rc` – return code.	Allows another process to be terminated if its handle is available. (The handle permissions mask must allow termination of the process.)
`GetExitInfo`	Purpose Gets information about a terminated process. Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions	N/A

	mask field. The handle identifies the terminated process. • [out] `status` – value indicating the reason for process termination. • [out] `info` – union containing information about the terminated process. • [out] `rc` – return code.	
`GetThreadContext`	Purpose Gets the context of a thread that is part of a frozen process. Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process that is in a frozen state. • [in] `index` – thread index. It is used to enumerate threads. Enumeration starts with zero. A thread in which an unhandled exception occurred has a zero index. • [out] `context` – structure containing the thread ID (TID) and thread context. • [out] `rc` – return code.	Enables disrupted isolation of a process that is in a frozen state. For example, the thread context may contain the values of variables.
`GetNextVmRegion`	Purpose Gets information about the virtual memory region that belongs to a frozen process. Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process that is in a frozen state.	Enables disrupted isolation of a process that is in a frozen state. Process isolation is disrupted due to the opened access to the process memory region.

	• [in] `after` – address that is followed by the virtual memory region. • [out] `next` – base address of the virtual memory region. • [out] `size` – size of the virtual memory region in bytes. • [out] `flags` – flags indicating the parameters of the virtual memory region. • [out] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the MDL buffer mapped to a virtual memory region. • [out] `rc` – return code.	
`TerminateAfterFreezing`	Purpose Terminates a frozen process. Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process that is in a frozen state. • [out] `rc` – return code.	Enables termination of a frozen process. This does not allow collection of data about this process for diagnostic purposes.
`GetName`	Purpose Gets the name of a calling process. Parameters • [out] `name` – process name. • [out] `rc` – return code.	N/A
`GetPath`	Purpose Gets the name of the executable file (in ROMFS) that was used to create the calling process.	N/A

	Parameters • [out] `path` – name of the executable file. • [out] `rc` – return code.	
`GetInitialThreadPriority`	Purpose Gets the priority of the initial thread of a process. Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process. • [out] `priority` – priority of the initial thread. • [out] `rc` – return code.	N/A
`SetInitialThreadPriority`	Purpose Defines the priority of the initial thread of a process. Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process. • [in] `priority` – priority of the initial thread. • [out] `rc` – return code.	Allows the priority of the initial thread of a process to be elevated to reduce the CPU time available to all other threads, including from other processes. It is recommended to monitor the priority of an initial thread.
`GetTasksList`	Purpose Gets information about existing processes. Parameters • [out] `notice` – value whose binary representation consists of multiple fields, including a handle	Allows the kernel memory to be used up by creating a multitude of objects within it.

	field and a handle permissions mask field. The handle identifies the notification receiver that is configured to receive notifications regarding the termination of processes. • [out] `strings` – sequence containing the parameters of processes. • [out] `pids` – sequence containing the identifiers of processes (the PID of each process). • [out] `rc` – return code.	
`SetInitialThreadSchedPolicy`	Purpose Defines the scheduler class and priority of the initial thread of a process. Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process. • [in] `policy` – scheduler class of the initial thread of the process. • [in] `priority` – priority of the initial thread of a process. • [in] `params` – union containing the parameters of the scheduler class of the initial thread of the process. • [out] `rc` – return code.	Allows the following: • Convert the initial thread of a process into a real-time thread that takes up all the CPU time from all other threads, including from other processes (it is recommended to monitor the scheduler class of the initial thread of the process). • Elevate the priority of the initial thread of a process to reduce the CPU time available to all other threads, including from other processes (it is recommended to monitor the priority of the initial thread of the process).
`ReseedAslr`	Purpose Defines the seed value for ASLR support. Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle	N/A

	field and a handle permissions mask field. The handle identifies the process. • [in] `seed` – sequence containing the seed value. • [out] `rc` – return code.	
`GetElfSyms`	Purpose Gets the address and size of the symbol table `.symtab` and string table `.strtab` for the calling process. Parameters • [out] `relocBase` – ELF image load offset (in bytes). • [out] `syms` – address of the symbol table `.symtab`. • [out] `symsCnt` – size (in bytes) of the symbol table `.symtab`. • [out] `strs` – address of the string table `.strtab`. • [out] `strsSize` – size (in bytes) of the string table `.strtab`. • [out] `rc` – return code.	N/A
`TransferHandle`	Purpose Transfers a handle to a process that is not yet running. Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process. • [in] `srcHandle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle field contains the transferred handle.	Allows the kernel memory to be used up by creating a multitude of objects within it.

	• [in] `srcBadge` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the resource transfer context object. • [in] `dstRights` – permissions mask of the descendant of the transferred handle. • [out] `dstHandle` – value of the descendant of the transferred handle (from the handle space of the process that received the handle). • [out] `rc` – return code.	
`GetPid`	Purpose Gets the process ID (PID). Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process. • [out] `pid` – process ID. • [out] `rc` – return code.	N/A

Synchronization endpoint

This endpoint is intended for working with futexes.

Information about methods of the endpoint is provided in the table below.

Methods of the sync.Sync endpoint (kl.core.Sync interface)

Method	Method purpose and parameters	Potential danger of the method
`Wait`	Purpose Locks execution of the calling thread if the futex value is equal to the expected value. Parameters	N/A

	• [in] `ptr` – pointer to the futex. • [in] `val` – expected value of the futex. • [in] `delay` – maximum lockout duration in milliseconds. • [out] `outDelay` – actual lockout duration in milliseconds. • [out] `rc` – return code.	
`Wake`	Purpose Resumes execution of threads that were blocked by a `Wait` method call with the defined futex. Parameters • [in] `ptr` – pointer to the futex. • [in] `nThreads` – maximum number of threads whose execution can be resumed. • [out] `wokenCnt` – actual number of threads whose execution was resumed. • [out] `rc` – return code.	N/A

File system endpoints

These endpoints are intended for working with the ROMFS file system used by the KasperskyOS kernel.

Information about methods of endpoints is provided in the tables below.

Methods of the fs.FS endpoint (kl.core.FS interface)

Method	Method purpose and parameters	Potential danger of the method
`Open`	Purpose Opens a file. Parameters • [in] `name` – name of the file. • [out] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the opened file. • [out] `rc` – return code.	Allows the kernel memory to be used up by creating a multitude of objects within it.

`Close`	Purpose Closes a file. Parameters • [in] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the opened file. • [out] `rc` – return code.	N/A
`Read`	Purpose Reads data from a file. Parameters • [in] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the opened file. • [in] `sectorNumber` – data block number. Enumeration starts with zero. • [out] `read` – size of the read data in bytes. • [out] `data` – sequence containing the read data. • [out] `rc` – return code.	N/A
`GetSize`	Purpose Gets the size of a file. Parameters • [in] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the opened file. • [out] `size` – file size in bytes. • [out] `rc` – return code.	N/A
`GetId`	Purpose Gets the unique ID of a file. Parameters • [in] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the opened file.	N/A

	• [out] `id` – unique ID of the file. • [out] `rc` – return code.	
`Count`	Purpose Gets the number of files in the file system. Parameters • [out] `count` – number of files in the file system. • [out] `rc` – return code.	N/A
`GetInfo`	Purpose Gets the name and unique ID of a file based on the file index. Parameters • [in] `index` – file index. Enumeration starts with zero. • [in] `nameLenMax` – buffer size for saving the file name. • [out] `name` – name of the file. • [out] `id` – unique ID of the file. • [out] `rc` – return code.	N/A
`GetFsSize`	Purpose Gets the size of the file system. Parameters • [out] `fsSize` – size of the file system in bytes. • [out] `rc` – return code.	N/A

Methods of the fs.FSUnsafe endpoint (kl.core.FSUnsafe interface)

Method	Method purpose and parameters	Potential danger of the method
`Change`	Purpose Changes the file system image. A different ROMFS image loaded into process memory will be used instead of the ROMFS image that was created during the solution build. Parameters	Allows the following: • Use an ROMFS image containing arbitrary programs and data. • Gain read-access to some kernel objects.

	• [in] `base` – pointer to the file system image. • [in] `size` – size of the file system image in bytes. • [out] `rc` – return code.	

Time endpoint

This endpoint is intended for setting the system time.

Information about methods of the endpoint is provided in the table below.

Methods of the time.Time endpoint (kl.core.Time interface)

Method	Method purpose and parameters	Potential danger of the method
`SetSystemTime`	Purpose Sets the system time. Parameters • [in] `secs` – time (in seconds) that has elapsed since January 1, 1970. • [in] `nsecs` – additional time (in nanoseconds) added to the time defined through the `secs` parameter. • [out] `rc` – return code.	Allows the system time to be set.
`SetSystemTimeAdj`	Purpose Starts gradual adjustment of the system time. Parameters • [in] `adj` – structure containing the amount of time by which the system time must be adjusted (*sec*10^9+nsec* nanoseconds). • [in] `slew` – rate of system time adjustment (microseconds per second). • [out] `prev` – structure containing the correction time value that remained for system time adjustment to be completed for the previous gradual time adjustment (*sec*10^9+nsec* nanoseconds). • [out] `rc` – return code.	Allows the system time to be changed.
`GetSystemTimeAdj`	Purpose	N/A

	Gets the correction time value remaining for system time adjustment so that gradual adjustment can be fully completed. Parameters • [out] `adj` – structure containing the correction time value remaining for system time adjustment so that the gradual adjustment can be fully completed (*sec*10^9+nsec* nanoseconds). • [out] `rc` – return code.	

Hardware abstraction layer endpoint

This endpoint is intended for receiving the values of HAL parameters, working with privileged registers, clearing the processor cache, providing diagnostic output, and receiving hardware-generated random numbers.

Information about methods of the endpoint is provided in the table below.

Methods of the hal.HAL endpoint (kl.core.HAL interface)

Method	Method purpose and parameters	Potential danger of the method
`GetEnv`	Purpose Gets the value of a HAL parameter. Parameters • [in] `name` – name of the parameter. • [out] `value` – value of the parameter. • [out] `rc` – return code.	Gets values of HAL parameters that could contain critical system information.
`GetPrivReg`	Purpose Gets the value of a privileged register. Parameters • [in] `reg` – name of the register. • [out] `val` – value of the register. • [out] `rc` – return code.	Sets up a data transfer channel with a process that has access to the `SetPrivReg` or `SetPrivRegRange` method. It is recommended to monitor the name of a register.
`SetPrivReg`	Purpose Sets the value of a privileged register.	Allows the following: • Set the value of a privileged register.

	Parameters • [in] `reg` – name of the register. • [in] `val` – value of the register. • [out] `rc` – return code.	• Set up a data transfer channel with a process that has access to the `GetPrivReg` or `GetPrivRegRange` method. It is recommended to monitor the name of a register.
`GetPrivRegRange`	Purpose Gets the value of a privileged register. Parameters • [in] `regRange` – name of the registers range. • [in] `offset` – register offset in the registers range. • [out] `val` – value of the register. • [out] `rc` – return code.	Sets up a data transfer channel with a process that has access to the `SetPrivReg` or `SetPrivRegRange` method. It is recommended to monitor the name of the registers range and the register offset in this range.
`SetPrivRegRange`	Purpose Sets the value of a privileged register. Parameters • [in] `regRange` – name of the registers range. • [in] `offset` – register offset in the registers range. • [in] `val` – value of the register. • [out] `rc` – return code.	Allows the following: • Set the value of a privileged register. • Set up a data transfer channel with a process that has access to the `GetPrivReg` or `GetPrivRegRange` method. It is recommended to monitor the name of the registers range and the register offset in this range.
`FlushCache`	Purpose Clears the processor cache. Parameters • [in] `type` – value defining the cache type (data cache, instructions cache, or joint data and instructions cache).	Allows the processor cache to be cleared.

	• [in] `va` – base address of the virtual memory region. The cache corresponding to this region is cleared. • [in] `size` – size of the virtual memory region. The cache corresponding to this region is cleared. • [out] `rc` – return code.	
`DebugWrite`	Purpose Puts data into the diagnostic output that is written, for example, to a COM port or USB port (version 3.0 or later, with DbC support). Parameters • [in] `data` – sequence containing the data to be put into the diagnostic output. • [out] `rc` – return code.	Populates diagnostic output with fictitious (uninformative) data.
`GetEntropy`	Purpose Gets hardware-generated random numbers. Parameters • [out] `buffer`—sequence containing random byte values. • [in] `size`—number of random byte values. • [out] `rc` – return code.	Creates a load on the hardware-based random number generator with frequent method calls so that other processes are unable to receive random numbers using this generator.

XHCI controller management endpoint

This endpoint is intended for disabling and re-enabling debug mode for the XHCI controller (with DbC support) when it is restarted.

Information about methods of the endpoint is provided in the table below.

Methods of the xhcidbg.XHCIDBG endpoint (kl.core.XHCIDBG interface)

Method	Method purpose and parameters	Potential danger of the method

`Start`	Purpose Enables debug mode of the XHCI controller. Parameters • [out] `rc` – return code.	Configures the XHCI controller to sends diagnostic output through a USB port (version 3.0 or later).
`Stop`	Purpose Disables debug mode of the XHCI controller. Parameters • [out] `rc` – return code.	Configures the XHCI controller to not send diagnostic output through a USB port (version 3.0 or later).

Audit endpoint

This endpoint is intended for reading messages from KasperskyOS kernel logs. There are two kernel logs: `kss` and `core`. The `kss` log contains security audit data. The `core` log contains diagnostic output. (Diagnostic output includes kernel output and the output of programs.)

Information about methods of the endpoint is provided in the table below.

Methods of the audit.Audit endpoint (kl.core.Audit interface)

Method	Method purpose and parameters	Potential danger of the method
`Open`	Purpose Opens the kernel log to read data from it. Parameters • [in] `name` – name of the kernel log (`kss` or `core`). • [out] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the kernel log. • [out] `rc` – return code.	N/A
`Close`	Purpose Closes the kernel log. Parameters	N/A

	• [in] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the kernel log. • [out] `rc` – return code.	
`Read`	Purpose Receives a message from a kernel log. Parameters • [in] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the kernel log. • [out] `msg` – sequence containing a message. • [out] `outDropMsgs` – number of messages that were not included in the kernel log due to an overflow of the buffer where this log is stored. • [out] `rc` – return code.	Extracts messages from the kernel log so that these messages are not received by another process.

Profiling endpoint

This endpoint is intended for profiling and collecting code coverage, and for receiving the values of performance counters.

Information about methods of the endpoint is provided in the table below.

Methods of the profiler.Profiler endpoint (kl.core.Profiler interface)

Method	Method purpose and parameters	Potential danger of the method
`GetCoverageData`	Purpose Gets information about code coverage. Parameters • [in] `index` – index for enumerating object files containing instrumented code for receiving coverage data. Enumeration starts with zero. • [out] `buf` – sequence containing information about the code coverage of an object file (in `gcda` format). • [out] `size` – size (in bytes) of data containing information about the code coverage of an object file.	N/A

	• [out] `name` – name of the `*.gcda` file that was assigned during compilation. • [out] `rc` – return code.	
`FlushGcov`	Purpose Output of data on code coverage in `gcda` format via UART. Parameters • [out] `rc` – return code.	N/A
`FlushGcovFile`	Purpose Output of data on code coverage in `gcda` format via UART. Parameters • [in] `name` – name of the `*.gcda` file that was assigned during compilation. • [in] `buf` – pointer to the buffer containing information about code coverage in `gcda` format. • [in] `size` – size of data containing code coverage information. • [out] `rc` – return code.	N/A
`GetCounters`	Purpose Gets the values of performance counters. Parameters • [in] `prefix` – prefix for names of performance counters. • [in] `names` – sequence containing the names of performance counters. • [out] `values` – sequence containing the values of performance counters. • [out] `rc` – return code.	N/A
`ObjectGetStat`	Purpose Gets the values of performance counters for a system resource (process or thread). Parameters	N/A

	• [in] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the system resource. • [in] `names` – sequence containing the names of performance counters. • [out] `values` – sequence containing the values of performance counters. • [out] `rc` – return code.	
`SamplingStart`	Purpose Starts sample code profiling. Sample profiling results in code execution statistics that reflect the duration of code section execution. Parameters • [in] `conf`—flags that define the profiling settings. • [in] `cpus` – value defining the CPUs (processor cores) for profiling. • [in] `contSize` – size (in bytes) of the container used to store data containing the code execution statistics obtained from profiling. The container is automatically created in the kernel memory. • [in] `interval` – fictitious parameter. • [out] `rc` – return code.	N/A
`SamplingStop`	Purpose Stops sample code profiling. Parameters • [out] `rc` – return code.	N/A
`SamplingRead`	Purpose Gets data containing the code execution statistics received from sample profiling. Parameters • [in] `unsafeBuffer` – pointer to the buffer used to save the container storing the code execution statistics obtained from profiling.	Gets the addresses and names of functions of other processes.

	• [in] `size` – size of the buffer whose pointer is defined through the `unsafeBuffer` parameter. • [out] `realSize` – size of the saved container. • [in] `timeout` – container filling timeout (in milliseconds). • [out] `rc` – return code.	
`SamplingAddPidToList`	Purpose Adds a process to the list of profiled processes. Parameters • [in] `pid` – process ID (PID). • [out] `rc` – return code.	N/A
`SamplingClearPidList`	Purpose Clears the list of profiled processes. Parameters • [out] `rc` – return code.	N/A
`LoadSegInfo`	Purpose Saves information about the loaded ELF image segment in the kernel. (This is necessary so that the code execution statistics received from sample profiling can contain additional information that lets you associate these statistics with the source code.) Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process. • [in] `addr` – segment address in process memory. • [in] `size` – segment size (in bytes). • [in] `offset` – offset of the segment in the ELF file (in bytes). • [in] `flags` – flags defining the access rights to the segment. • [in] `buildId` – build ID. The linker writes this ID to the ELF file.	Allows the kernel memory to be used up by creating a multitude of objects within it.

	• [out] `rc` – return code.	
`UnloadSegInfo`	Purpose Deletes information about the loaded ELF image segment that was saved in the kernel using the `LoadSegInfo` method. Parameters • [in] `task` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the process. • [in] `addr` – segment address in process memory. • [in] `size` – segment size (in bytes). • [out] `rc` – return code.	N/A
`KcovAlloc`	Purpose Allocates the resources required for collecting kernel code coverage data when handling system calls executed by the calling process. Parameters • [in] `numThreads` —maximum number of threads for which code coverage data will be collected. • [in] `maxPoints` —maximum number of coverage points for one thread. • [out] `rc` – return code.	Exhausts RAM.
`KcovFree`	Purpose Frees the resources required for collecting kernel code coverage data when handling system calls executed by the calling process. Parameters • [out] `rc` – return code.	N/A
`KcovStart`	Purpose Starts the collection of kernel code coverage data when handling system calls executed by the calling thread. Parameters	N/A

	• [out] `rc` – return code.	
`KcovStop`	Purpose Stops the collection of kernel code coverage data when handling system calls executed by the calling thread. Also gets information about kernel code coverage. Parameters • [in] `points`—pointer to the buffer used to store kernel code coverage data. • [in] `maxPoints`—maximum number of coverage points that can be stored in the buffer defined via the `points` parameter. • [out] `numPoints`—actual number of coverage points stored in the buffer defined via the `points` parameter. • [out] `rc` – return code.	N/A

I/O memory isolation management endpoint

This endpoint is intended for managing the isolation of physical memory regions used by devices on a PCIe bus for DMA. (Isolation is provided by the IOMMU.)

