RN00161

Real-time Edge Software Release Notes

Rev. 1.0 — 29 March 2024 **Release notes**

Document information

Information	Content
Keywords	RN00161, Real-time Edge software, release notes, Industrial Networking, Real-time System, Industrial Protocols, i.MX, QorIQ, Layerscape, Heterogeneous Multicore Framework, Heterogeneous Multi-SoC Framework, EtherCAT, TSN, High-availability Seamless Redundancy (HSR), NXP hardware platforms
Abstract	This document contains important information about Real-time Edge software contents, supported features, known issues and limitations in this release.

1 Feature introduction

1.1 Introduction

'Real-time Edge Software' is a software suite provided by NXP Semiconductors for the industrial and IoT domains. It offers Real-time System, Heterogeneous Multicore Framework, Heterogeneous multi-SoC Framework, and Industrial Networking components. The software provides comprehensive support for control of IO devices, selection of operating systems with different schedule latencies, and intercore communication. It allows expansion to multiple SoCs, construction of industrial networks, and network redundancy. Real-time Edge software can be used for various use cases in industrial and IoT domains. Factory Automation, Process Automation, Building and Energy, Home Appliances, and EV chargers are some of these applications.

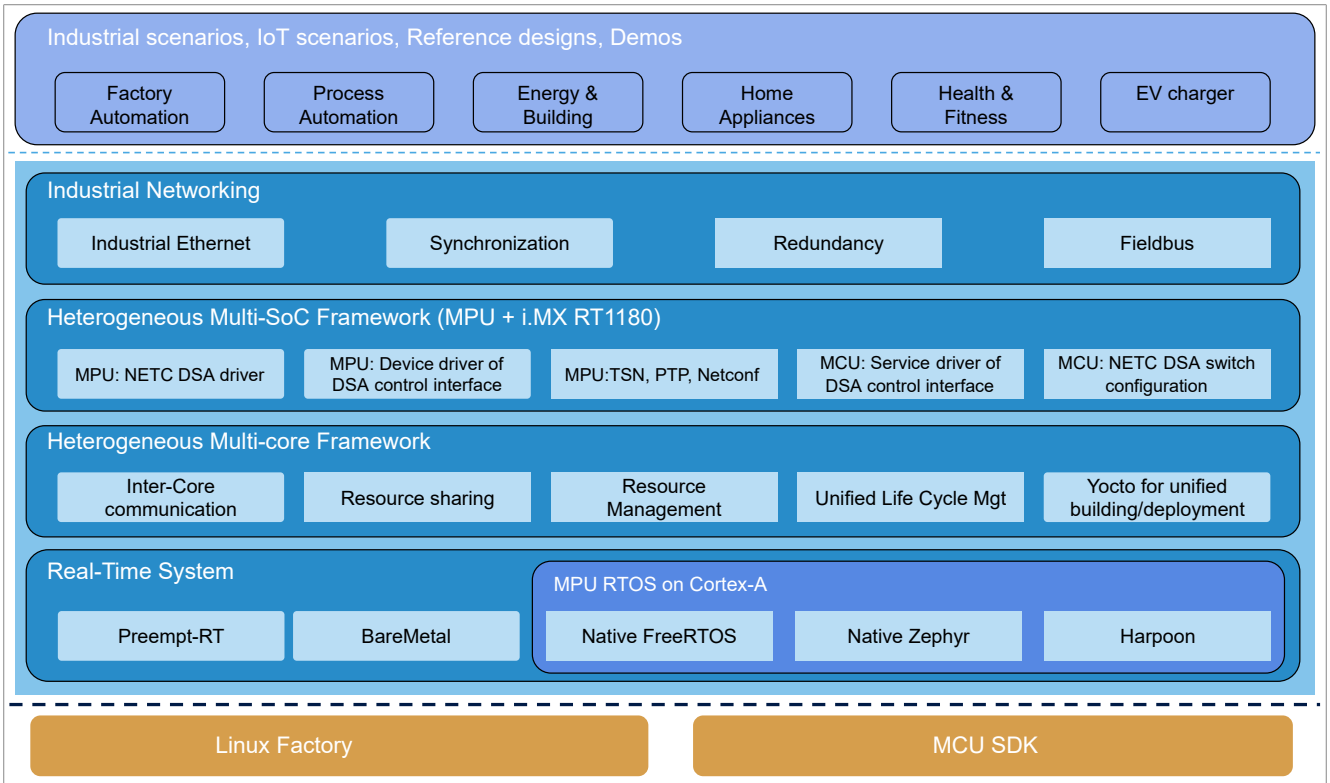


Figure 1. Real-time Edge Software architecture

1.2 Real-time System

For industrial or IoT development, customers first select the appropriate Real-time operating system based on the application scenario. To meet various schedule and latency requirements, the real-time system provides Preempt-RT Linux, native RTOS on Cortex-A core and Cortex-M core, RTOS on Cortex-A core with Jailhouse and BareMetal. It also offers a flexible combination of different cores running Preempt-RT Linux and RTOS/ BareMetal.

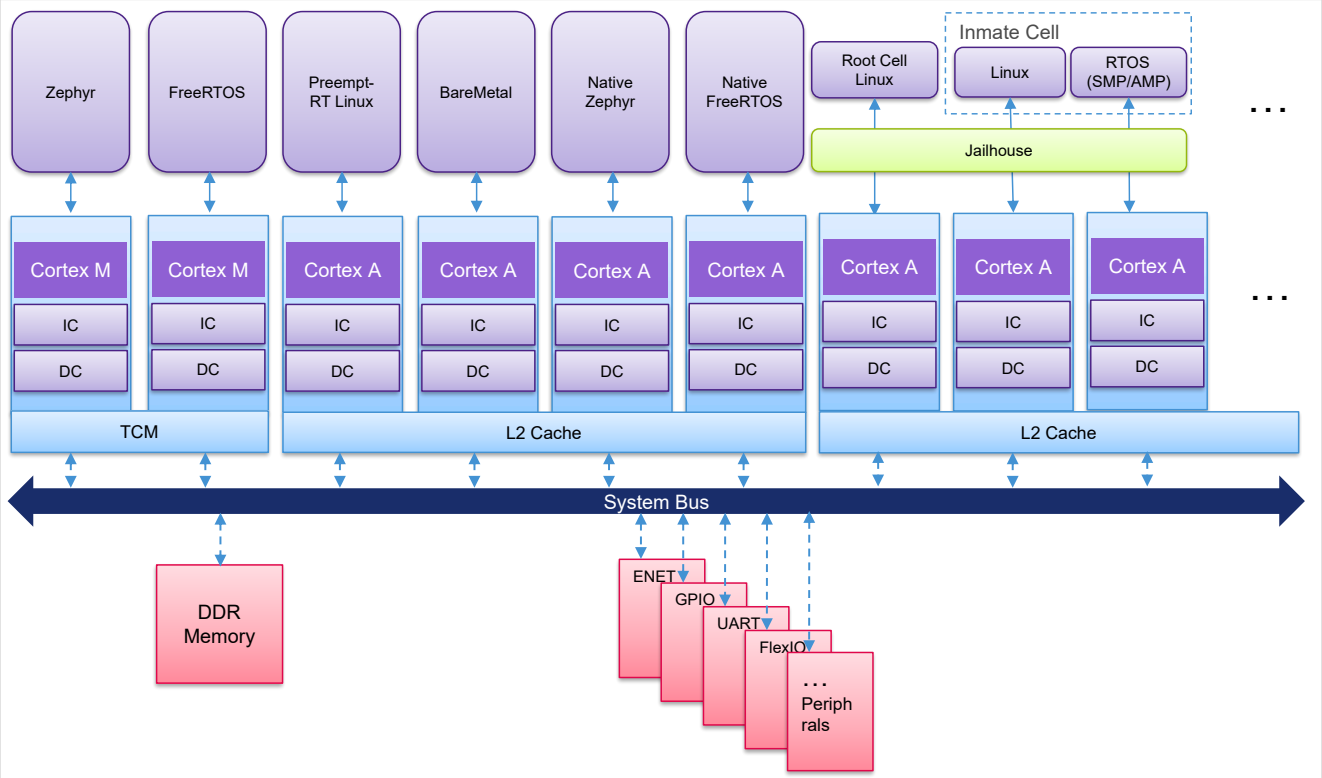


Figure 2. Real-time System on A/M cores

1.2.1 Preempt-RT Linux on Cortex-A core

PREEMPT-RT introduces preemptible and low-latency features to the Linux kernel, transforms Linux into a real-time system. Preempt-RT Linux is suitable for time-critical applications.