Information about methods of the endpoint is provided in the table below.

Methods of the iommu.IOMMU endpoint (kl.core.IOMMU interface)

Method	Method purpose and parameters	Potential danger of the method
`Attach`	Purpose Attaches a device on a PCIe bus to the IOMMU domain associated with the calling process. Parameters • [in] `bdf` – address of the device on the PCIe bus in BDF format. • [out] `rc` – return code.	Attaches a device on a PCIe bus managed by another process to an IOMMU domain associated with the calling process, which leads to failure of the device. It is recommended to monitor the address of a device on a PCIe bus.
`Detach`	Purpose Detaches a device on a PCIe bus from the IOMMU domain associated with the calling process. Parameters	N/A

	• [in] `bdf` – address of the device on the PCIe bus in BDF format. • [out] `rc` – return code.	

Connections endpoint

This endpoint is intended for dynamic creation of IPC channels.

Information about methods of the endpoint is provided in the table below.

Methods of the cm.CM endpoint (kl.core.CM interface)

Method	Method purpose and parameters	Potential danger of the method
`Connect`	Purpose Requests to create an IPC channel with a server for use of the defined endpoint. Parameters • [in] `server` – name of the server. • [in] `service` – qualified name of the endpoint. • [in] `msecs` – request fulfillment timeout, in milliseconds. • [out] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle is the client IPC handle. • [out] `id` – endpoint ID (RIID). • [out] `rc` – return code.	Creates a load on a server by sending a large number of requests to create an IPC channel.
`Listen`	Purpose Receives a client request to create an IPC channel for use of an endpoint. Parameters • [in] `filter` – fictitious parameter. • [in] `msecs` – client request timeout, in milliseconds. • [out] `client` – client name. • [out] `service` – qualified name of the endpoint. • [out] `rc` – return code.	N/A

`Drop`	Purpose Rejects a client request to create an IPC channel for use of the defined endpoint. Parameters • [in] `client` – client name. • [in] `service` – qualified name of the endpoint. • [out] `rc` – return code.	N/A
`Accept`	Purpose Accepts a client request to create an IPC channel for use of the defined endpoint. Parameters • [in] `client` – client name. • [in] `service` – qualified name of the endpoint. • [in] `id` – endpoint ID. • [in] `listener` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle is the listener handle. • [out] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle is the server IPC handle. • [out] `rc` – return code.	N/A

Power management endpoint

This endpoint is intended for changing the power management mode of a computer (for example, shutting down or restarting the computer), and for enabling and disabling processors (processor cores).

Information about methods of the endpoint is provided in the table below.

Methods of the pm.PM endpoint (kl.core.PM interface)

Method	Method purpose and parameters	Potential danger of the method
`Request`	Purpose Requests to change the power mode of a computer.	Allows the computer power mode to be changed.

	Parameters • [in] `request` – value defining the necessary power mode of the computer. • [out] `rc` – return code.	
`SetCpusOnline`	Purpose Requests to enable and/or disable processors. Parameters • [in] `request` – value defining a large number of processors in the active state. • [in] `timeout` – request fulfillment timeout, in milliseconds. • [out] `rc` – return code.	Disables and enables processors.
`GetCpusOnline`	Purpose Gets information regarding which processors are in the active state. Parameters • [out] `online` – value indicating the set of processors in the active state. • [out] `rc` – return code.	N/A

Notifications endpoint

This endpoint is intended for working with notifications about events that occur with resources.

Information about methods of the endpoint is provided in the table below.

Methods of the notice.Notice endpoint (kl.core.Notice interface)

Method	Method purpose and parameters	Potential danger of the method
`Create`	Purpose Creates a notification receiver. Parameters • [out] `notify` – value whose binary representation consists of multiple fields, including a handle field and a	Allows the kernel memory to be used up by creating a multitude of objects within it.

	handle permissions mask field. The handle identifies the notification receiver. • [out] `rc` – return code.	
`SubscribeToObject`	Purpose Adds a "resource–event mask" entry to the notification receiver so that it can receive notifications about events that occur with the defined resource and match the defined event mask. Parameters • [in] `notify` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the notification receiver. • [in] `object` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the resource. • [in] `evMask` – event mask. • [in] `evId` – ID of the "resource–event mask" entry. • [out] `rc` – return code.	Allows the kernel memory to be used up by creating a multitude of objects within it.
`UnsubscribeFromEvent`	Purpose Removes from the notification receiver "resource—event mask" entries with the specified identifier to prevent the receiver from getting notifications about events that match these entries. Parameters • [in] `notify` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the notification receiver. • [in] `evId` – ID of the "resource–event mask" entry. • [out] `rc` – return code.	N/A
`UnsubscribeFromObject`	Purpose Removes from the notification receiver "resource—event mask" entries that match the specified resource to prevent the receiver from getting notifications about events that match these entries.	N/A

	Parameters • [in] `notify` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the notification receiver. • [in] `object` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the resource. • [out] `rc` – return code.	
`GetEvent`	Purpose Extracts notifications from the receiver. Parameters • [in] `notify` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the notification receiver. • [in] `mdelay` – timeout for notifications to appear in the receiver, in milliseconds. • [out] `events` – sequence of notifications comprised of structures containing a "resource–event mask" entry ID and a mask of events occurring with the resource. • [out] `rc` – return code.	N/A
`DropAndWake`	Purpose Removes from the specified notification receiver all "resource—event mask" entries, resumes all threads waiting for notifications to appear in the specified receiver; optionally prohibits adding of "resource—event mask" entries to the specified notification receiver. Parameters • [in] `notify` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the notification receiver. • [in] `finish` – value defining whether or not the addition of "resource–event mask" entries will be prohibited (`0` – will not be prohibited, `1` – will be prohibited). • [out] `rc` – return code.	N/A

`SetObjectEvent`	Purpose Signals that events from the defined event mask occurred with the defined user resource. Parameters • [in] `object` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the user resource. • [in] `evMask` – mask of events to be signaled. • [out] `rc` – return code.	N/A

Hypervisor endpoint

This endpoint is intended for working with a hypervisor.

Methods of the `hypervisor.Hypervisor` endpoint (`kl.core.Hypervisor` interface) are potentially dangerous. Access to these methods can be granted only to the specialized `vmapp` program.

Trusted Execution Environment endpoints

These endpoints are intended for transferring data between a *Trusted Execution Environment* (TEE) and a *Rich Execution Environment* (REE), and for obtaining access to the physical memory of the REE from the TEE.

Information about methods of endpoints is provided in the tables below.

Methods of the tee.TEE endpoint (kl.core.TEE interface)

Method	Method purpose and parameters	Potential danger of the method
`Dispatch`	Purpose Sends and receives messages transferred between a TEE and a REE. This method is used in the TEE and in the REE. Parameters • [in] `msgIn` – structure containing a request for the TEE (when the method is called in the REE) or a response for the REE (when the method is called in the TEE). • [out] `msgOut` – structure containing a response from the TEE (when the method is called in the REE) or a request from the REE (when the method is called in the TEE).	Allows a process in a REE to receive a response from a TEE regarding a request from another process in the REE.

	• [out] `rc` – return code.	
`FreeToken`	Purpose Frees the values of unique IDs of messages transferred between a TEE and a REE. (These values must be freed so that they can become available for re-use.) This method is used in REE. Parameters • [in] `token` – value of the unique ID of a message. • [out] `rc` – return code.	Frees the values used by other processes in a REE as unique IDs of messages transferred between a TEE and a REE.

Methods of the tee.TEEVMM endpoint (kl.core.TEEVMM interface)

Method	Method purpose and parameters	Potential danger of the method
`MdlAllocate`	Purpose Creates a blank MDL buffer so that physical memory from an REE can be subsequently added to it. This method is used in TEE. Parameters • [in] `size` – size of the MDL buffer in bytes. • [in] `prot` – flags defining the access rights to the MDL buffer. • [out] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the MDL buffer. • [out] `rc` – return code.	Allows the kernel memory to be used up by creating a multitude of objects within it.
`MdlAddFrame`	Purpose Adds a REE physical memory region to the blank MDL buffer created by the `MdlAllocate` method. This method is used in TEE. Parameters • [in] `handle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the MDL buffer.	Allows access to an arbitrary region of the physical memory of a REE from a TEE.

	• [in] `pa` – base address of the physical memory region. • [in] `pages` – size of the physical memory region, in memory pages. • [out] `rc` – return code.	

IPC interrupt endpoint

This endpoint is intended for interrupting the `Call()` and `Recv()` locking system calls. (For example, this may be required to correctly terminate a process.)

Information about methods of the endpoint is provided in the table below.

Methods of the ipc.IPC endpoint (kl.core.IPC interface)

Method	Method purpose and parameters	Potential danger of the method
`CreateSyncObject`	Purpose Creates an IPC synchronization object. An IPC synchronization object is used to interrupt `Call()` and `Recv()` locking system calls in threads of the calling process. A `Call()` can be interrupted only when it is awaiting a `Recv()` call by the server. `Recv()` can be interrupted only when it is waiting to receive an IPC request from a client. The handle of an IPC synchronization object cannot be transferred to another process because the necessary flag for this operation is not set in the permissions mask of this handle. Parameters • [out] `syncHandle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the IPC synchronization object. • [out] `rc` – return code.	Allows the kernel memory to be used up by creating a multitude of objects within it.
`SetInterrupt`	Purpose Switches the defined IPC synchronization object to a state in which the `Call()` and `Recv()` system calls are interrupted. Parameters • [in] `syncHandle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the IPC synchronization object.	N/A

	• [out] `rc` – return code.	
`ClearInterrupt`	Purpose Switches the defined IPC synchronization object to a state in which the `Call()` and `Recv()` system calls are not interrupted. Parameters • [in] `syncHandle` – value whose binary representation consists of multiple fields, including a handle field and a handle permissions mask field. The handle identifies the IPC synchronization object. • [out] `rc` – return code.	N/A

CPU frequency management endpoint

This endpoint is intended for changing the frequency of processors (processor cores).

Information about methods of the endpoint is provided in the table below.

Methods of the cpufreq.CpuFreq endpoint (kl.core.CpuFreq interface)

Method	Method purpose and parameters	Potential danger of the method
`GetLayout`	Purpose Allows you to receive information about processor groups. Processor group information lists the existing processor groups while indicating the possible values of the performance parameter for each of them. This parameter is a combination of the matching frequency and voltage (Operating Performance Point, or OPP). The frequency is indicated in kiloherz (kHz) and the voltage is indicated in microvolts (μV). Parameters • [out] `layout` – sequence containing information about processor groups. • [out] `rc` – return code.	N/A
`GetCurOppId`	Purpose Gets the index of the current OPP for the defined processor group. Parameters • [in] `cpuGroupId` – index of the processor group. Enumeration starts with zero.	N/A

	• [out] `oppId` – index of the current OPP. Enumeration starts with zero. • [out] `rc` – return code.	
`SetOppId`	Purpose Sets the defined OPP for the defined processor group. Parameters • [in] `GroupId` – index of the processor group. Enumeration starts with zero. • [in] `oppId` – OPP index. Enumeration starts with zero. • [out] `rc` – return code.	Changes the frequency of a processor group.

Using the system programs Klog and KlogStorage to perform a security audit

To perform a security audit, the system program `Klog` receives audit data from the KasperskyOS kernel by using the `libkos` library, decodes this data and forwards it via IPC to the system program `KlogStorage`, which acts as the server in this IPC interaction. The `KlogStorage` program sends audit data to standard output (or standard error) or saves it to a file by using VFS. The `KlogStorage` program can also forward file-written audit data to other programs via IPC.

The executable files of the `Klog` and `KlogStorage` programs are not provided in the KasperskyOS SDK. You will need to create them based on the provided static libraries.

Example of adding the system program Klog to a solution

Source code of the program

einit/src/klog_entity.c

```
#include <klog/system_audit.h>
#include <klog_storage/client.h>
#include <ping/KlogEntity.edl.h>

int main(int argc, char *argv[])
{
    /* This function call creates a thread
     * that receives audit data from the kernel, decodes it and forwards it
     * via IPC to the KlogStorage program.
     * (The constant ping_KlogEntity_klog_audit_iid is defined in the header
     * file KlogEntity.edl.h, which contains the automatically generated
     * transport code.) */
    return klog_system_audit_run(KLOG_SERVER_CONNECTION_ID ":"
                                 " KLOG_STORAGE_SERVER_CONNECTION_ID,
```

```
                                    ping_KlogEntity_klog_audit_iid);
}
```

Building a program

einit/CMakeLists.txt

```
...
# Import Klog libraries from the
# KasperskyOS SDK
find_package (klog REQUIRED)
include_directories (${klog_INCLUDE})

# Generate transport code based on the formal specification of the
# Klog program
nk_build_edl_files (klog_edl_files
                    NK_MODULE "ping"
                    # The KlogEntity.edl file and other files
                    # in the formal specification of the Klog program
                    # are provided in the KasperskyOS SDK.
                    EDL "${RESOURCES}/edl/KlogEntity.edl")

# Create the executable file of the Klog program for the hardware platform
add_executable (KlogEntityHw "src/klog_entity.c")
target_link_libraries (KlogEntityHw ${klog_SYSTEM_AUDIT_LIB})
add_dependencies (KlogEntityHw klog_edl_files)

# Create the executable file of the Klog program for QEMU.
# (Identical to creating the executable file of the Klog program for
# the hardware platform, except for the build target name.
# Requires two build targets for the executable file of the
# Klog program with different names because the KLOG_ENTITY parameter of the
# CMake commands build_kos_hw_image() and build_kos_qemu_image()
# must specify different build targets.)
add_executable (KlogEntityQemu "src/klog_entity.c")
target_link_libraries (KlogEntityQemu ${klog_SYSTEM_AUDIT_LIB})
add_dependencies (KlogEntityQemu klog_edl_files)

# The Klog program does not need to be specified together with other programs
# to be included in the solution image. To include the Klog program
# in a solution, you must define the name of the build target for the executable file
of this
# program via the KLOG_ENTITY parameter of the CMake commands
# build_kos_hw_image() and build_kos_qemu_image().
set (ENTITIES Client Server KlogStorageEntity FileVfs)
...
# The INIT_KlogEntity_PATH variable is used in the init.yaml.in file
# to define the name of the Klog program executable file. (The executable
# files of the Klog program for QEMU and for the hardware platform have
# different names that match the names of the build targets
# of these files by default.)
set (INIT_KlogEntity_PATH "KlogEntityHw")

# You must define the KLOG_ENTITY parameter
build_kos_hw_image (kos-image
                    EINIT_ENTITY EinitHw
                    ...
                    KLOG_ENTITY KlogEntityHw
                    IMAGE_FILES ${ENTITIES})
```

```
# The INIT_KlogEntity_PATH variable is used in the init.yaml.in file
# to define the name of the Klog program executable file. (The executable
# files of the Klog program for QEMU and for the hardware platform have
# different names that match the names of the build targets
# of these files by default.)
set (INIT_KlogEntity_PATH "KlogEntityQemu")

# You must define the KLOG_ENTITY parameter
build_kos_qemu_image (kos-qemu-image
                      EINIT_ENTITY EinitQemu
                      ...
                      KLOG_ENTITY KlogEntityQemu
                      IMAGE_FILES ${ENTITIES})
```

Program process dictionary in the init description template

einit/src/init.yaml.in

```
...
- name: ping.KlogEntity
  # The variable INIT_KlogEntity_PATH is defined in the file einit/CMakeLists.txt.
  path: @INIT_KlogEntity_PATH@
  connections:
  - target: ping.KlogStorageEntity
    id: {var: KLOG_STORAGE_SERVER_CONNECTION_ID, include: klog_storage/client.h}
...
```

Policy description for the program

einit/src/security.psl.in

```
...
use nk.base._
...
use EDL kl.core.Core
...
use EDL ping.KlogEntity
use EDL ping.KlogStorageEntity
...
use audit_profile._
use core._
...
/* Interaction with the KlogStorage program */

request dst=ping.KlogStorageEntity {
    match endpoint=klogStorage.storage {
        match method=write {
            match src=ping.KlogEntity { grant () }
        }
    }
}

response src=ping.KlogStorageEntity {
    match endpoint=klogStorage.storage {
        match method=write {
```

```
            match dst=ping.KlogEntity { grant () }
        }
    }
}

error src=ping.KlogStorageEntity {
    match endpoint=klogStorage.storage {
        match method=write {
            match dst=ping.KlogEntity { grant () }
        }
    }
}
...
```

einit/src/core.psl

```
...
/* Interaction with the kernel */

request dst=kl.core.Core {
    match endpoint=sync.Sync {
        match method=Wake {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
        match method=Wait {
           ...
            match src=ping.KlogEntity { grant () }
          ...
            }
    }
    match endpoint=task.Task {
        match method=FreeSelfEnv {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
        match method=GetPath {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
        match method=GetName {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
        match method=Exit {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
    }
    match endpoint=vmm.VMM {
        match method=Allocate {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
        match method=Commit {
```

```
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
        match method=Protect {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
        match method=Free {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
    }
    match endpoint=thread.Thread {
        match method=SetTls {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
        match method=Create {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
        match method=Resume {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
        match method=Attach {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
        match method=Exit {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
        match method=GetSchedPolicy {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
        match method=SetSchedPolicy {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
    }
    match endpoint=hal.HAL {
        match method=GetEntropy {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
        match method=DebugWrite {
            ...
            match src=ping.KlogEntity { grant () }
            ...
```

```
            }
        match method=GetEnv {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
    }
    match endpoint=handle.Handle {
        match method=Close {
            ...
            match src=ping.KlogEntity { grant () }
            ...
            }
    }
    match endpoint=audit.Audit {
        match src=ping.KlogEntity { grant () }
        }
}

response src=kl.core.Core {
    ...
    match dst=ping.KlogEntity { grant () }
    ...
}

error src=kl.core.Core {
    ...
    match dst=ping.KlogEntity { grant () }
    ...
}
...
```

Example of adding the system program KlogStorage to a solution to forward audit data to standard error

Source code of the program

klog_storage/src/klog_storage_entity.c

```c
#include <klog_storage/server.h>
#include <ping/KlogStorageEntity.edl.h>
#include <stdio.h>

/* Define the data type for a fictitious context.
 * Required for defining functions that implement
 * interface methods, and for dispatcher configuration. */
struct Context
{
    int some_data;
};

/* Define the function that forwards audit data to
 * standard error. (Use of the ctx parameter is not required, but a
 * void* type parameter must be the first parameter in the function signature to
 * match the type of pointer that is used by the dispatcher
 * to call this function.) */
```

```
static int _write(struct Context *ctx, const struct kl_KlogStorage_Entry *entry)
{
    fprintf(stderr, "%s\n", entry->msg);
    return 0;
}

/* Define a fictitious function for reading audit data.
 * (Required for dispatcher configuration to avoid errors
 * if the interface method for reading audit data is called.) */
static int _read_range(struct Context *ctx, nk_uint64_t first_id,
nk_uint64_t last_id, struct kl_KlogStorage_Entry *entries)
{
    return 0;
}

/* Define a fictitious function for reading audit data.
 * (Required for dispatcher configuration to avoid errors
 * if the interface method for reading audit data is called.) */
static int _read(struct Context *ctx, nk_uint32_t num_entries,
struct kl_KlogStorage_Entry *entries)
{
    return 0;
}

int main(int argc, char *argv[])
{
    /* Declaration of a fictitious context */
    static struct Context ctx;

    /* Configure the dispatcher so that when IPC requests
     * containing audit data are received from the Klog program, the dispatcher calls
the function that forwards
     * this data to standard error. (The functions for reading audit data
     * and the context are fictitious. However, you can create your own
     * implementations of the _write(), _read() and _read_range() functions for
working with
     * audit data storage. In this case, the context may be
     * used to store the storage state.) */
    struct kl_KlogStorage *iface =
    klog_storage_IKlog_storage_dispatcher(&ctx,
                                          (kl_KlogStorage_write_func)_write,
                                          (kl_KlogStorage_read_func)_read,

(kl_KlogStorage_read_range_func)_read_range);
    struct kl_KlogStorage_component *comp =klog_storage_storage_component(iface);

    /* This function call starts the IPC request processing loop.
     * (The constants ping_KlogStorageEntity_klogStorage_iidOffset and
     * ping_KlogStorageEntity_klogStorage_storage_iid are defined in the header file
     * KlogStorageEntity.edl.h, which contains the automatically generated
     * transport code.) */
    return klog_storage_run(KLOG_STORAGE_SERVER_CONNECTION_ID,
                            ping_KlogStorageEntity_klogStorage_iidOffset,
                            ping_KlogStorageEntity_klogStorage_storage_iid,
                            comp);
}
```