1.2.2 BareMetal on Cortex-A core

Real-time BareMetal uses U-Boot to provide a driver-rich BareMetal environment. Single or multiple BareMetal instances run on Cortex-A cores with zero schedule latency.

1.2.3 Native RTOS SMP/AMP on Cortex-A Core

Native RTOS (FreeRTOS or Zephyr) is kicked to one or more Cortex-A Core from U-Boot, no Jailhouse is used and targets lower latency and higher performance as compared to RTOS with Jailhouse.

1.2.4 RTOS SMP/AMP on Corex-A Core with Jailhouse

RTOS (FreeRTOS or Zephyr) runs in Jailhouse inmate with hardware resource isolation on Cortex-A core. Harpoon RTOS provides an environment for developing real-time demanding applications on an RTOS running on one (or several) Cortex-A core(s) in parallel of a Linux distribution. Harpoon applies Jailhouse to partition the hardware and run the RTOS as a Linux guest.

1.2.5 RTOS and Baremetal on Cortex-M Core

Cortex-M cores exhibit deterministic behavior, ensuring consistent and predictable response times when handling real-time tasks. Both RTOS and BareMetal on Cortex-M cores are suitable for deterministic real-time applications.

1.3 Heterogeneous Multicore Framework

When customers choose multiple systems to run on different cores, they encounter problems such as inter-core communication and resource sharing. Heterogeneous Multicore Framework provides a general software framework to help customers solve these issues. It enables AMP to be inter-connected and provides a unified resource management and life-cycle management. It provides the functions illustrated in below figure to help users accelerate solution development based on multicore platforms.