Building a program

klog_storage/CMakeLists.txt

```
# Import KlogStorage libraries from the
# KasperskyOS SDK
find_package (klog_storage REQUIRED)
include_directories (${klog_storage_INCLUDE})

# Generate transport code based on the formal specification of the
# KlogStorage program
nk_build_edl_files (klog_storage_edl_files
                    NK_MODULE "ping"
                    # The KlogStorageEntity.edl file and other files
                    # in the formal specification of the KlogStorage program
                    # are provided in the KasperskyOS SDK.
                    EDL "${RESOURCES}/edl/KlogStorageEntity.edl")

# Create the executable file of the KlogStorage program
add_executable (KlogStorageEntity "src/klog_storage_entity.c")
target_link_libraries (KlogStorageEntity ${klog_storage_SERVER_LIB})
add_dependencies (KlogStorageEntity klog_edl_files klog_storage_edl_files)
```

Program process dictionary in the init description template

einit/src/init.yaml.in

```
...
- name: ping.KlogStorageEntity
...
```

Policy description for the program

einit/src/security.psl.in

```
...
use nk.base._
...
use EDL kl.core.Core
...
use EDL ping.KlogEntity
use EDL ping.KlogStorageEntity
...
use audit_profile._
use core._
...
/* Interaction with the Klog program */

request dst=ping.KlogStorageEntity {
    match endpoint=klogStorage.storage {
        match method=write {
            match src=ping.KlogEntity { grant () }
        }
    }
}

response src=ping.KlogStorageEntity {
    match endpoint=klogStorage.storage {
```

```
        match method=write {
            match dst=ping.KlogEntity { grant () }
        }
    }
}

error src=ping.KlogStorageEntity {
    match endpoint=klogStorage.storage {
        match method=write {
            match dst=ping.KlogEntity { grant () }
        }
    }
}
...
```

einit/src/core.psl

```
...
/* Interaction with the kernel */

request dst=kl.core.Core {
    match endpoint=sync.Sync {
        match method=Wake {
            ...
            match src=ping.KlogStorageEntity { grant () }
            ...
            }
        match method=Wait {
            ...
            match src=ping.KlogStorageEntity { grant () }
            ...
            }
    }
    match endpoint=task.Task {
        match method=FreeSelfEnv {
            ...
            match src=ping.KlogStorageEntity { grant () }
            ...
            }
        match method=GetPath {
            ...
            match src=ping.KlogStorageEntity { grant () }
            ...
            }
        match method=GetName {
            ...
            match src=ping.KlogStorageEntity { grant () }
            ...
            }
        match method=Exit {
            ...
            match src=ping.KlogStorageEntity { grant () }
            ...
            }
    }
    match endpoint=vmm.VMM {
        match method=Allocate {
            ...
            match src=ping.KlogStorageEntity { grant () }
            ...
            }
```

```
        match method=Commit {
            ...
            match src=ping.KlogStorageEntity { grant () }
            ...
            }
        match method=Protect {
            ...
            match src=ping.KlogStorageEntity { grant () }
            ...
            }
        match method=Free {
            ...
            match src=ping.KlogStorageEntity { grant () }
            ...
            }
    }
    match endpoint=thread.Thread {
        match method=SetTls {
            ...
            match src=ping.KlogStorageEntity { grant () }
            ...
            }
        match method=Create {
            ...
            match src=ping.KlogStorageEntity { grant () }
            ...
            }
        match method=Resume {
            ...
            match src=ping.KlogStorageEntity { grant () }
            ...
            }
    }
    match endpoint=hal.HAL {
        match method=GetEntropy {
            ...
            match src=ping.KlogStorageEntity { grant () }
            ...
            }
        match method=DebugWrite {
            ...
            match src=ping.KlogStorageEntity { grant () }
            ...
            }
        match method=GetEnv {
            ...
            match src=ping.KlogStorageEntity { grant () }
            ...
            }
    }
    match endpoint=handle.Handle {
        match method=Close {
            ...
            match src=ping.KlogStorageEntity { grant () }
            ...
            }
    }
}

response src=kl.core.Core {
    ...
    match dst=ping.KlogStorageEntity { grant () }
```

```
    ...
}

error src=kl.core.Core {
    ...
    match dst=ping.KlogStorageEntity { grant () }
    ...
}
...
```

Example of adding the system program KlogStorage to a solution to write audit data to a file

Source code of the program

klog_storage/src/klog_storage_entity.c

```
#include <klog_storage/server.h>
#include <klog_storage/file_storage.h>
#include <ping/KlogStorageEntity.edl.h>

int main(int argc, char *argv[])
{
    /* This function call starts the IPC request processing loop.
     * The audit data will be written to the file /etc/klog_storage.log, which can
     * hold no more than 100 entries. When the file is completely full, the previous
     * entries will be replaced by new entries starting at the beginning of the file.
If the last parameter
     * of the function has a value other than 1, the KlogStorage program at startup
     * opens the existing file and begins to write audit data at the specific position
     * that was set in the file after the previous write operation. If the last
     * parameter of the function has a value of 1, a new empty file will be created.
     * (The constants ping_KlogStorageEntity_klogStorage_iidOffset and
     * ping_KlogStorageEntity_klogStorage_storage_iid are defined in the header
     * file KlogStorageEntity.edl.h, which contains the automatically generated
     * transport code.) */
    return klog_storage_file_storage_run(KLOG_STORAGE_SERVER_CONNECTION_ID,
                                         "/etc/klog_storage.log",
                                         ping_KlogStorageEntity_klogStorage_iidOffset,

ping_KlogStorageEntity_klogStorage_storage_iid,
                                         100,
                                         0);
}
```

Building a program

The difference between the `CMake` commands for building the `KlogStorage` program that writes audit data to a file and the `CMake` commands for building the version of this program that sends audit data to standard error comprises the following modification:

klog_storage/CMakeLists.txt

```
...
# When creating the executable file of the KlogStorage program, you must
# link it to the klog_storage_file_storage library.
target_link_libraries (KlogStorageEntity ${klog_storage_FILE_STORAGE_LIB})
...
```

Program process dictionary in the init description template

einit/src/init.yaml.in

```
...
- name: ping.KlogStorageEntity
  connections:
  - target: file_vfs.FileVfs
    id: {var: _VFS_CONNECTION_ID, include: vfs/defs.h}
...
```

Security policy description for the program

The difference between a policy description for a `KlogStorage` program that writes audit data to a file and a policy description for a version of this program that sends audit data to standard error comprises the following addition:

einit/src/security.psl.in

```
...
use EDL file_vfs.FileVfs
...
use vfs._
...
```

einit/src/vfs.psl

```
...
/* Interaction with the VFS program */

request dst=file_vfs.FileVfs {
    match src=ping.KlogStorageEntity { grant () }
}

response src=file_vfs.FileVfs {
    match dst=ping.KlogStorageEntity { grant () }
}

error src=file_vfs.FileVfs {
    match dst=ping.KlogStorageEntity { grant () }
}
...
```

Forwarding audit data to other programs

To forward file-written audit data via IPC, the `KlogStorage` program provides the `read` and `readRange` interface methods defined in the file `sysroot-*-kos/include/kl/KlogStorage.idl` from the KasperskyOS SDK.

The executable file of the program that needs to receive the audit data must be linked to the client library of the `KlogStorage` program:

klog_reader/CMakeLists.txt

```
# Import KlogStorage libraries from the
# KasperskyOS SDK
find_package (klog_storage REQUIRED)
include_directories (${klog_storage_INCLUDE})
...
# Create the executable file of the program that needs to
# receive audit data from the KlogStorage program.
add_executable (KlogReader "src/klog_reader.c")
target_link_libraries (KlogReader ${klog_storage_CLIENT_LIB})
...
```

Source code for receiving audit data from the `KlogStorage` program:

klog_reader/src/klog_reader.c

```
#include <klog_storage/client.h>
...
int main(int argc, char *argv[])
{
...
    struct Klog_storage_ctx *storage =
    klog_storage_init(KLOG_STORAGE_SERVER_CONNECTION_ID);

    struct kl_KlogStorage_Entry first_entries[10], latest_entries [10];

    /* Read the first ten entries */
    int f_count = klog_storage_read_range(klog_storage_IKlog_storage(storage),
                                          1,
                                          10,
                                          first_entries);

    /* Read the last ten entries */
    int l_count = klog_storage_read(klog_storage_IKlog_storage(storage),
                                    10,
                                    latest_entries);
...
}
```

Security patterns for development under KasperskyOS

Each KasperskyOS-based solution has specific usage scenarios and is designed to counteract specific security threats. Nonetheless, there are some typical scenarios and threats encountered in many different solutions. This section describes the typical risks and threats, and contains a description of architectural patterns that can be employed to increase the security of a solution.

A *security pattern (or template)* describes a specific recurring security issue that arises in certain known contexts, and provides a well-proven, general scheme for resolving this kind of security issue. A pattern is not a finished project that can be converted directly into code. Instead, it is a solution to a general problem encountered in various projects.

A *security pattern system* is a set of security patterns together with instructions on their implementation, combination, and practical use when designing secure software systems.

Security patterns resolve security issues at different levels, beginning with patterns at the architectural level, including high-level design of the system, and ending with implementation-level patterns that contain recommendations on how to implement functions or methods.

This section describes the set of security patterns whose implementation examples are provided in KasperskyOS Community Edition.

> Security patterns are described in a multitude of information security resources. Each pattern is accompanied by a list of the resources that were used to prepare its description.

Distrustful Decomposition pattern

Description

When using a monolithic application, a single process must be granted all the privileges necessary for the application to operate. This issue is resolved by the `Distrustful Decomposition` pattern.

The purpose of the `Distrustful Decomposition` pattern is to divide application functionality among individual processes that require different levels of privileges, and to control the interaction between these processes instead of creating a monolithic application.

Using the `Distrustful Decomposition` pattern reduces the following:

- Attack surface for each process.
- Functionality and data that a hacker will be able to access if one of the processes is compromised.

Alternate names

`Privilege Reduction`.

Context

Different functions of an application require different levels of privileges.

Problem

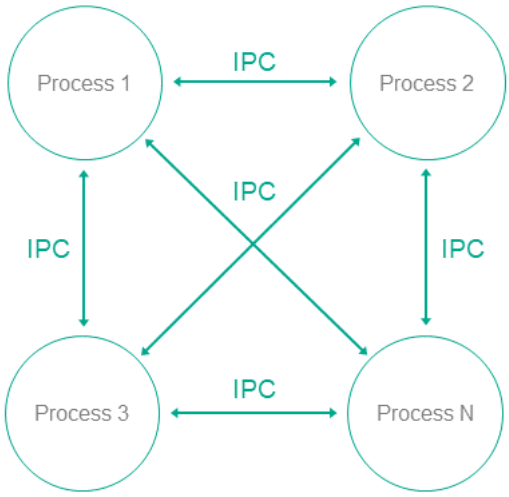
An unsophisticated implementation of an application combines many functions requiring different privileges into one component. This component would need to be run with the maximum level of privileges required for any one of these many functions.

Solution

The `Distrustful Decomposition` pattern divides functionality among individual processes and isolates potential vulnerabilities within a small subset of the system. A cybercriminal who conducts a successful attack will be able to use only the functionality and data of a single compromised component instead of the entire application.

Structure

This pattern divides one monolithic application into multiple applications that are run as individual processes that could potentially have different privileges. Each process implements a small, clearly defined set of functions of the application. Processes use interprocess communication mechanism to exchange data.



Operation

- In KasperskyOS, an application is divided into processes.
- Processes can exchange messages via IPC.
- A user or remote system connects to the process that provides the necessary functionality with the level of privileges sufficient to perform the requested functions.

Implementation recommendations

Interaction between processes can be unidirectional or bidirectional. It is recommended to always use unidirectional interaction whenever possible. Otherwise, the potential attack surface of individual components increases, which reduces the overall security of the entire system. If bidirectional IPC is used, processes should not trust bidirectional data exchange. For example, if a file system is used for IPC, file contents cannot be trusted.

Specialized implementation in KasperskyOS

In universal operating systems such as Linux or Windows, this pattern does not use anything except the standard process/privileges model that already exists in these operating systems. Each program is run in its own process space with potentially different privileges of the specific user in each process. However, an attack on the OS kernel would reduce the effectiveness of this pattern.

Use of this pattern when developing for KasperskyOS means that control over processes and IPC is entrusted to the microkernel, which is difficult to successfully attack. The Kaspersky Security Module is used for IPC control.

Use of KasperskyOS mechanisms ensures a high level of reliability of the software system with the same or less effort required from the developer when compared to the use of this pattern in programs running under universal operating systems.

In addition, KasperskyOS provides the capability for flexible configuration of security policies. Moreover, the process of defining and editing security policies is potentially independent of the process of developing the applications.

Linked patterns

Use of the `Distrustful Decomposition` pattern involves use of the Defer to Kernel and Policy Decision Point patterns.

Implementation examples

Examples of an implementation of the `Distrustful Decomposition` pattern:

- Secure Logger
- Separate Storage

Sources of information

The `Distrustful Decomposition` pattern is described in detail in the following resources:

- Chad Dougherty, Kirk Sayre, Robert C. Seacord, David Svoboda, Kazuya Togashi (JPCERT/CC), "Secure Design Patterns" (March-October 2009). Software Engineering Institute. https://resources.sei.cmu.edu/asset_files/TechnicalReport/2009_005_001_15110.pdf
- Dangler, Jeremiah Y., "Categorization of Security Design Patterns" (2013). Electronic Theses and Dissertations. Paper 1119. https://dc.etsu.edu/etd/1119

Secure Logger example

The `Secure Logger` example demonstrates use of the Distrustful Decomposition pattern for separating event log read/write functionality.

Example architecture

The security goal of the `Secure Logger` example is to prevent any possibility of distortion or deletion of information from the event log. This example utilizes the capabilities provided by KasperskyOS to achieve this security goal.

A logging system can be examined by distinguishing the following functional steps:

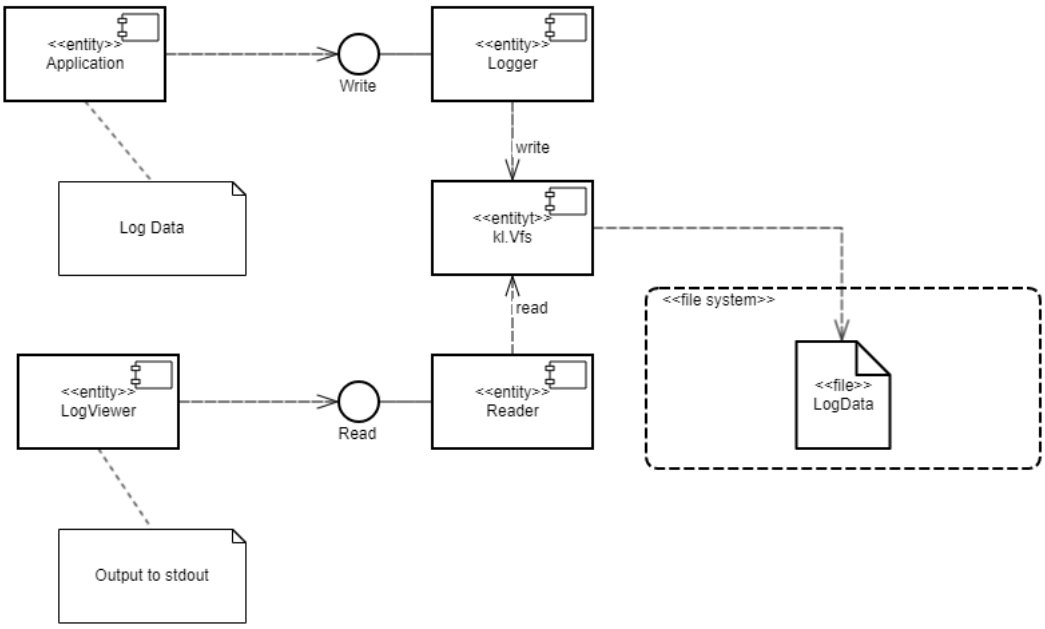
- Generate information to be written to the log.
- Save information to the log.
- Read entries from the log.
- Provide entries in a convenient format for the consumer.

Accordingly, the logging subsystem can be divided into four processes depending on the required functional capabilities of each process.

For this purpose, the `Secure Logger` example contains the following four programs: `Application`, `Logger`, `Reader` and `LogViewer`.

- The `Application` program initiates the creation of entries in the event log maintained by the `Logger` program.
- The `Logger` program creates entries in the log and writes them to the disk.
- The `Reader` program reads entries from the disk to send them to the `LogViewer` program.
- The `LogViewer` program sends entries to the user.

The IPC interface provided by the `Logger` program is intended *only* for writing to storage. The IPC interface of the `Reader` program is intended only for reading from storage. The example architecture looks as follows:



- The `Application` program uses the interface of the `Logger` program to save log entries.
- The `LogViewer` program uses the interface of the `Reader` program to read the log entries and present them to a user.

The `LogViewer` program normally has external channels for interacting with a user (for example, to receive data write commands and to provide data to a user). Naturally, this program is an untrusted component of the system, and therefore could potentially be used to conduct an attack. However, even if a successful attack results in the infiltration of unauthorized executable code into the `LogViewer` program, information in the log cannot be distorted through this program. This is because the program can only utilize the data read interface, which cannot actually be used to distort or delete data. Moreover, the `LogViewer` program does not have the capability to gain access to other interfaces because this access is controlled by the security module.