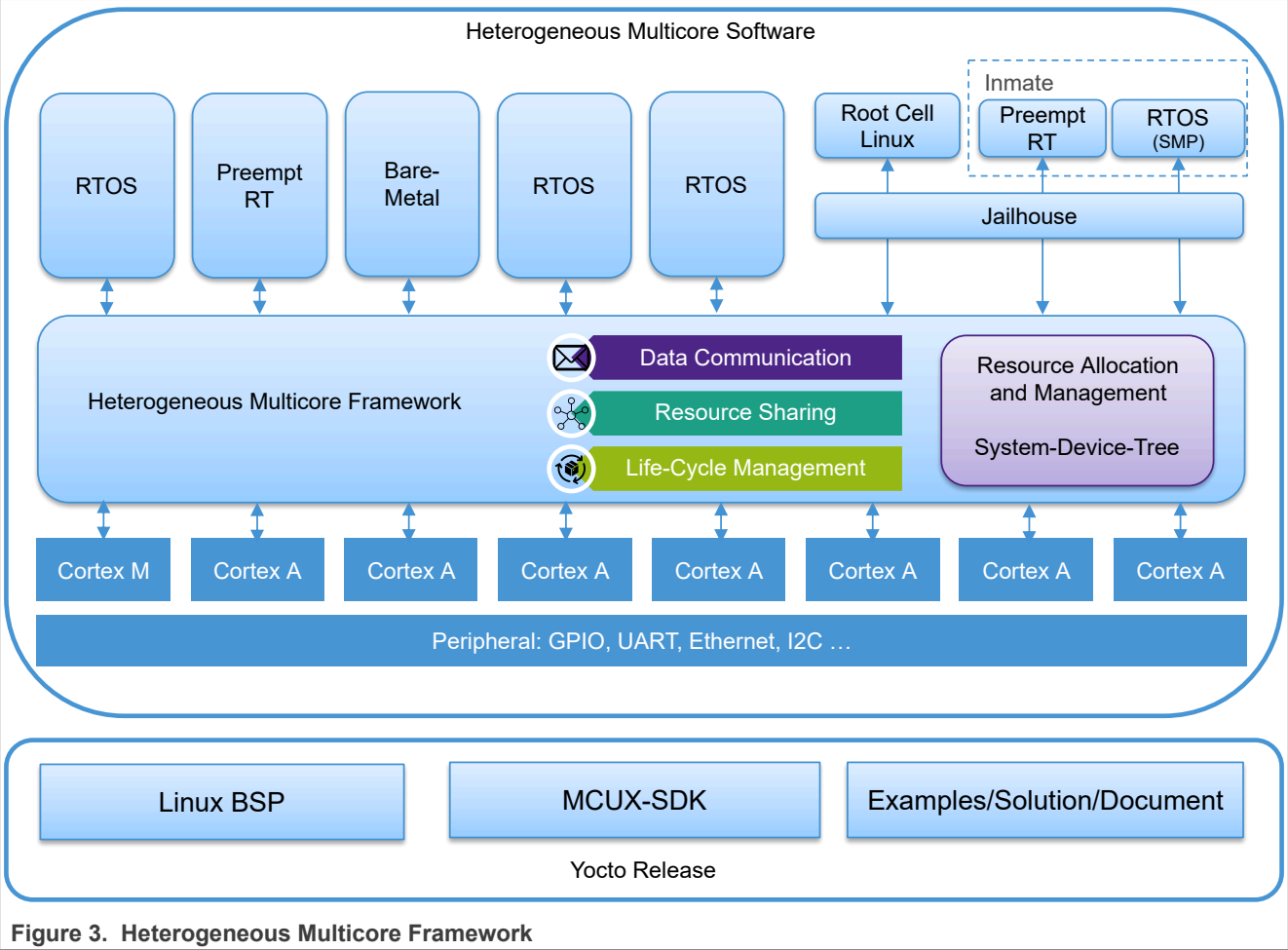


Figure 3. Heterogeneous Multicore Framework

1.3.1 Flexible Real-time System

NXP MPU platforms support Flexible Real-time System. Such a system can run single or multiple RTOS on Cortex-M Core and Cortex-A Core with or without running Linux on Cortex-A core simultaneously. The system provides a RAM console to make it easy to debug multiple OSes in case enough physical UART consoles are not used. The Flexible Real-time System also provides a few common software stacks, such as lwIP networking stack on Cortex-A or Cortex-M cores.

1.3.2 Data communication between different operating systems

The following techniques can be used for data communication between different operating systems. The communication can be between Cortex-M Core and Cortex-A Core, or between different Cortex-A Cores, or between multiple CPU cores simultaneously.

- RPMSG: RPMSG is a standard inter-core communication protocol supported on Linux and RTOS.
- Heterogeneous Multicore VirtIO: Heterogeneous Multicore VirtIO applies para-virtualization VirtIO technology to build high performance inter-core data path, customized data path is defined according to different use cases.

1.3.3 Resource sharing between different operating systems

Resource sharing enables sharing physical resources between different operating systems. In general, one OS owns and controls the hardware resources while the other OS uses a virtual device. The following mechanism is followed to build the control path and data path to access the physical resource.

- **RPMsg**

Use RPMsg to build control and data path crossing OS, physical resource is shared with another OS in terms of virtual device. Simplified Real-time Messaging (SRTM) protocol provided in Real-time Edge is an implementation based on RPMSG. It is used to share the physical resources of Cortex-M core with Cortex-A core in terms of virtual device in Linux.

- **Heterogeneous Multicore VirtIO**

Heterogeneous Multicore VirtIO has a better performance than RPMSG, and it can also be used for resource sharing. POSIX compatible API can be used to access virtual device, and some existing VirtIO device drivers in Linux can be reused. Networking sharing is provided in Real-time Edge to share the same networking interface between multiple OSes.

1.3.4 Unified Life-Cycle Management

Heterogeneous Multicore Framework provides Unified Life Cycle Management for both Cortex-A and Cortex-M cores.

1.3.5 Unified SW release and development environment

Separate Yocto meta layer for Cortex-A and Cortex-M cores defines compilation methods with different cross tool chain. With a single command, all applications on Cortex-A and Cortex-M cores can be compiled and installed into the rootfs.

1.4 Heterogeneous Multi-SoC framework

In some complex scenarios, an SoC might have few limitations. In such scenarios, users must combine multiple SoCs such as an MPU and MCU to jointly complete the control task. Customers can use the real-time processing capability, industrial protocols, and TSN switch support of MCUs in addition to the high compute power and rich software of MPUs. Heterogeneous Multi-SoC Framework helps customers to implement this support. It flexibly extends an MCU as an MPU's hardware extension.