A security policy in the `Secure Logger` example has the following characteristics:

- The `Application` program has the capability to query the `Logger` program to create a new entry in the event log.
- The `LogViewer` program has the capability to query the `Reader` program to read entries from the event log.
- The `Application` program *does not* have the capability to query the `Reader` program to read entries from the event log.
- The `LogViewer` program *does not* have the capability to query the `Logger` program to create a new entry in the event log.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/secure_logger
```

Building and running example

See Building and running examples section.

Separate Storage example

The `Separate Storage` example demonstrates use of the Distrustful Decomposition pattern to separate data storage for trusted and untrusted applications.

Example architecture

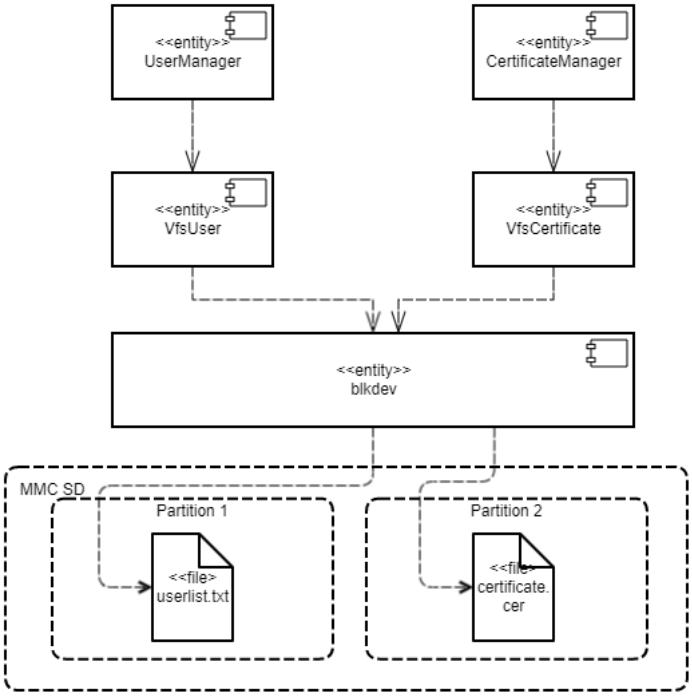
The `Separate Storage` example contains two user programs: `UserManager` and `CertificateManager`.

These programs work with data located in the corresponding files:

- The `UserManager` program works with data from the `userlist.txt` file.

- The `CertificateManager` program works with data from the `certificate.cer` file.

Each of these programs uses its own instance of the VFS program to access a separate file system. Each VFS program includes a block device driver linked to an individual logical drive partition. The `UserManager` program does not have access to the file system of the `CertificateManager` program, and vice versa.



This architecture guarantees that if there is an attack or error in any of the `UserManager` or `CertificateManager` programs, this program will not be able to access any file that was not intended for the specific program's operations.

A security policy in the `Separate Storage` example has the following characteristics:

- The `UserManager` program has access to the file system *only* through the `VfsUser` program.
- The `CertificateManager` program has access to the file system *only* through the `VfsCertificate` program.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/separate_storage
```

Building and running example

To run an example on QEMU, go to the directory containing the example, build the example and run the following commands:

```
$ cd build/einit
# Before running the following command, be sure that the path to
# the directory with the qemu-system-aarch64 executable file is saved in
```

```
# the PATH environment variable. If it is not there,
# add it to the PATH variable.
$ qemu-system-aarch64 -m 2048 -machine vexpress-a15 -nographic -monitor none -sd
sdcard0.img -kernel kos-qemu-image
```

See also Building and running examples section.

Preparing an SD card to run on Raspberry Pi 4 B

To run the `Separate Storage` example on Raspberry Pi 4 B, the following additional actions are necessary:

- Create a `/lib` directory in the SD card boot sector unless one already exists.
- Copy the contents of the `build/hdd/part1/lib` directory that was generated while building the example to the `/lib` directory in the SD card boot sector.
- The SD card must contain both a bootable partition with the solution image as well as 2 additional partitions with the `ext2` or `ext3` file systems.
- The first additional partition must contain the `userlist.txt` file from the `./resources/files/` directory.
- The second additional partition must contain the `certificate.cer` file from the `./resources/files/` directory.

> To run the `Separate Storage` example on Raspberry Pi 4 B, you can use an SD card prepared for running the `vfs_extfs` example on Raspberry Pi 4 B after copying the `userlist.txt` and `certificate.cer` files to the appropriate partitions.

Defer to Kernel pattern

Description

The `Defer to Kernel` pattern takes advantage of permission control at the OS kernel level.

The purpose of this pattern is to utilize mechanisms available at the OS kernel level to clearly separate the functionality requiring elevated privileges from the functionality that does not require elevated privileges. By using kernel mechanisms, we do not have to implement new tools for arbitrating security decisions at the user level.

Alternate names

`Policy Enforcement Point (PEP)`, `Protected System`, `Enclave`.

Context

The `Defer to Kernel` pattern is applicable if the system has the following characteristics:

- The system has processes that run without elevated privileges, including user processes.
- Some system functions require elevated privileges that must be verified before processes are granted access to data.
- You need to verify not only the privileges of the requesting process, but also the overall permissibility of the requested operation within the operational context of the entire system and its overall security.

Problem

When functionality is divided among various processes with different levels of privileges, these privileges must be verified when a request is made from one process to another. These verifications must be carried out and their resulting permissions must be granted by trusted code that has a minimal risk of being compromised. The trustworthiness of application code is almost always questionable due to its sheer volume and due to its primary orientation toward implementation of functional requirements.

Solution

Clearly separate privileged functionality and data from non-privileged functionality and data at the process level, and give the OS kernel control of interprocess communication (IPC), including verification of access rights when there is a request for functionality or data requiring elevated privileges, and verification of the overall state of the system and the states of individual processes at the time of the request.

Structure

Operation

- Functionality and management of data with various privileges are compartmentalized among processes.
- The OS kernel ensures isolation of processes.
- `Process-1` wants to request privileged functionality or data from `Process-2` using IPC.
- The kernel controls IPC and allows or denies communication based on security policies and based on the available information regarding the operational context and state of `Process-1`.

Implementation recommendations

To ensure that a specific implementation of a pattern operates securely and reliably, the following is required:

- **Isolation**

Complete and guaranteed isolation of processes must be ensured.

- **Inability to bypass the kernel**

  Absolutely all IPC interactions must be controlled by the kernel.

- **Kernel self-defense**

  The trustworthiness of the kernel must be ensured through its own means of protection against compromise.

- **Provability**

  The kernel requires a certain level of guaranteed security and reliability.

- **Capability for external computation of access permissions**

  Access permissions must be computed at the OS level, and must not be implemented in application code.

  For this purpose, tools must be provided for describing access policies so that security policies are detached from the business logic.

Specialized implementation in KasperskyOS

The KasperskyOS kernel guarantees isolation of processes and serves as a Policy Enforcement Point (PEP).

Linked patterns

The `Defer to Kernel` pattern is a special case of the Distrustful Decomposition and Policy Decision Point patterns. The `Policy Decision Point` pattern defines the abstraction process that intercepts all requests to resources and verifies that they comply with the defined security policy. The distinctive feature of the `Defer to Kernel` pattern is that the verification process is performed by the OS kernel, which is a more reliable and portable solution that reduces the time spent on development and testing.

Impacts

By making the OS kernel responsible for applying the access policy, you separate the security policy from the business logic (which may be very complicated) and thereby simplify development and improve portability through the use of OS kernel functions.

This also makes it possible to prove the overall security of a solution by simply demonstrating that the kernel is operating correctly. The difficulty in proving correct execution of code grows nonlinearly as the size of the code increases. The `Defer to Kernel` pattern minimizes the amount of trusted code, provided that the OS kernel itself is not too large.

Implementation examples

Example of a `Defer to Kernel` pattern implementation: Defer to Kernel example.

Sources of information

The `Defer to Kernel` pattern is described in detail in the following resources:

- Chad Dougherty, Kirk Sayre, Robert C. Seacord, David Svoboda, Kazuya Togashi (JPCERT/CC), "Secure Design Patterns" (March-October 2009). Software Engineering Institute. https://resources.sei.cmu.edu/asset_files/TechnicalReport/2009_005_001_15110.pdf

- Dangler, Jeremiah Y., "Categorization of Security Design Patterns" (2013). Electronic Theses and Dissertations. Paper 1119. https://dc.etsu.edu/etd/1119

- Schumacher, Markus, Fernandez-Buglioni, Eduardo, Hybertson, Duane, Buschmann, Frank, and Sommerlad, Peter. "Security Patterns: Integrating Security and Systems Engineering" (2006)

Defer to Kernel example

The `Defer to Kernel` example demonstrates the use of Defer to Kernel and Policy Decision Point patterns.

The `Defer to Kernel` example contains three user programs: `PictureManager`, `ValidPictureClient` and `NonValidPictureClient`.

In this example, the `ValidPictureClient` and `NonValidPictureClient` programs query the `PictureManager` program to receive information.

Only the `ValidPictureClient` program is allowed to interact with the `PictureManager` program.

The KasperskyOS kernel guarantees isolation of running programs (processes).

Control of interaction between programs in KasperskyOS is delegated to the Kaspersky Security Module. The subsystem analyzes each sent request and response and decides whether to allow or deny delivery based on the defined security policy.

A security policy in the `Defer to Kernel` example has the following characteristics:

- The `ValidPictureClient` program is explicitly allowed to interact with the `PictureManager` program.

- The `NonValidPictureClient` program is explicitly *not* allowed to interact with the `PictureManager` program. This means that this interaction is denied (based on the *Default Deny principle*).

Dynamically created IPC channels

The example also demonstrates the capability to dynamically create IPC channels between processes. IPC channels are dynamically created by using a name server, which is a special kernel service provided by the `NameServer` program. The capability to dynamically create IPC channels allows you to change the topology of interaction between programs on the fly.

Any program that is allowed to interact with `NameServer` via IPC can register its own interfaces in the name server. Another program can request the registered interfaces from the name server, and then connect to the relevant interface.

The security module is used to control interactions via IPC (even those that were created dynamically).

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/defer_to_kernel
```

Building and running example

See Building and running examples section.

Policy Decision Point pattern

Description

The `Policy Decision Point` pattern encapsulates the computation of decisions based on security model methods into a separate system component that ensures that these security methods are performed in their full scope and correct sequence.

Alternate names

`Check Point`, `Access Decision Function`.

Context

The system has functions with different levels of privileges, and the security policy is complex (contains many security model methods bound to security events).

Problem

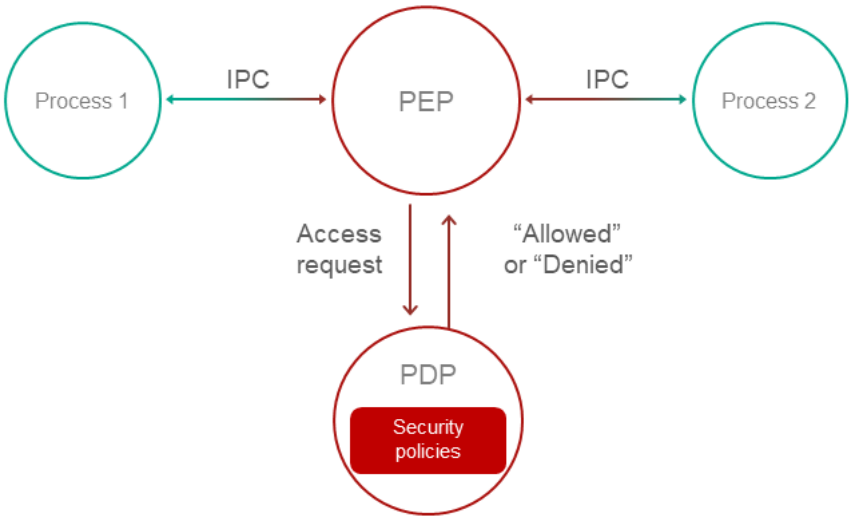
If security policy checks are divided among different system components, the following issues arise:

- You have to carefully make sure that all necessary checks are performed in all required cases.
- It is difficult to ensure that all checks are performed in the correct order.
- It is difficult to prove that the verification system is operating correctly, has no conflicts, and its integrity has not been compromised.
- The security policy is linked to the business logic. This means that any modification of the security policy requires changes to the business logic, which complicates support and increases the likelihood of errors.

Solution

All verifications of security policy compliance are conducted in a separate component called a Policy Decision Point (PDP). This component is responsible for ensuring that verifications are conducted in their correct sequence and scope. Policy checks are separated from the code that implements the business logic.

Structure



Operation

- A Policy Enforcement Point (PEP) receives a request to access functionality or data.

  For example, the PEP may be the OS kernel. For more details, refer to Defer to Kernel pattern.
- The PEP gathers the request attributes required for making decisions on access control.
- The PEP requests an access control decision from the Policy Decision Point (PDP).
- The PDP computes a decision on whether to grant access based on the security policy and based on the information received in the request from the PEP.
- The PEP denies or allows interaction based on the decision of the PDP.

Implementation recommendations

Implementations must take into account the problem of "Verification time vs. Usage time". For example, if a security policy depends on the quickly changing status of a specific system object, a computed decision loses its relevance as quickly as the status changes. In a system that utilizes the **Policy Decision Point** pattern, you must take care to minimize the time interval between the access decision and the time when the request based on this decision is fulfilled.

Specialized implementation in KasperskyOS

The KasperskyOS kernel guarantees isolation of processes and serves as a Policy Enforcement Point (PEP).

Control of interaction between processes in KasperskyOS is delegated to the Kaspersky Security Module. This module analyzes each sent request and response and decides whether to allow or deny delivery based on the defined security policy. Therefore, the Kaspersky Security Module performs the role of the Policy Decision Point (PDP).

Impacts

This pattern configures a security policy without making any modifications to the code that implements the business logic, and delegates system support involving information security.

Linked patterns

Use of the `Policy Decision Point` pattern involves use of the Distrustful Decomposition and Defer to Kernel patterns.

Implementation examples

Example of a `Policy Decision Point` pattern implementation: Defer to Kernel example.

Sources of information

The `Policy Decision Point` pattern is described in detail in the following resources:

- Chad Dougherty, Kirk Sayre, Robert C. Seacord, David Svoboda, Kazuya Togashi (JPCERT/CC), "Secure Design Patterns" (March-October 2009). Software Engineering Institute. https://resources.sei.cmu.edu/asset_files/TechnicalReport/2009_005_001_15110.pdf
- Dangler, Jeremiah Y., "Categorization of Security Design Patterns" (2013). Electronic Theses and Dissertations. Paper 1119. https://dc.etsu.edu/etd/1119
- Schumacher, Markus, Fernandez-Buglioni, Eduardo, Hybertson, Duane, Buschmann, Frank, and Sommerlad, Peter. "Security Patterns: Integrating Security and Systems Engineering" (2006)
- Bob Blakley, Craig Heath, and members of The Open Group Security Forum. "Security Design Patterns" (April 2004). The Open Group. https://pubs.opengroup.org/onlinepubs/9299969899/toc.pdf

Privilege Separation pattern

Description

The `Privilege Separation` pattern involves the use of non-privileged isolated system modules for interaction with clients (other modules or users) that do not have any privileges. The purpose of the `Privilege Separation` pattern is to reduce the amount of code that is executed with special privileges without impacting or restricting application functionality.

The `Privilege Separation` pattern is a special case of the Distrustful Decomposition pattern.

Example

An unauthenticated user connects to a system that has functions requiring elevated privileges.

Context

The system has components with a large attack surface due to their high number of connections with unsafe sources and/or a complicated, potentially error-prone implementation.

Problem

When a client with unknown privileges interacts with a privileged component of the system, there are risks that the data and functionality accessible to that component could be compromised.

Solution

Interactions with unsafe clients must be conducted only through specially allocated components that have no privileges. The `Privilege Separation` pattern does not modify system functionality. Instead, it merely separates functionality into components with different privileges.

Operation

Pattern operations can be divided into two phases:

- **Pre-Authentication.** The client is not yet authenticated. It sends a request to a privileged master process. The master process creates a child process with no privileges (and no access to the file system). This child process performs client authentication.
- **Post-Authentication.** The client is authenticated and authorized. The privileged master process creates a new child process that has privileges corresponding to the permissions of the client. This process is responsible for all subsequent interaction with the client.

Recommendations on implementation in KasperskyOS

At the **Pre-Authentication** phase, the master process can save the state of each non-privileged process in the form of a finite-state machine and change the state of the finite-state machine during authentication.

Requests from child processes to the master process are performed using standard IPC mechanisms. However, interaction control is conducted using the Kaspersky Security Module.

Impacts

If attackers gain control of a non-privileged process, they will not gain access to any privileged functions or data. If attackers gain control of an authorized process, they will obtain only the privileges of this process.

In addition, code that is organized in this manner is easier to check and test. You just have to pay special attention to the functionality that operates with elevated privileges.

Implementation examples

Example of a `Privilege Separation` pattern implementation: Device Access example.

Sources of information

The `Privilege Separation` pattern is described in detail in the following resources:

- Chad Dougherty, Kirk Sayre, Robert C. Seacord, David Svoboda, Kazuya Togashi (JPCERT/CC), "Secure Design Patterns" (March-October 2009). Software Engineering Institute.

https://resources.sei.cmu.edu/asset_files/TechnicalReport/2009_005_001_15110.pdf

- Dangler, Jeremiah Y., "Categorization of Security Design Patterns" (2013). Electronic Theses and Dissertations. Paper 1119. https://dc.etsu.edu/etd/1119

Device Access example

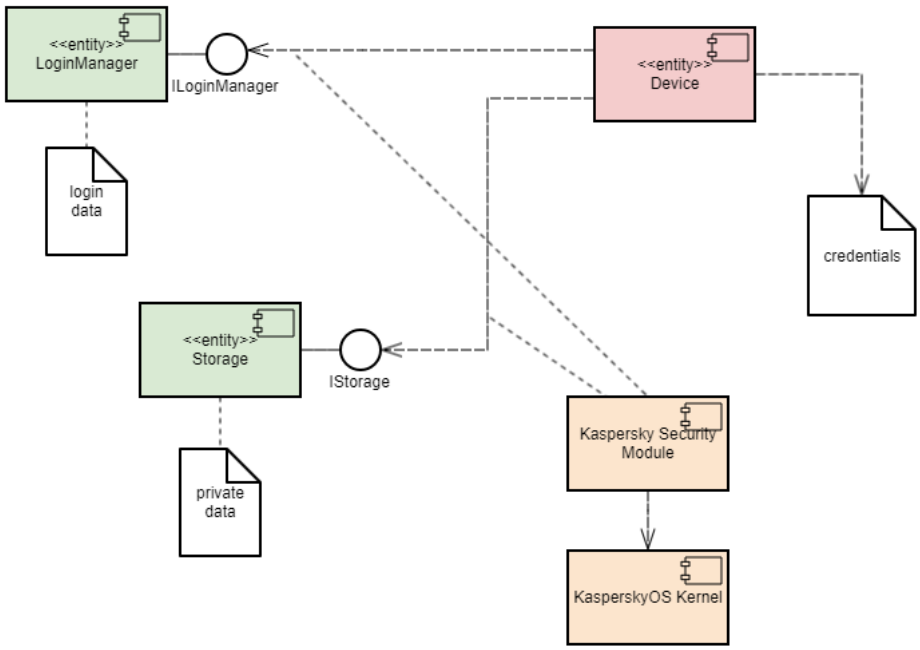
The `Device Access` example demonstrates use of the Privilege Separation pattern.

Example architecture

The example contains the following three programs: `Device`, `LoginManager` and `Storage`.

In this example, the `Device` program queries the `Storage` program to receive information and queries the `LoginManager` program for authorization.

The `Device` program obtains access to the `Storage` program after successful authorization.



This example demonstrates the capability to separate the authorization logic and the data access logic into independent components. This separation guarantees that data access can be opened only after successful authorization. The security module monitors whether authorization was successfully completed. This architecture also enables independent development and testing of the authorization logic and the data access provision logic.

A security policy in the `Device Access` example has the following characteristics:

- The `Device` program has the capability to query the `LoginManager` program for authorization.
- Calls of the `GetInfo()` method of the `Storage` program are managed by methods of the Flow security model:
  - The finite-state machine described in the `session` object configuration has two states: `unauthenticated` and `authenticated`.
  - The initial state is `unauthenticated`.

- Only transitions from `unauthenticated` to `authenticated` and vice versa are allowed.
- The `session` object is created when the `Device` program is started.
- When the `Device` program successfully calls the `Login()` method of the `LoginManager` program, the state of the `session` object changes to `authenticated`.
- When the `Device` program successfully calls the `Logout()` method of the `LoginManager` program, the state of the `session` object changes to `unauthenticated`.
- When the `Device` program calls the `GetInfo()` method of the `Storage` program, the current state of the `session` object is verified. The call is allowed only if the current state of the object is `authenticated`.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/device_access
```

Building and running example

See Building and running examples section.

Information Obscurity pattern

Description

The purpose of the `Information Obscurity` pattern is to encrypt confidential data in otherwise unsafe environments and thereby protect against data theft.

Context

This pattern should be used when data is frequently transferred between parts of a system and/or between the system and other (external) systems.

Problem

Confidential data may be transmitted through an untrusted environment within one system (through untrusted components) or between different systems (through untrusted networks). If this environment is compromised, confidential data could be intercepted by a cybercriminal.

Solution

Data must be separated based on its specific level of confidentiality so that you can determine which data should be encrypted and which encryption algorithms should be used. Encryption and decryption may take a lot of time, therefore their use should be limited whenever possible. The `Information Obscurity` pattern resolves this issue by utilizing a specific confidentiality level to determine what exactly must be concealed with encryption.

Implementation examples

Example of an `Information Obscurity` pattern implementation: Secure Login example.

Sources of information

The `Information Obscurity` pattern is described in detail in the following resources:

- Dangler, Jeremiah Y., "Categorization of Security Design Patterns" (2013). Electronic Theses and Dissertations. Paper 1119. https://dc.etsu.edu/etd/1119
- Schumacher, Markus, Fernandez-Buglioni, Eduardo, Hybertson, Duane, Buschmann, Frank, and Sommerlad, Peter. "Security Patterns: Integrating Security and Systems Engineering" (2006)

Secure Login (Civetweb, TLS-terminator) example

The `Secure Login` example demonstrates use of the Information Obscurity pattern. This example demonstrates the capability to transmit critical system information through an untrusted environment.

Example architecture

This example simulates the acquisition of remote access to an IoT device by sending user account credentials (user name and password) to this device. The untrusted environment within the IoT device is the web server that responds to requests from users. Practical experience has shown that this kind of web server is easy to detect and frequently attacked successfully because IoT devices do not have built-in tools for protection against intrusion and other attacks. Users also gain access to the IoT device through an untrusted network. Obviously, encryption algorithms must be used in these types of conditions to protect user account credentials from being compromised.

In terms of the architecture in these systems, the following objects can be distinguished:

- Data source: user's browser.
- Point of communication with the device: web server.
- Subsystem for processing information from the user: authentication subsystem.

To employ cryptographic protection, the following steps must be completed:

1. Configure interaction between the data source and the device over the HTTPS protocol. This helps prevent unauthorized surveillance of HTTP traffic and MITM (man-in-the-middle) attacks.
2. Generate a shared secret between the data source and the information processing subsystem.

3. Use this secret to encrypt information on the data source side and to decrypt the information on the information processing subsystem side. This helps prevent data within the device from being compromised (at the point of communication).

The `Secure Login` example includes the following components:

- `Civetweb` web server (untrusted component, `WebServer` program).
- User authentication subsystem (trusted component, `AuthService` program).
- TLS terminator (trusted component, `TlsEntity` program). This component supports the TLS (transport layer security) mechanism. Together with the web server, the TLS terminator supports the HTTPS protocol on the device side (the web server interacts with the browser through the TLS terminator).

The user authentication process occurs as follows:

1. Using their browser, the user opens the page at `https://localhost:1106` (when running the example on QEMU) or at `https://<Raspberry Pi IP address>:1106` (when running the example on Raspberry Pi 4 B). HTTP traffic between the browser and TLS terminator will be transmitted in encrypted form, but the web server will work only with unencrypted HTTP traffic.

   > This example uses a self-signed certificate, so most up-to-date browsers will warn you that the connection is not secure. You need to agree to use this "insecure" connection, which will actually be encrypted despite the warning. In some browsers, you may encounter the message `"TLS: Error performing handshake: -30592: errno = Success"`.

2. The `Civetweb` web server running in the `WebServer` program displays the `index.html` page containing an authentication prompt.
3. The user clicks the `Log in` button.
4. The `WebServer` program queries the `AuthService` program via IPC to get the page containing the user name and password input form.
5. The `AuthService` program performs the following actions:
   - Generates a private key and public settings, and calculates the public key based on the Diffie-Hellman algorithm.
   - Creates the `auth.html` page containing the user name and password input form (the page code contains the public settings and the public key).
   - Transfers the received page to the `WebServer` program via IPC.
6. The `Civetweb` web server running in the `WebServer` program displays the `auth.html` page containing the user name and password input form.
7. The user completes the form and clicks the `Submit` button (correct data for authentication is contained in the file `secure_login/auth_service/src/authservice.cpp`).
8. The `auth.html` page code executed by the browser performs the following actions:
   - Generates a private key and calculates the public key and shared secret key based on the Diffie-Hellman algorithm.

- Encrypts the password by using the `XOR` operation with the shared secret key.
- Transmits the user name, encrypted password and public key to the web server.

9. The `WebServer` program queries the `AuthService` program via IPC to get the page containing the authentication result by transmitting the user name, encrypted password and public key.
10. The `AuthService` program performs the following actions:
    - Calculates the shared secret key based on the Diffie-Hellman algorithm.
    - Decrypts the password by using the shared secret key.
    - Returns the `result_err.html` page or `result_ok.html` page depending on the authentication result.
11. The `Civetweb` web server running in the `WebServer` program displays the `result_err.html` page or the `result_ok.html` page.

This way, confidential data is transmitted only in encrypted form through the network and web server. In addition, all HTTP traffic is transmitted through the network in encrypted form. Data is transferred between components via IPC interactions controlled by the Kaspersky Security Module.

Unit testing using the GoogleTest framework

In addition to the Information Obscurity pattern, the `Secure Login` example demonstrates use of the GoogleTest framework to conduct unit testing of applications developed for KasperskyOS (this framework is provided in KasperskyOS Community Edition).

The source code of the tests is located at the following path:

`/opt/KasperskyOS-Community-Edition-<version>/examples/secure_login/tests`

These unit tests are designed for verification of certain CPP modules of the authentication subsystem and web server.

To start testing:

1. Go to the directory with the `Secure Login` example.
2. Delete the `build` directory containing the results of the previous build by running the following command:

   ```
   sudo rm -rf build/
   ```

3. Run the command to start testing:

   ```
   $ RUN_TESTS=YES ./cross-build.sh
   ```

Tests are conducted in the `TestEntity` program. The `AuthService` and `WebServer` programs are not started in this case. Therefore, the example cannot be used to demonstrate the Information Obscurity pattern when testing is being conducted.

After testing is finished, the results of the tests are displayed.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/secure_login
```

Building and running example

To run an example on QEMU, go to the directory containing the example, build the example and run the following commands:

```
$ cd build/einit
# Before running the following command, be sure that the path to
# the directory with the qemu-system-aarch64 executable file is saved in
# the PATH environment variable. If it is not there,
# add it to the PATH variable.
$ qemu-system-aarch64 -m 2048 -machine vexpress-a15 -nographic -monitor none -net
nic,macaddr=52:54:00:12:34:56 -net user,hostfwd=tcp::1106-:1106 -sd sdcard0.img -
kernel kos-qemu-image
```

See also Building and running examples section.

To ensure that the `secure_login` example will correctly run in Raspberry Pi, you must do the following after building the example and preparing your bootable SD card:

- Copy the `certs` and `www` directories located at the path `/opt/KasperskyOS-Community-Edition-<version>/examples/secure_login/resources/hdd` to the root directory of the bootable SD card.
- Create the `/lib` directory on the bootable SD card if this directory doesn't already exist.
- Open the `build/hdd/lib` directory that was generated when building the example and copy the directory contents to the `/lib` directory on the bootable SD card.

Appendices

This section provides additional information to supplement the primary text of the document.

Additional examples

This section provides descriptions of additional examples that are included in KasperskyOS Community Edition.

See also the descriptions of security pattern implementation examples:

- Secure Logger example
- Separate Storage example
- Defer to Kernel example
- Device Access example
- Secure Login (Civetweb, TLS-terminator) example

hello example

The `hello.c` code looks familiar and simple to a developer that uses C, and is fully compatible with POSIX:

hello.c

```c
#include <stdio.h>
#include <stdlib.h>

int main(int argc, const char *argv[])

{

    fprintf(stderr,"Hello world!\n");

    return EXIT_SUCCESS;

}
```

Compile this code using `aarch64-kos-gcc`, which is included in the development tools of KasperskyOS Community Edition:

```
aarch64-kos-gcc -o hello hello.c
```

> The program name (and, consequently, the name of the executable file) must begin with an uppercase letter.

EDL description of the Hello process class

A static description of the `Hello` program consists of a single file named `Hello.edl` that must indicate the name of the process class:

Hello.edl

```
/* The process class name follows the reserved word "entity". */
entity Hello
```

> The process class name must begin with an uppercase letter. The name of an EDL file must match the name of the class that it describes.

Creating the Einit initializing program

> When KasperskyOS is loaded, the kernel starts a program named `Einit`. The `Einit` program starts all other programs included in the solution, which means that it serves as the *initializing program*.
> The KasperskyOS Community Edition toolkit includes the einit tool, which generates the code of the initializing program (`einit.c`) based on the *init description*. In the example provided below, the file containing the init description is named `init.yaml`, but it can have any name.
> For more details, refer to "Starting processes".

If you want the `Hello` program to start after the operating system is loaded, all you need to do is specify its name in the `init.yaml` file and build an `Einit` program based on it.

init.yaml

```
entities:
# Start the "Hello" application.
- name: Hello
```

Building the security module

The hello example contains a basic solution security policy (`security.psl`) that allows all interactions.

The security module (`ksm.module`) is built based on `security.psl`.

Example files

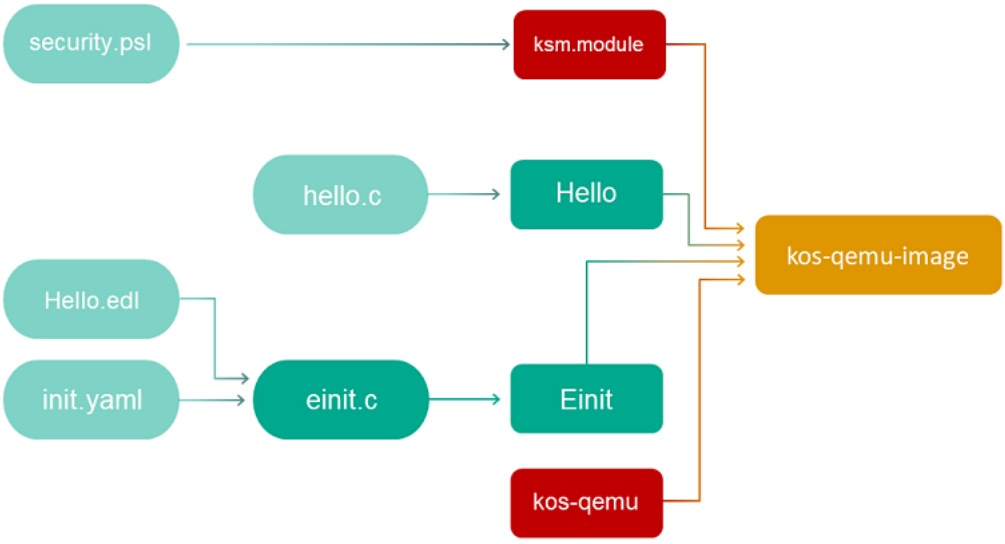
The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/hello
```

Building and running example

See Building and running examples section.

The general build scheme for the hello example looks as follows:



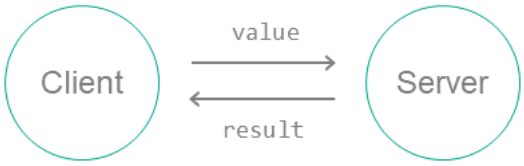
echo example

The echo example demonstrates the use of IPC transport.

It shows how to use the main tools that let you implement interaction between programs.

The echo example describes a basic case of interaction between two programs:

1. The `Client` program sends a number (`value`) to the `Server` program.
2. The `Server` program modifies this number and sends the new number (`result`) to the `Client` program.
3. The `Client` program prints the `result` number to the screen.

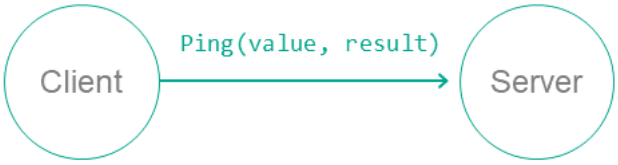


To set up this interaction between programs:

1. Connect the `Client` and `Server` programs by using the init description.
2. On the server, implement an interface with a single `Ping` method that has one input argument (the original number (`value`)) and one output argument (the modified number (`result`)).

   Description of the `Ping` method in the IDL language:

```
Ping(in UInt32 value, out UInt32 result);
```



3. Create static description files in the EDL, CDL and IDL languages. Use the NK compiler to generate files containing transport methods and types (proxy object, dispatchers, etc.).

4. In the code of the `Client` program, initialize all required objects (transport, proxy object, request structure, etc.) and call the interface method.

5. In the code of the `Server` program, prepare all the required objects (transport, component dispatcher and program dispatcher, etc.), accept the request from the client, process it and send a response.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/echo
```

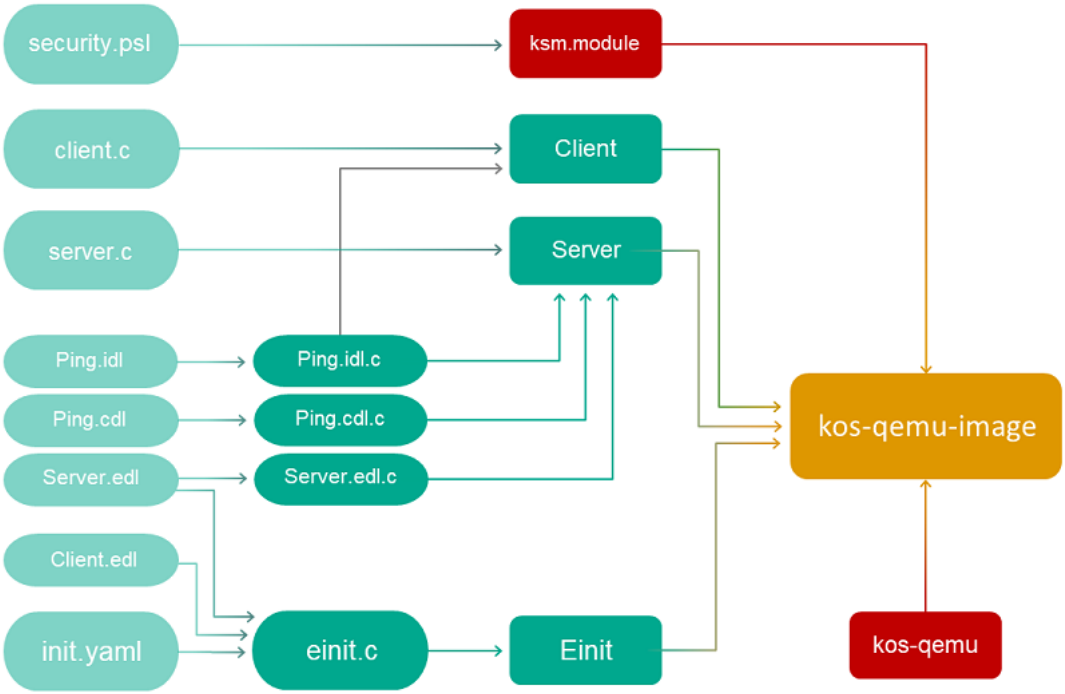
The echo example consists of the following source files:

- `client/src/client.c` contains implementation of the `Client` program.
- `server/src/server.c` contains implementation of the `Server` program.
- `resources/Server.edl`, `resources/Client.edl`, `resources/Responder.cdl`, `resources/Pingable.idl` are static descriptions.
- `init.yaml` contains the init description.

Building and running example

See Building and running examples section.

The build scheme for the echo example looks as follows:



ping example

The ping example demonstrates the use of a solution security policy to control interactions between programs.

The ping example includes four programs: `Client`, `Server`, `KlogEntity` and `KlogStorageEntity`.

The `Server` program provides two identical `Ping` and `Pong` methods that receive a number and return a modified number:

```
Ping(in UInt32 value, out UInt32 result);
Pong(in UInt32 value, out UInt32 result);
```

The `Client` program calls both of these methods in a different sequence. If the method call is denied by the solution security policy, a message regarding the failed call attempt is displayed.

The system programs `KlogEntity` and `KlogStorageEntity` perform a security audit.

> The transport part of the ping example is virtually identical to its counterpart in the echo example. The only difference is that the ping example uses two methods (`Ping` and `Pong`) instead of just one.

Solution security policy in the ping example

The solution security policy in this example allows startup of the KasperskyOS kernel and the Einit program, which is allowed to start all programs in the solution. Queries to the `Server` program are managed by methods of the Flow security model.

The finite-state machine described in the configuration of the `request_state` Flow security model object has two states: `not_sent` and `sent`. The initial state is `not_sent`. Only transitions from `not_sent` to `sent` and vice versa are allowed.

When the `Ping` and `Pong` methods are called, the current state of the `request_state` object is checked. In the `not_sent` state, only a `Ping` call is allowed, in which case the state changes to `sent`. Likewise, in the `sent` state, only a `Pong` call is allowed, in which case the state changes to `not_sent`.

Therefore, the `Ping` and `Pong` methods can be called only in succession.

Fragment of the security.psl file

```
/* Solution security policy for demonstrating use of the
 * Flow security model in the ping example */

/* Include PSL files containing formal representations of
 * Base and Flow security models */
use nk.base._
use nk.flow._

/* Including EDL files */
use EDL Einit
use EDL ping.Client
use EDL ping.Server

/* Create Flow security model object */
policy object request_state : Flow {
    type States = "not_sent" | "sent"
    config = {
        states      : [ "not_sent", "sent" ],
        initial     : "not_sent",
        transitions : {
            "not_sent" : [ "sent" ],
            "sent"     : [ "not_sent" ]
        }
    }
}

/* When the Einit program starts the Server program,
 * the initial state is set for the finite-state machine */
execute src=Einit dst=ping.Server method=main {
    request_state.init { sid: dst_sid }
}

/* When a client of the ping.Client class calls the Ping method of the
controlimpl.connectionimpl endpoint
 * of a server of the ping.Server class, the system checks whether the request_state
object is
 * in the "not_sent" state. If it is, receipt of the request is allowed and
 * the request_state object is set to the "sent" state. */
request src=ping.Client dst=ping.Server endpoint=controlimpl.connectionimpl
method=Ping {
    request_state.allow { sid: dst_sid, states: [ "not_sent" ] }
    request_state.enter { sid: dst_sid, state: "sent" }
}

/* When a client of the ping.Client class calls the Pong method of the
controlimpl.connectionimpl endpoint
 * of a server of the ping.Server class, the system checks whether the request_state
object is
 * in the "sent" state. If it is, receipt of the request is allowed and
 * the request_state object is set to the "not_sent" state. */
request src=ping.Client dst=ping.Server endpoint=controlimpl.connectionimpl
method=Pong {
    request_state.allow { sid: dst_sid, states: [ "sent" ] }
```

```
    request_state.enter { sid: dst_sid, state: "not_sent" }
}
/* A server of the ping.Server class is allowed to respond to queries from a client of
the ping.Client class
 * that calls the Ping and Pong methods of the controlimpl.connectionimpl endpoint. */
response src=ping.Server dst=ping.Client endpoint=controlimpl.connectionimpl {
    match method=Ping { grant () }
    match method=Pong { grant () }
}
```

The security policy description in the ping example also contains a section for solution security policy tests.

For an example of such a policy, see the "Example 2" section in "Examples of tests for KasperskyOS-based solution security policies".

The full security policy description for the ping example is located in the `security.psl.in` and `core.psl` files at the following path: `/opt/KasperskyOS-Community-Edition-<version>/examples/ping/einit/src`.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/ping
```

Building and running example

See Building and running examples section.

net_with_separate_vfs example

This example presents a basic case of network interaction using Berkeley sockets.

The example consists of `Client` and `Server` programs linked by a TCP socket using a loopback interface. Standard POSIX functions are used in the code of the programs.

To connect programs using a socket through a loopback, they must use the same network stack instance. This means that they must interact with a "shared" VFS program (in this example, this program is called `NetVfs`).

The CMake system, which is included with KasperskyOS Community Edition, is used to build and run the example.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/net_with_separate_vfs
```

Building and running example

See Building and running examples section.

net2_with_separate_vfs example

This example demonstrates the special features of a solution in which a program uses standard POSIX functions to interact with an external server.

The `net2_with_separate_vfs` example is a modified `net_with_separate_vfs` example. In contrast to the `net_with_separate_vfs` example, in this example a program interacts over the network with an external server rather than another program running in KasperskyOS.

This example consists of the `Client` program running in KasperskyOS on QEMU or Raspberry Pi and the `Server` program running in a Linux host operating system. The `Client` program and `Server` program are bound by a TCP socket. Standard POSIX functions are used in the code of the `Client` program.

To connect the `Client` program and the `Server` program using a socket, the `Client` program must interact with the `NetVfs` program. During the build, the `NetVfs` program is linked to a network driver that supports interaction with the `Server` program running in Linux.

The CMake system, which is included with KasperskyOS Community Edition, is used to build and run the example.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/net2_with_separate_vfs
```

Building and running example

See Building and running examples section.

To ensure that an example runs correctly, you must run the `Server` program in a Linux host operating system or on a computer connected to Raspberry Pi.

After performing the build, the `server` executable file of the `Server` program is located in the following directory:

```
/opt/KasperskyOS-Community-Edition-
<version>/examples/net2_with_separate_vfs/build/host/server/
```

To independently build the executable file of the `Server` program, you need to run the following commands:

```
$ cd net2_with_separate_vfs/server/src/
$ gcc -o server server.c
```

embedded_vfs example

This example demonstrates how to embed the virtual file system (VFS) provided in KasperskyOS Community Edition into a program being developed.

In this example, the `Client` program fully encapsulates the VFS implementation from KasperskyOS Community Edition. This lets you eliminate the use of IPC for all the standard I/O functions (`stdio.h`, `socket.h`, etc.) for debugging or performance improvement purposes, for example.

The `Client` program tests the following operations:

- Create a folder.
- Create and delete a file.
- Read from a file and write to a file.

Supplied resources

The example includes the `hdd.img` image of a hard drive with the FAT32 file system.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/embedded_vfs
```

Building and running example

See Building and running examples section.

vfs_extfs example

This example shows how to embed a new file system into the virtual file system (VFS) that is provided in KasperskyOS Community Edition.

In this example, the `Client` program tests the operation of file systems (`ext2`, `ext3`, `ext4`) on block devices. To do so, the `Client` queries the virtual file system (the `FileVfs` program) via IPC, and `FileVfs` in turn queries the block device via IPC.

The `ext2` and `ext3` file systems work with the default settings. The `ext4` file system works if you disable `extent` (`mkfs.ext4 -O ^64bit,^extent /dev/foo`).

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/vfs_extfs
```

Building and running example

See Building and running examples section.

Preparing an SD card to run on Raspberry Pi 4 B

To run the `vfs_extfs` example on Raspberry Pi 4 B, the SD card must have a bootable partition with the solution image as well as 3 additional partitions with the `ext2`, `ext3` and `ext4` file systems, respectively.

multi_vfs_ntpd example

This example shows how to use an external NTP server in KasperskyOS. The `Ntpd` program is included in KasperskyOS Community Edition and is an implementation of an NTP client, which gets time parameters from external NTP servers in the background and passes them to the KasperskyOS kernel.

The example also demonstrates the use of various virtual file systems (VFS) in a single solution:

- The `VfsNet` program is used for working with the network.
- The `VfsSdCardFs` program is used to work with the file system.

The `Client` program uses standard `libc` library functions for getting time data. These functions are converted into queries to the VFS program via IPC.

The CMake system, which is included with KasperskyOS Community Edition, is used to build and run the example.

Supplied resources

- The directory `./resources/edl` contains the `Client.edl` file, which contains a static description of the `Client` program.
- The directory `./resources/hdd/etc` contains the configuration files for the `VfsNet`, `Dhcpcd` and `Ntpd` programs: `hosts`, `dhcpcd.conf` and `ntp.conf`, respectively.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/multi_vfs_ntpd
```

Building and running example

See Building and running examples section.

multi_vfs_dns_client example

This example shows how to use an external DNS server in KasperskyOS.

The example also demonstrates the use of various virtual file systems (VFS) in a single solution:

- The `VfsNet` program is used for working with the network.
- The `VfsSdCardFs` program is used to work with the file system.

The `Client` program uses standard `libc` library functions for contacting an external DNS service. These functions are converted into queries to the `VfsNet` program via IPC.

The CMake system, which is included with KasperskyOS Community Edition, is used to build and run the example.

Supplied resources

- The directory `./resources/edl` contains the `Client.edl` file, which contains a static description of the `Client` program.
- The directory `./resources/hdd/etc` contains the configuration files for the `VfsNet` and `Dhcpcd` programs: `hosts` and `dhcpcd.conf`, respectively.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/multi_vfs_dns_client
```

Building and running example

See Building and running examples section.

multi_vfs_dhcpcd example

Example use of the `kl.rump.Dhcpcd` program.

The `Dhcpcd` program is an implementation of a DHCP client, which gets network interface parameters from an external DHCP server in the background and passes them to a virtual file system (hereinafter referred to as a VFS).

The example also demonstrates the use of different VFSes in a single solution. The example uses different VFS to access the functions for working with the file system and functions for working with the network:

- The `VfsNet` program is used for working with the network.

- The `VfsSdCardFs` program is used to work with the file system.

The `Client` program uses standard `libc` library functions for getting information on network interfaces (`ioctl`). These functions are converted into queries to the VFS program via IPC.

The CMake system, which is included with KasperskyOS Community Edition, is used to build and run the example.

Supplied resources

The `./resources/hdd/etc` directory contains configuration files for the VFS and `Dhcpcd` programs. The standard syntax of `dhcpcd.conf` is used for the `Dhcpcd` program configuration.

The `CMakeLists.txt` root file defines the values of variables that determine the selected configuration file:

- `DHCPCD_FALLBACK`

  Dynamically receive the parameters of network interfaces from an external DHCP server but statically define the parameters if the DHCP server is not available. This value is used by default.

- `DHCPCD_DYNAMIC`

  Dynamically receive the parameters of network interfaces from an external DHCP server.

- `DHCPCD_STATIC`

  Statically define the parameters of network interfaces.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/multi_vfs_dhcpcd
```

Building and running example

See Building and running examples section.

mqtt_publisher (Mosquitto) example

Example use of the MQTT protocol in KasperskyOS.

In this example, an MQTT subscriber must be started on the host operating system, and an MQTT publisher must be started on KasperskyOS. The `Publisher` program is an implementation of an MQTT publisher that publishes the current time with a 5-second interval.

When the example starts and runs successfully, an MQTT subscriber started on the host operating system prints a `"received PUBLISH"` message with a `"datetime"` topic.

The example also demonstrates the use of various virtual file systems (VFS) in a single solution:

- The `VfsNet` program is used for working with the network.

- The `VfsSdCardFs` program is used to work with the file system.

The CMake system, which is included with KasperskyOS Community Edition, is used to build and run the example.

Starting Mosquitto

To run this example, a Mosquitto MQTT broker must be installed and started on the host system. To install and start Mosquitto, run the following commands:

```
$ sudo apt install mosquitto mosquitto-clients
$ sudo /etc/init.d/mosquitto start
```

To start an MQTT subscriber on the host system, run the following command:

```
$ mosquitto_sub -d -t "datetime"
```

Supplied resources

- The directory `./resources/edl` contains the `Publisher.edl` file, which contains a static description of the `Publisher` program.
- The directory `./resources/hdd/etc` contains the configuration files for the `VfsNet`, `Dhcpcd` and `Ntpd` programs: `hosts`, `dhcpcd.conf` and `ntp.conf`, respectively.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/mqtt_publisher
```

Building and running example

See Building and running examples section.

mqtt_subscriber (Mosquitto) example

Example use of the MQTT protocol in KasperskyOS.

In this example, an MQTT publisher must be started on the host operating system, and an MQTT subscriber must be started on KasperskyOS. The `Subscriber` program is an implementation of an MQTT subscriber.

When the example starts and runs successfully, an MQTT subscriber started on KasperskyOS prints a `"Got message with topic: my/awesome/topic, payload: hello"` message.

The example also demonstrates the use of various virtual file systems (VFS) in a single solution:

- The `VfsNet` program is used for working with the network.
- The `VfsSdCardFs` program is used to work with the file system.

The CMake system, which is included with KasperskyOS Community Edition, is used to build and run the example.

Starting Mosquitto

To run this example, a Mosquitto MQTT broker must be installed and started on the host system. To install and start Mosquitto, run the following commands:

```
$ sudo apt install mosquitto mosquitto-clients
$ sudo /etc/init.d/mosquitto start
```

To start an MQTT publisher on the host system, run the following command:

```
$ mosquitto_pub  -t "my/awesome/topic" -m "hello"
```

Supplied resources

- The directory `./resources/edl` contains the `Subscriber.edl` file, which contains a static description of the `Subscriber` program.
- The directory `./resources/hdd/etc` contains the configuration files for the `VfsNet`, `Dhcpcd` and `Ntpd` programs: `hosts`, `dhcpcd.conf` and `ntp.conf`, respectively.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/mqtt_subscriber
```

Building and running example

See Building and running examples section.

gpio_input example

Example use of the GPIO driver.

This example lets you verify the functionality of GPIO input pins. The "gpio0" port is used. All pins except those indicated in `exceptionPinArr` array are set for input by default. The voltage on the pins corresponds to the state of the registers of the pull-up resistors. The state of all pins, starting from GPIO0 (accounting for the pins indicated in the `exceptionPinArr` array), will be read in succession. Messages about the state of the pins will be displayed on the console. The delay between the readings of adjacent pins is determined by the `DELAY_S` macro (the time is indicated in seconds).

`exceptionPinArr` is an array of GPIO pin numbers that need to be excluded from the example. This may be necessary if some pins are already being used for other functions, e.g. if pins are being used for a UART connection during debugging.

If you build and run this example on QEMU, an error will occur. This is the expected behavior, because there is no GPIO driver for QEMU.

If you build and run this example on Raspberry Pi 4 B, an error will occur.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/gpio_input
```

Building and running example

See Building and running examples section.

gpio_output example

Example use of the GPIO driver.

This example lets you verify the functionality of GPIO output pins. The "gpio0" port is used. The initial state of all GPIO pins should correspond to a logical zero (no voltage on the pin). All pins other than those indicated in the `exceptionPinArr` array are configured for output. Each pin, starting with GPIO0 (accounting for those indicated in the `exceptionPinArr` array), will be sequentially changed to a logical one (voltage on the pin) and then to a logical zero. The delay between the changes of pin state is determined by the `DELAY_S` macro (the time is indicated in seconds). The pins are turned on/off from `GPIO0` to `GPIO27` and then back against to `GPIO0`.

`exceptionPinArr` is an array of GPIO pin numbers that need to be excluded from the example. This may be necessary if some pins are already being used for other functions, e.g. if pins are being used for a UART connection during debugging.

If you build and run this example on QEMU, an error will occur. This is the expected behavior, because there is no GPIO driver for QEMU.

If you build and run this example on Raspberry Pi 4 B, an error will occur.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/gpio_output
```

Building and running example

See Building and running examples section.

gpio_interrupt example

Example use of the GPIO driver.

This example lets you verify the functionality of GPIO pin interrupts. The "gpio0" port is used. In the `pinsBitmap` bitmask of the `CallBackContext` interrupt context, the pins from `exceptionPinArr` array are marked as handled so that the example can properly terminate later. All pins other than those indicated in the `exceptionPinArr` array are switched to the `PINS_MODE` state. An interrupt handler will be registered for all pins other than those indicated in the `exceptionPinArr` array.

In an endless loop, the example checks whether the `pinsBitmap` bitmask from the `CallBackContext` interrupt context is equal to the `DONE_BITMASK` bitmask (which corresponds to the condition when an interrupt has occurred on each GPIO pin). Additionally, the handler function for the latest interrupted pin is removed in the loop. When a pin is interrupted for the first time, the handler function is called, which marks the corresponding pin in the `pinsBitmap` bitmask in the `CallBackContext` interrupt context. The handler function for this pin is removed later.

Keep in mind how the example may be affected by the initial state of the registers of pull-up resistors for each pin.

Interrupts for the `GPIO_EVENT_LOW_LEVEL` and `GPIO_EVENT_HIGH_LEVEL` events are not supported.

`exceptionPinArr` is an array of GPIO pin numbers that need to be excluded from the example. This may be necessary if some pins are already being used for other functions, e.g. if pins are being used for a UART connection during debugging.

If you build and run this example on QEMU, an error will occur. This is the expected behavior, because there is no GPIO driver for QEMU.

If you build and run this example on Raspberry Pi 4 B, an error will occur.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/gpio_interrupt
```

Building and running example

See Building and running examples section.

gpio_echo example

Example use of the GPIO driver.

This example makes it possible to verify the functionality of GPIO pins as well as the operation of GPIO interrupts. The "gpio0" port is used. The output pin (`GPIO_PIN_OUT`) should be connected to the input pin (`GPIO_PIN_IN`). The output pin (the pin number is defined in the `GPIO_PIN_OUT` macro) as well as the input pin (`GPIO_PIN_IN`) are configured. Use of the input pin is configured in the `IN_MODE` macro. The interrupt handler for the input pin is registered. The state of the output pin changes several times. If the example works correctly, then when the state of the output pin changes the interrupt handler will be called and will display the state of the input pin. What's more, the state of the output pin and the input pin must match.

If you build and run this example on QEMU, an error will occur. This is the expected behavior, because there is no GPIO driver for QEMU.

If you build and run this example on Raspberry Pi 4 B, an error will occur.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/gpio_echo
```

Building and running example

See Building and running examples section.

koslogger example

This example demonstrates use of the `spdlog` library in KasperskyOS using the `KOSLogger` wrapper library.

In this example, the `Client` program creates log entries that are saved on an SD card (when running the example on Raspberry Pi) or in the image file named `build/einit/sdcard0.img` (when running the example in QEMU).

The example also demonstrates the use of various virtual file systems (VFS) in a single solution. The example uses different VFS to access the functions for working with the file system and functions for working with the network:

- The `VfsNet` program is used for working with the network.
- The `VfsSdCardFs` program is used to work with the file system.

The `kl.Ntpd` program is included in KasperskyOS Community Edition and is an implementation of an NTP client, which gets time parameters from external NTP servers in the background and passes them to the KasperskyOS kernel.

The `kl.rump.Dhcpcd` program is included in KasperskyOS Community Edition and is an implementation of a DHCP client, which gets the parameters of network interfaces from an external DHCP server in the background and passes them to the virtual file system.

The `CMake` system, which is included with KasperskyOS Community Edition, is used to build and run the example.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/koslogger
```

Building and running example

See Building and running examples section.

To ensure that the `koslogger` example will correctly run in Raspberry Pi, you must do the following after building the example and preparing your bootable SD card:

- Create the `/lib` directory on the bootable SD card if this directory doesn't already exist.
- Open the `build/hdd/lib` directory that was generated when building the example and copy the directory contents to the `/lib` directory on the bootable SD card.

pcre example

This example demonstrates use of the `pcre` library in KasperskyOS.

In this example, the `Client` program uses the `pcre` library and prints the results to the console.

The `CMake` system, which is included with KasperskyOS Community Edition, is used to build and run the example.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/pcre
```

Building and running example

See Building and running examples section.

To ensure that the `pcre` example will correctly run in Raspberry Pi, you must do the following after building the example and preparing your bootable SD card:

- Create the `/lib` directory on the bootable SD card if this directory doesn't already exist.
- Open the `build/hdd/lib` directory that was generated when building the example and copy the directory contents to the `/lib` directory on the bootable SD card.

messagebus example

This example demonstrates use of the `MessageBus` component in KasperskyOS.

In this example, the `Publisher`, `SubscriberA` and `SubscriberB` programs use the MessageBus component to exchange messages.

The `MessageBus` component implements the message bus. The `Publisher` program is the publisher that transfers messages to the bus. The `SubscriberA` and `SubscriberB` programs are the subscribers that receive messages from the bus.

The example also demonstrates the use of various virtual file systems (VFS) in a single solution. The example uses different VFS to access the functions for working with the file system and functions for working with the network:

- The `VfsNet` program is used for working with the network.
- The `VfsSdCardFs` program is used to work with the file system.

The `kl.Ntpd` program is included in KasperskyOS Community Edition and is an implementation of an NTP client, which gets time parameters from external NTP servers in the background and passes them to the KasperskyOS kernel.

The `kl.rump.Dhcpcd` program is included in KasperskyOS Community Edition and is an implementation of a DHCP client, which gets the parameters of network interfaces from an external DHCP server in the background and passes them to the virtual file system.

The `CMake` system, which is included with KasperskyOS Community Edition, is used to build and run the example.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/messagebus
```

Building and running example

See Building and running examples section.

To ensure that the `messagebus` example will correctly run in Raspberry Pi, you must do the following after building the example and preparing your bootable SD card:

- Create the `/lib` directory on the bootable SD card if this directory doesn't already exist.
- Open the `build/hdd/lib` directory that was generated when building the example and copy the directory contents to the `/lib` directory on the bootable SD card.

I2c_ds1307_rtc example

This example demonstrates use of the `i2c` driver (Inter-Integrated Circuit) in KasperskyOS.

In this example, the `I2cClient` program uses the `i2c` driver interface.

The client library of the `i2c` driver is statically linked to the `I2cClient` program. The `i2c` driver implementation uses a BSP (Board Support Platform) subsystem for configuring clock frequencies (Clocks) and pins multiplexing (PinMux). Therefore, to ensure correct operation of the driver, you need to do the following:

- Link the `I2cClient` program to the `i2c_CLIENT_LIB` client library.
- Link the `I2cClient` program to the `bsp_CLIENT_LIB` client library.
- Create an IPC channel between the `I2cClient` program and the `kl.drivers.I2C` driver.
- Create an IPC channel between the `I2cClient` program and the `kl.drivers.BSP` driver.

The `CMake` system, which is included with KasperskyOS Community Edition, is used to build and run the example.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/i2c_ds1307_rtc
```

Building and running example

> This example is intended to run only on Raspberry Pi. For the example to work correctly, you must connect a DS1307Z real-time clock module to the i2c port.

See Building and running examples section.

iperf_separate_vfs example

This example demonstrates use of the `iperf` library in KasperskyOS.

In this example, the `Server` program uses the `iperf` library.

By default, the example uses network software emulation (SLIRP) in QEMU. If you configured TAP interfaces for QEMU, you need to change the network settings for starting QEMU (`QEMU_FLAGS` variable) in the `einit/CMakeLists.txt` file to make sure that the example works correctly (for more details, see the comments in the file).

The example does not use DHCP, therefore the IP address of the network interface must be manually indicated in the code of the `Server` program (`server/src/main.cpp`). SLIRP uses the default values.

The `iperf` library in the example is used in server mode. To connect to this server, install the `iperf3` program on the host machine and run it by using the `iperf3 -c localhost` command. If you configured TAP interfaces, indicate the current IP address instead of `localhost`.

The first startup of the example may take a long time because the `iperf` client uses `/dev/urandom` to fill packets with random data. To avoid this, run the `iperf` client with the `--repeating-payload` parameter.

The `CMake` system, which is included with KasperskyOS Community Edition, is used to build and run the example.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/iperf_separate_vfs
```

Building and running example

See Building and running examples section.

Uart example

Example use of the UART driver.

This example shows how to print "Hello World!" to the appropriate port using the UART driver.

When running the example simulation in QEMU, `-serial stdio` is indicated in the QEMU flags. This means that the first UART port will be printed only to the standard stream of the host machine.

A full description of the UART driver interface is provided in the file `/opt/KasperskyOS-Community-Edition-<version>/sysroot-aarch64-kos/include/uart/uart.h`.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/uart
```

Building and running example

See Building and running examples section.

spi_check_regs example

This example demonstrates use of the `SPI` (Serial Peripheral Interface) driver in KasperskyOS.

The example shows how to work with the SPI interface on the Sense HAT add-on board for Raspberry Pi. In this example, the `Client` program uses the `SPI` driver interface. The program opens an SPI channel, displays its parameters and sets the necessary operating mode. Then the program sends a data sequence over this channel and waits to receive the ID of the ATTiny controller installed on the Sense HAT board.

The client library of the `SPI` driver is statically linked to the `Client` program. The `Client` program also uses the `gpio` driver to set the controller operating mode and the BSP (Board Support Platform) subsystem for configuring clock frequencies (Clocks) and pins multiplexing (PinMux).

The `CMake` system, which is included with KasperskyOS Community Edition, is used to build and run the example.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/spi_check_regs
```

Building and running example

> This example is intended to run only on Raspberry Pi. For the example to work correctly, you must connect the Sense HAT module to the SPI port.

See Building and running examples section.

barcode_scanner example

This example demonstrates use of a `USB` (Universal Serial Bus) driver in KasperskyOS using the `libevdev` library.

In this example, the `BarcodeScanner` program uses the `libevdev` library for interaction with a barcode scanner connected to the USB port of Raspberry Pi.

The program waits for signals from the barcode scanner and prints the obtained data to `stderr`.

The `CMake` system, which is included with KasperskyOS Community Edition, is used to build and run the example.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/barcode_scanner
```

Building and running example

> This example is intended to run only on Raspberry Pi. For the example to work correctly, you must connect a barcode scanner running in keyboard emulation mode (such as Zebra Symbol LS2208) to the USB port.

See Building and running examples section.

perfcnt example

This example demonstrates use of the performance counters in KasperskyOS.

The example includes two programs: `Worker` and `Monitor`.

The `Worker` program performs computations in a loop by periodically loading the processor and utilizing memory.

The `Monitor` program uses the `KnProfilerGetCounter()` function of the `libkos` library to get the values of performance counters for the `Worker` program and prints them to the console.

The `CMake` system, which is included with KasperskyOS Community Edition, is used to build and run the example.

> If you build and run this example on QEMU, some performance counters may not function correctly.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/perfcnt
```

Building and running example

See Building and running examples section.

watchdog_system_reset example

This example demonstrates use of the `Watchdog` driver in KasperskyOS.

In this example, the `Client` program uses the `Watchdog` driver interface to interact with the Watchdog timer as follows:

- Receives the current parameters of the `Watchdog` driver and prints them to `stderr`.
- Changes the default value of the timer to a new value and starts the timer.
- Resets the timer several times.
- Waits for the system to restart when the timer is triggered.

The client library of the `Watchdog` driver is statically linked to the `Client` program.

The `CMake` system, which is included with KasperskyOS Community Edition, is used to build and run the example.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/watchdog_system_reset
```

Building and running example

See Building and running examples section.

shared_libs example

This example demonstrates use of static and dynamic libraries in KasperskyOS.

In the example, the `Client` program performs the following actions:

- Calls a function from the `hello_s` static library.
- Calls a function from the `hello_d1` dynamic library that is linked together with the program and loaded into memory when the process is started.
- Calls a function from the `hello_d2` dynamic library that is loaded into memory when calling the `dlopen()` function of the POSIX interface.

To ensure that dynamic libraries can be shared among different processes, the system program named `BlobContainer` is included in the example.

The `CMake` system, which is included with KasperskyOS Community Edition, is used to build and run the example.

Example files

The code of the example and build scripts are available at the following path:

```
/opt/KasperskyOS-Community-Edition-<version>/examples/shared_libs
```

Building and running example

See Building and running examples section.

To ensure that the `shared_libs` example will correctly run in Raspberry Pi, you must do the following after building the example and preparing your bootable SD card:

- Create the `/lib` directory on the bootable SD card if this directory doesn't already exist.
- Open the `build/hdd/lib` directory that was generated when building the example and copy the directory contents to the `/lib` directory on the bootable SD card.

Information about certain limits set in the system

Header files and IDL files from the KasperskyOS SDK contain constants that set limits in the system (see table below).

Constants that set limits in the system

Subsystem	Constants
`POSIX`	The constants in the `sysroot-*-kos/include/limits.h` file.
`BlobContainer`	The constants in the `sysroot-*-kos/include/kl/EntityLauncher.idl(.h)` files: • `MaxArgSize (kl_EntityLauncher_MaxArgSize)` – maximum program launch parameter and environment variable size in bytes. • `MaxArgsCount (kl_EntityLauncher_MaxArgsCount)` – maximum number of launch parameters and environment variables for a program.
`CertificateStorage`	The constants in the `sysroot-*-kos/include/kl/CertificateStorage.idl(.h)` files: • `MaxNumCerts (kl_CertificateStorage_MaxNumCerts)` – maximum number of certificates in a storage. • `MaxCertSize (kl_CertificateStorage_MaxCertSize)` – maximum certificate size in bytes. • `HashSize (kl_CertificateStorage_HashSize)` – size of the certificate storage hash, in bytes.
`Tls`	The constants in the `sysroot-*-kos/include/kl/CertificatePolicy.idl(.h)` files: • `MaxDERCertDataSize (kl_CertificatePolicy_MaxDERCertDataSize)` – maximum DER certificate size in bytes. • `MaxHostAddressBufferSize (kl_CertificatePolicy_MaxHostAddressBufferSize)` – maximum host address buffer size in bytes. The constants in the `sysroot-*-kos/include/kl/crypto/tls/TlsEvent.idl(.h)` files: • `FunctionNameSize (kl_crypto_tls_TlsEvent_FunctionNameSize)` – maximum function name size in bytes. • `IdSize (kl_crypto_tls_TlsEvent_IdSize)` – session identifier size in bytes. • `HostnameSize (kl_crypto_tls_TlsEvent_HostnameSize)` – maximum host name size in bytes.

	• `PkiEntrySize (kl_crypto_tls_TlsEvent_PkiEntrySize)` – maximum PKI certificate size in bytes. • `MaxCertificatesInChain (kl_crypto_tls_TlsEvent_MaxCertificatesInChain)` – maximum number of certificates in a chain. • `MaxCertificatesInTrustedSet (kl_crypto_tls_TlsEvent_MaxCertificatesInTrustedSet)` – maximum number of trusted certificates. • `KeyFingerprintLength (kl_crypto_tls_TlsEvent_KeyFingerprintLength)` – key fingerprint size in bytes. • `MbedTlsDescriptionSize (kl_crypto_tls_TlsEvent_MbedTlsDescriptionSize)` – maximum MbedTLS error description size in bytes. • `VfsDescriptionSize (kl_crypto_tls_TlsEvent_VfsDescriptionSize)` – maximum VFS error description size in bytes. • `DescriptionSize (kl_crypto_tls_TlsEvent_DescriptionSize)` – maximum event description size in bytes.
`ExecutionManager`	The constants in the `sysroot-*-kos/include/kl/execution_manager/Types.idl(.h)` files: • `NkAppNameMaxSize (kl_execution_manager_Types_NkAppNameMaxSize)` – maximum program name size in bytes. • `NkPathMaxSize (kl_execution_manager_Types_NkPathMaxSize)` – maximum executable file path size in bytes. • `NkEntityNameMaxSize (kl_execution_manager_Types_NkEntityNameMaxSize)` – maximum process name size in bytes. • `NkEiidMaxSize (kl_execution_manager_Types_NkEiidMaxSize)` – maximum process class name size in bytes. • `NkTaskNameMaxSize (kl_execution_manager_Types_NkTaskNameMaxSize)` – maximum process name size in bytes. • `NkArgMaxLen (kl_execution_manager_Types_NkArgMaxLen)` – maximum program launch parameter size in bytes. • `NkEnvMaxLen (kl_execution_manager_Types_NkEnvMaxLen)` – maximum environment variable size in bytes. • `NkArgsArrayMaxSize (kl_execution_manager_Types_NkArgsArrayMaxSize)` – maximum number of program launch parameters.

	• `NkEnvsArrayMaxSize (kl_execution_manager_Types_NkEnvsArrayMaxSize)` – maximum number of environment variables for a program.
`KlogStorage`	The constants in the `sysroot-*-kos/include/kl/KlogStorage.idl(.h)` files: • `StringSize (kl_KlogStorage_StringSize)` – maximum message size in bytes. • `MaxMessages (kl_KlogStorage_MaxMessages)` – maximum number of messages.
`Env`	The constants in the `sysroot-*-kos/include/kl/Env.idl(.h)` files: • `MaxArgsCount (kl_Env_MaxArgsCount)` – maximum number of launch parameters and environment variables for a program. • `MaxArgSize (kl_Env_MaxArgSize)` – maximum program launch parameter and environment variable size in bytes. • `MaxNameSize (kl_Env_MaxNameSize)` – maximum process name size in bytes.
`VFS`	The constants in the `sysroot-*-kos/include/kl/VfsTypes.idl(.h)` files: • `MaxBytesCount (kl_VfsTypes_MaxBytesCount)` – maximum `VFS` data transmission buffer size in bytes. • `MaxPathSize (kl_VfsTypes_MaxPathSize)` – maximum path size in bytes. • `MaxDevnameSize (kl_VfsTypes_MaxDevnameSize)` – maximum device name size in bytes. • `MaxFstypeSize (kl_VfsTypes_MaxFstypeSize)` – maximum file system name size in bytes. • `MaxFsDataSize (kl_VfsTypes_MaxFsDataSize)` – maximum data size for the `data` parameter of the `mount()` function, in bytes. • `MaxFcntlTSize (kl_VfsTypes_MaxFcntlTSize)` – maximum data size for an optional parameter of the `fcntl()` function, in bytes. • `MaxIoctlTSize (kl_VfsTypes_MaxIoctlTSize)` – maximum data size for an optional parameter of the `ioctl()` function, in bytes. • `MaxSockAddrSize (kl_VfsTypes_MaxSockAddrSize)` – maximum IP address size in bytes. • `MaxSockOptionSize (kl_VfsTypes_MaxSockOptionSize)` – maximum data size for the `option_value` parameter of the `getsockopt()` and `setsockopt()` functions, in bytes.

	• MaxHostnameSize (kl_VfsTypes_MaxHostnameSize) – maximum host name size in bytes. • MaxServnameSize (kl_VfsTypes_MaxServnameSize) – maximum data size for the servname parameter of the getaddrinfo() function and the service parameter of the getnameinfo() function, in bytes. • MaxMsgNameSize (kl_VfsTypes_MaxMsgNameSize) – maximum data size for the msg_name element of the message parameter of the recvmsg() and sendmsg() functions, in bytes. • MaxMsgDataSize (kl_VfsTypes_MaxMsgDataSize) – maximum data size for a msg_control element of the message parameter of the recvmsg() and sendmsg() functions, in bytes. • MaxIovDataSize (kl_VfsTypes_MaxIovDataSize) – maximum number of the buffer described by the iovec structure in the message parameter of the recvmsg() and sendmsg() functions, and in the iov parameter of the readv() and writev() functions, in bytes. • MaxIovecsCount (kl_VfsTypes_MaxIovecsCount) – maximum number of iovec structures in the message parameter of the recvmsg() and sendmsg() functions, and in the iov parameter of the readv() and writev() functions. • MaxAddrinfoSize (kl_VfsTypes_MaxAddrinfoSize) – maximum data size for the res parameter of the getaddrinfo() function, in bytes. • VfsHostent (kl_VfsTypes_MaxHostentSize) – maximum data size for a return value of the gethostbyname() function, in bytes. • VfsDnsName (kl_VfsTypes_MaxDnsNameSize) – maximum data size for the name parameter of the getnetbyname() function, in bytes. • MaxProtoentNameSize (kl_VfsTypes_MaxProtoentNameSize) – maximum protocol name size in the name parameter of the getprotobyname() function, and in the return value of the getprotobyname() and getprotobynumber() functions, in bytes. • MaxProtoentAliasesSize (kl_VfsTypes_MaxProtoentAliasesSize) – maximum protocol alias size in the return values of the getprotobyname() and getprotobynumber() functions, in bytes.
MessageBus	The constants in the sysroot-*-kos/include/kl/MessageBusTypes.idl(.h) files: • MaxStringLength (kl_MessageBusTypes_MaxStringLength) – maximum message size in bytes.
Dhcpcd	The constants in the sysroot-*-kos/include/kl/rump/DhcpcdConfig.idl(.h) files: • MaxDhcpcdStrSize (kl_rump_DhcpcdConfig_MaxDhcpcdStrSize) – maximum size of a parameter set received from a DHCP server, in bytes.

`Terminal`	The constants in the `sysroot-*-kos/include/kl/Terminal.idl(.h)` files: • `MaxTerminalBytesCount (kl_Terminal_MaxTerminalBytesCount)` – maximum terminal read/write buffer size in bytes. • `MaxTerminalConnectionIdSize (kl_Terminal_MaxTerminalConnectionIdSize)` – maximum terminal identifier size in bytes.

Licensing

The *End User License Agreement* is a legally binding agreement between you and AO Kaspersky that stipulates the terms on which you may use KasperskyOS Community Edition.

> Please carefully read the terms of the End User License Agreement before you begin using KasperskyOS Community Edition.

You can view the terms of the End User License Agreement (EULA) in the following ways:

- Read the text of the End User License Agreement before downloading the KasperskyOS Community Edition distribution package.
- Read the document named EULA.<language code>.txt located in the directory `/opt/KasperskyOS-Community-Edition-<version>` after installing KasperskyOS Community Edition.

You accept the terms of the End User License Agreement by selecting the **I agree** check box under the text of the End User License Agreement before downloading the KasperskyOS Community Edition distribution package.

If you do not accept the terms of the End User License Agreement, you must cancel the download of the distribution package and must not use KasperskyOS Community Edition.

Data provision

KasperskyOS Community Edition versions

KasperskyOS Community Edition is distributed in two different versions:

- Version that can be downloaded from the Russian-language website https://os.kaspersky.ru/development.
- Version that can be downloaded from the English-language website https://os.kaspersky.com/development.

Versions differ in the contents of their End User License Agreement, file and differ in the specific information that they automatically transmit to Kaspersky servers when a solution is built using CMake libraries from the SDK.

Data provision in KasperskyOS Community Edition

The version of KasperskyOS Community Edition downloaded from the Russian-language website automatically transmits the following information to Kaspersky servers when a solution build is started:

- Number of the installed version of KasperskyOS Community Edition.
- Unique hardware ID consisting of the checksum of the creation date of the directory /opt/KasperskyOS-Community-Edition-<version>.

The version of KasperskyOS Community Edition downloaded from the English-language website automatically transmits the following information to Kaspersky servers when a solution build is started:

- Number of the installed version of KasperskyOS Community Edition.

In addition to data transmission during the solution build process, both versions also check for the availability of a newer version of KasperskyOS Community Edition.

> If there is no active Internet connection, the solution build occurs without transmitting data or checking for updates.

You can disable the check for SDK updates and transmission of SDK version information to the Kaspersky server by using the `NO_NEW_VERSION_CHECK` parameter of the CMake command `initialize_platform()` during the solution build.

Data is transmitted to account for the number of users of KasperskyOS Community Edition and to obtain information about the distribution and use of KasperskyOS Community Edition.

Any received information is protected by Kaspersky in accordance with the requirements established by law and in accordance with current Kaspersky regulations. Data is transmitted over encrypted communication channels.

Glossary

Application

Program that is designed for interaction with a solution user and for performing user tasks.

Related sections:
Building a KasperskyOS-based solution

Arena chunk descriptor

Structure containing the offset of the arena chunk in bytes (relative to the start of the arena) and the size of the arena chunk in bytes.

Related sections:
Working with an IPC message arena

Arena descriptor

Structure containing three pointers: one pointer to the start of the arena, one pointer to the start of the unused part of the arena, and one pointer to the end of the arena.

Related sections:
Working with an IPC message arena

Callable handle

A *callable handle* is a client IPC handle that simultaneously identifies an IPC channel to a server and an endpoint of this server.

Related sections:
Creating handles

Capability

Each handle is associated with access rights to the resource identified by this handle, which means it is a capability in terms of the capability-based security mechanism known as Object Capability (OCap). By receiving a handle, a process obtains the access rights to the resource that is identified by this handle. For example, these access rights may consist of read permissions, write permissions, and/or permissions to allow another process to perform operations on the resource (handle transfer permission).

Related sections:
Managing access to resources
Managing handles (handle_api.h)

CDL

Component Definition Language is a declarative language used to create a formal specification of a solution component.

Related sections:
Formal specifications of KasperskyOS-based solution components
CDL description

Client

In the context of IPC, *client* refers to the client process.

Client library of the solution component

Transport library that converts local calls into IPC requests.

Related sections:
Transport code for IPC

Client Process

Process that uses the endpoint of another process via the IPC mechanism. One process can use multiple IPC channels at the same time. A process may act as a client for some IPC channels while acting as a server for other IPC channels.

Related sections:
IPC mechanism

Conditional variable

Synchronization primitive that is used to notify one or more threads about the fulfillment of a condition required by these threads. It is used together with a mutex.

Related sections:
Using synchronization primitives (event.h, mutex.h, rwlock.h, semaphore.h, condvar.h)

Constant part of an IPC message

The part of an IPC message that contains the RIID, MID and (optionally) fixed-size parameters of interface methods.

Related sections:
Overview: IPC message structure
Working with an IPC message arena
IDL data types

Critical section

Section of code in which the resources shared by threads are accessed.

Related sections:
Using synchronization primitives (event.h, mutex.h, rwlock.h, semaphore.h, condvar.h)

Description of a security policy for a KasperskyOS-based solution

A set of interrelated text files with the `psl` extension that contain declarations in the PSL language.

Related sections:
Describing a security policy for a KasperskyOS-based solution
General information about a KasperskyOS-based solution security policy description
Security.psl.in template
Example descriptions of basic security policies for KasperskyOS-based solutions
Methods of KasperskyOS core endpoints

Direct memory access

Direct memory access (DMA) is a feature that allows data exchange between devices and the main system memory independently of the processor.

Related sections:
Using DMA (dma.h)
Managing I/O memory isolation (iommu_api.h)

DMA

Direct memory access

DMA buffer

Buffer that consists of one or more physical memory regions (blocks) that are used for direct memory access.

Related sections:
Using DMA (dma.h)
Managing I/O memory isolation (iommu_api.h)

EDL

Entity Definition Language is a declarative language used to create a formal specification of a solution component.

Related sections:
Formal specifications of KasperskyOS-based solution components
EDL description

Endpoint

Set of logically related methods available via the IPC mechanism (for example, an endpoint for receiving and transmitting data over the network, or an endpoint for handling interrupts).

Related sections:
Overview
IPC mechanism
Methods of KasperskyOS core endpoints

Endpoint ID

A *Runtime Implementation Identifier* (RIID) is the sequence number of an endpoint within the set of endpoints of a server (starting at zero).

Related sections:
IPC mechanism
Overview: IPC message structure

Endpoint Interface

Set of signatures for endpoint methods. The endpoint interface is defined in the IDL description.

Related sections:
Formal specifications of KasperskyOS-based solution components
IDL description

Endpoint method

Interface Method

Endpoint Method ID

An *Endpoint Method ID* (MID) is the sequence number of the endpoint method within the set of methods of this endpoint (starting at zero).

Related sections:
IPC mechanism
Overview: IPC message structure

Event

Synchronization primitive that is used to notify one or more threads about the fulfillment of a condition required by these threads.

Related sections:
Using synchronization primitives (event.h, mutex.h, rwlock.h, semaphore.h, condvar.h)

Event mask

Value whose bits are interpreted as events that should be tracked or that have already occurred. An event mask has a size of 32 bits and consists of a general part and a specialized part. The common part describes events that are not specific to any resources. The specialized part describes events that are specific to certain resources.

Related sections:
Using notifications (notice_api.h)
Transferring handles

Execute interface

Interface used by the KasperskyOS kernel when querying the Kaspersky Security Module to notify it about kernel startup or about initiating the startup of a process by the kernel or by other processes.

Related sections:
Setting the global parameters of a KasperskyOS-based solution security policy
Binding methods of security models to security events

Formal specification of the KasperskyOS-based solution component

A system of IDL, CDL and EDL descriptions of a solution component (IDL and CDL descriptions are optional).

Related sections:
Formal specifications of KasperskyOS-based solution components

Handle

A *handle* is an identifier of a resource (for example, a memory area, port, network interface, or IPC channel). The handle of an IPC channel is called an IPC handle.

Related sections:
Managing access to resources
Managing handles (handle_api.h)

KasperskyOS also uses the following descriptors:

- Arena descriptor
- Arena chunk descriptor

Handle dereferencing

Operation in which the client sends a handle to the server, and the server receives a pointer to the resource transfer context, the permissions mask of the sent handle, and the ancestor of the handle sent by the client and already owned by the server. Dereferencing occurs when a client that called methods for working with a resource (such as read/write or access closure) sends the server the handle that was received from this server when access to the resource was opened.

Related sections:
Managing handles (handle_api.h)
Dereferencing handles

Handle inheritance tree

Hierarchy of generated resource handles stored in the KasperskyOS kernel.

Related sections:
Managing handles (handle_api.h)

Handle permissions mask

Value whose bits are interpreted as access rights to the resource that is identified by the specific handle.

Related sections:
Managing access to resources
Handle permissions mask
Managing handles (handle_api.h)

Handle transport container

Structure consisting of the following three fields: handle field, handle permissions mask field, and the resource transfer context field. It is used to transfer handles via IPC.

Related sections:
Transferring handles
OCap usage example

Hardware interrupt

Signal sent from a device to direct the processor to immediately pause execution of the current program and instead handle an event related to this device. For example, pressing a key on the keyboard invokes a hardware interrupt that ensures the required response to this pressed key (for example, input of a character).

Related sections:
Managing interrupt processing (irq.h)

IDL

Interface Definition Language is a declarative language used to create a formal specification of a solution component.

Related sections:
Formal specifications of KasperskyOS-based solution components
IDL description

Init description

An init description consists of a text file containing data in YAML format that identifies the processes and IPC channels that are created when the solution starts. The init description file is normally named `init.yaml`.

Related sections:
Overview: Einit and init.yaml
Example init descriptions
Init.yaml.in template

Initializing program

The `Einit` program, which is started by the KasperskyOS kernel, starts other programs according to the init description and creates IPC channels.

Related sections:
Overview: Einit and init.yaml
CMakeLists.txt file for building the Einit program
Structure and startup of a KasperskyOS-based solution
einit

Interface Method

Subprogram that is called via IPC.

Related sections:
IPC mechanism
IDL description
Methods of KasperskyOS core endpoints

Interprocess communication

Interprocess communication (IPC) is a mechanism for interaction between different processes and between a process and the KasperskyOS kernel.

Related sections:
IPC
Initializing IPC transport for interprocess communication and managing IPC request processing (transport-kos.h, transport-kos-dispatch.h)
POSIX support limitations

IPC

Interprocess communication

IPC channel

KasperskyOS kernel object that allows processes to interact with each other by transmitting IPC messages. An IPC channel has a client side and a server side, which are identified by a client and server IPC handle, respectively.

Related sections:
IPC mechanism
Creating IPC channels

IPC handle

An *IPC handle* is a handle that identifies an IPC channel. A client IPC handle is necessary for executing a `Call()` system call. A server IPC handle is necessary for executing the `Recv()` and `Reply()` system calls. The callable handle and listener handle are IPC handles.

Related sections:
IPC mechanism
Creating handles
Creating IPC channels

IPC message

Data packet that is transmitted between different processes and between processes and the KasperskyOS kernel for IPC. An IPC message contains a constant part and an (optional) arena.

Related sections:
Overview: IPC message structure

IPC message arena

Optional part of an IPC message that contains variable-size parameters of interface methods (and/or elements of these parameters).

Related sections:
Overview: IPC message structure
Working with an IPC message arena

IPC request

IPC message sent to a server from a client.

Related sections:
IPC mechanism

IPC response

IPC message sent to a client from a server.

Related sections:
IPC mechanism

IPC transport

Add-on that works on top of system calls for sending and receiving IPC messages and works separately with the constant part and arena of IPC messages. Transport code works on top of this add-on.

Related sections:
Initializing IPC transport for interprocess communication and managing IPC request processing (transport-kos.h, transport-kos-dispatch.h)
Initializing IPC transport for querying the security module (transport-kos-security.h)

KasperskyOS

A specialized operating system based on a separation microkernel and security monitor.

Related sections:
Overview

KasperskyOS Security Model

Framework for implementing security policies for solutions.

Related sections:
Describing a security policy for a KasperskyOS-based solution
KasperskyOS security models

KasperskyOS-based solution

System software (including the KasperskyOS kernel and Kaspersky Security Module) and applications integrated to work as part of a software/hardware system.

Related sections:
Overview
Structure and startup of a KasperskyOS-based solution
Building a KasperskyOS-based solution

KasperskyOS-based solution component

Program included in a solution.

Related sections:
Overview
Formal specifications of KasperskyOS-based solution components

KSM

The Kaspersky Security Module is the KasperskyOS kernel module that allows or denies interaction between different processes and between processes and the kernel, and handles queries of processes via the security interface.

Related sections:
IPC control
Managing access to resources

KSS

Kaspersky Security System technology lets you implement solution security policies. This technology prescribes the creation of formal specifications of solution components and descriptions of solution security policies using security models.

Related sections:
Overview
Developing security policies

Listener handle

A *listener handle* is a server IPC handle with extended rights that allow it to add IPC channels to the set of IPC channels identified by this handle.

Related sections:
Creating IPC channels
Creating handles
Initializing IPC transport for interprocess communication and managing IPC request processing (transport-kos.h, transport-kos-dispatch.h)
Dynamically creating IPC channels (cm_api.h, ns_api.h)

Memory barrier

A *memory barrier* is an instruction for a compiler or processor that guarantees that memory access operations specified in source code before setting a barrier will be executed before the memory access operations specified in source code after setting a barrier.

Related sections:
Using memory barriers (barriers.h)

Message signaled interrupt (MSI)

Message signaled interrupt (MSI) is a hardware interrupt that occurs when the device accesses the interrupt controller via MMIO memory.

Related sections:
Managing interrupt processing (irq.h)

MID

Endpoint Method ID

Mutex

A synchronization primitive that provides for mutually exclusive execution of critical sections.

Related sections:
Using synchronization primitives (event.h, mutex.h, rwlock.h, semaphore.h, condvar.h)
POSIX support limitations

Notification receiver

KasperskyOS kernel object that collects notifications about events that occur with resources.

Related sections:
Using notifications (notice_api.h)
Managing handles (handle_api.h)

OCap

Object Capability is a security mechanism that is based on capabilities.

Related sections:
Managing access to resources
Managing handles (handle_api.h)

Operating Performance Point

Operating Performance Point (OPP) is a combination of the matching frequency and voltage for a processor group.

Related sections:
CPU frequency management endpoint

OPP

Operating Performance Point

PAL

Policy Assertion Language is a declarative language used to create solution security policy tests.

Related sections:
Creating and performing tests for a KasperskyOS-based solution security policy
Examples of tests for KasperskyOS-based solution security policies

Process

A running program that has the following distinguishing characteristics:

- It can provide endpoints to other processes and/or use the endpoints of other processes via the IPC mechanism.
- It uses KasperskyOS core endpoints via the IPC mechanism.
- It is associated with a solution security policy that regulates the interactions of the process with other processes and with the KasperskyOS kernel.

Related sections:
Overview
Starting processes
init.yaml.in template

Program

Code that is executed within the context of an individual process.

Related sections:
Building a KasperskyOS-based solution

PSL

Policy Specification Language is a declarative language used to create a solution security policy description.

Related sections:
Describing a security policy for a KasperskyOS-based solution
PSL language syntax

Read-write lock

Synchronization primitive that is used to allow access to resources shared between threads for either write access for one thread or read access for multiple threads at the same time.

Related sections:
Using synchronization primitives (event.h, mutex.h, rwlock.h, semaphore.h, condvar.h)

Recursive mutex

Mutex that can be acquired by a single thread multiple times.

Related sections:
Using synchronization primitives (event.h, mutex.h, rwlock.h, semaphore.h, condvar.h)

Resource

KasperskyOS-based software/hardware system object that can be accessed by processes. Resources can be system resources or user resources.

Related sections:
Managing access to resources

Resource consumer

Process that uses the resources provided by the KasperskyOS kernel or other processes.

Related sections:
Managing access to resources
Managing handles (handle_api.h)
Mic security model

Resource integrity level

Level of trust afforded to a resource. The level of trust in a resource depends on whether this resource was created by a trusted subject within a software/hardware system running KasperskyOS or if it was received from an untrusted external software/hardware system, for example.

Related sections:
Mic security model

Resource provider

Process that manages user resources and manages access to those resources for other processes. For example, drivers are resource providers.

Related sections:
Managing access to resources
Managing handles (handle_api.h)

Resource transfer context

Data that allows the server to identify the resource and its state when access to the resource is requested via descendants of the transferred handle. This normally consists of a data set with various types of data (structure). For example, the transfer context of a file may include the name, path, and cursor position.

Related sections:
Managing handles (handle_api.h)

Resource transfer context object

KasperskyOS kernel object that stores the pointer to the resource transfer context.

Related sections:
Managing handles (handle_api.h)

RIID

Endpoint ID

Security audit

A security audit consists of the following sequence of actions. The Kaspersky Security Module provides the KasperskyOS kernel with information about decisions made by this module. Then the kernel forwards this data to the system program `Klog`, which decodes this information and forwards it to the system program `KlogStorage` (data is transmitted via IPC). The latter sends the received audit data to standard output (or standard error) or writes it to a file.

Related sections:
Creating security audit profiles
Examples of security audit profiles
Using the system programs Klog and KlogStorage to perform a security audit

Security audit configuration

Element of a security audit profile that defines the security model objects covered by the security audit and the conditions for performing the security audit.

Related sections:
Creating security audit profiles
Examples of security audit profiles

Security audit data

Information about decisions made by the Kaspersky Security Module, including the actual decisions ("granted" or "denied"), descriptions of security events, results from calling methods of security models, and data on incorrect IPC messages.

Related sections:
Creating security audit profiles

Security audit profile

Set of security audit configurations, each of which defines the security model objects covered by the security audit and the conditions for performing the security audit.

Related sections:
Creating security audit profiles
Binding methods of security models to security events
Examples of security audit profiles
Setting the global parameters of a KasperskyOS-based solution security policy

Security audit runtime-level

The security audit runtime-level is a global parameter of a solution security policy and consists of an unsigned integer that defines the active security audit configuration. (The word "level" here refers to the configuration variant and does not necessarily involve a hierarchy.)

Related sections:
Creating security audit profiles
Setting the global parameters of a KasperskyOS-based solution security policy

Security context

Data that is associated with a security ID and is used by the Kaspersky Security Module to make decisions.

Related sections:
Managing access to resources

Security event

A signal indicating the initiation of communication between a process and another process or between a process and the KasperskyOS kernel.

Related sections:
General information about a KasperskyOS-based solution security policy description
Binding methods of security models to security events
Examples of binding security model methods to security events

Security ID

A *Security Identifier* (SID) is a globally unique identifier of a resource. The Kaspersky Security Module identifies resources based on their security IDs.

Related sections:
Managing access to resources
Getting a security ID (SID)

Security interface

Interface that is used for interaction between a process and the Kaspersky Security Module. The security interface is defined in the IDL description.

Related sections:
Formal specifications of KasperskyOS-based solution components
EDL description
CDL description
IDL description
Binding methods of security models to security events
Initializing IPC transport for querying the security module (transport-kos-security.h)

Security model expression

Security model method that returns values that can be used as input data for other methods of security models.

Related sections:
General information about a KasperskyOS-based solution security policy description
Binding methods of security models to security events
KasperskyOS security models

Security model method

Element of a security model that determines the permissibility of interactions between various processes and between processes and the KasperskyOS kernel.

Related sections:
General information about a KasperskyOS-based solution security policy description
Binding methods of security models to security events
Examples of binding security model methods to security events
KasperskyOS security models

Security model object

Instance of a class whose definition is a formal description of a security model (in a PSL file).

Related sections:
General information about a KasperskyOS-based solution security policy description
Creating security model objects
KasperskyOS security models

Security model rule

Security model method that returns a "granted" or "denied" decision.

Related sections:
General information about a KasperskyOS-based solution security policy description
Binding methods of security models to security events
Examples of binding security model methods to security events
KasperskyOS security models

Security module decision

A decision on whether to allow or deny a specific interaction between different processes or between a process and the KasperskyOS kernel.

Related sections:
Overview
IPC control
General information about a KasperskyOS-based solution security policy description

Security pattern

A security pattern (or security template) describes a specific recurring security issue that arises in certain known contexts, and provides a well-proven, general scheme for resolving this kind of security issue. A pattern is not a finished project that can be converted directly into code. Instead, it is a solution to a general problem encountered in various projects.

Related sections:
Security patterns for development under KasperskyOS

Security pattern system

Set of security patterns together with instructions on their implementation, combination, and practical use when designing secure software systems.

Related sections:
Security patterns for development under KasperskyOS

Security policy for a KasperskyOS-based solution

Logic for processing security events in the solution. This logic is implemented by the Kaspersky Security Module. The source code of the Kaspersky Security Module is generated from the solution security policy description and formal specifications of solution components.

Related sections:
Overview

Security template

A security template (or security pattern) describes a specific recurring security issue that arises in certain known contexts, and provides a well-proven, general scheme for resolving this kind of security issue. A template is not a finished project that can be converted directly into code. Instead, it is a solution to a general problem encountered in various projects.

Related sections:
Security patterns for development under KasperskyOS

Seed

Starting number of the random number generator (seed) , which determines the sequence of the generated random numbers. In other words, if the same seed value is set, the generator creates identical sequences of random numbers. (The entropy of these numbers is fully determined by the entropy of the seed value, which means that these numbers are not entirely random, but pseudorandom.)

Related sections:
Generating random numbers (random_api.h)

Semaphore

Synchronization primitive based on a counter whose value can be atomically changed.

Related sections:
Using synchronization primitives (event.h, mutex.h, rwlock.h, semaphore.h, condvar.h)
POSIX support limitations

Server

In the context of IPC, *server* refers to the server process.

Server library of the solution component

Transport library that converts IPC requests into local calls.

Related sections:
Transport code for IPC

Server process

Process that provides endpoints to other processes via the IPC mechanism. One process can use multiple IPC channels at the same time. A process may act as a server for some IPC channels while acting as a client for other IPC channels.

Related sections:
IPC mechanism

SID

Security ID

Subject integrity level

Level of trust afforded to a subject. The trust level of a subject depends on whether the subject interacts with untrusted external software/hardware systems or whether it has a proven standard of quality, for example.

Related sections:
Mic security model

System program

A program that creates the infrastructure for application software (for example, it facilitates hardware operations, supports the IPC mechanism, and implements file systems and network protocols).

Related sections:
Building a KasperskyOS-based solution

System resource

Resource that is managed by the KasperskyOS kernel. Some examples of system resources include processes, memory regions, and interrupts.

Related sections:
Managing access to resources
Managing handles (handle_api.h)

Thread

A *thread* is an abstraction used to manage the execution of program code. One process can include one or more threads. CPU time is allocated separately for each thread. Each thread may execute the entire code of the program or just a part of the code. The same program code may be executed in multiple threads.

Related sections:
POSIX support limitations

Transport code

C-language methods and types for IPC.

Related sections:
Transport code for IPC
Example generation of transport methods and types

Transport library

To use a supplied solution component via IPC, the KasperskyOS SDK provides the following transport libraries:

- Solution component's client library, which converts local calls into IPC requests.
- Solution component's server library, which converts IPC requests into local calls.

Related sections:
Transport code for IPC

User resource

Resource that is managed by a process. Examples of user resources: files, input-output devices, data storage.

Related sections:
Managing access to resources
Managing handles (handle_api.h)

User resource context

Data that allows the resource provider to identify the resource and its state when access to the resource is requested by other processes. This normally consists of a data set with various types of data (structure). For example, the context of a file may include the name, path, and cursor position.

Related sections:
Managing handles (handle_api.h)

Information about third-party code

Information about third-party code is contained in the file named legal_notices.txt in the application installation folder.

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