A typical use case is a combination of i.MX MPU with i.MX RT1180 MCU as the industrial TSN switch. Using this architecture, the i.MX RT1180 MCU acts as an extension that supports not only the switch functionality but also the TSN functionality and different industrial protocols. In this use case, i.MX RT1180 runs real-time tasks such as industrial protocols, in the real-time domain. The MPU takes up the processing of compute-heavy tasks in the non-real-time domain. The external Ethernet ports of i.MX RT1180 MCU are exposed to the MPU side

as standard Ethernet interfaces in the data path. Different interfaces, such as LPSPI or I2C can be used for the control path between MPU and i.MX RT1180.

The Linux Distributed Switch Architecture (DSA) framework is used to expose the i.MX RT1180 NETC switch ports to MPU side. In this architecture, one of the NETC switch ports or ENETC port is used as the data interface. Different interfaces (for example, LPSPI, I2C or message unit) can be used as management interfaces.

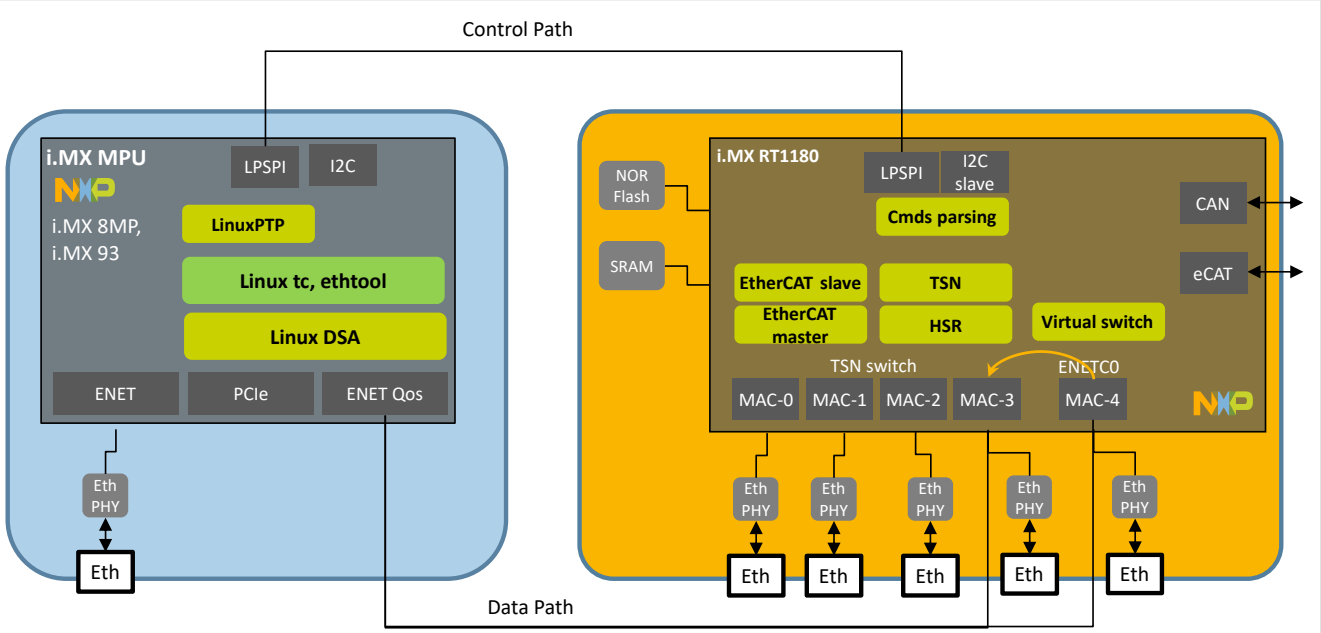


Figure 4. Heterogeneous Multi-SoC framework

- On MPU Linux side, the standard Ethernet port can use Linux configuration tools such as ethtool, tc to control the TSN switch port of i.MX RT1180 MCU.
- On MCU RTOS side, a service driver is added to parse the command to support Linux configuration tool. The virtual switch forwards packets among the NETC switch and ENETC port0 and DSA CPU port.

1.5 Industrial networking

1.5.1 EtherCAT

Real-time Edge software provides full stack support for EtherCAT (Ethernet for Control Automation Technology). Real-time Edge integrates IGH and Codesys for EtherCAT master on Cortex-A core and SOEM on Cortex-M core. This feature helps users get rid of the low-level development directly on EtherCAT protocol and provides a common API for real-time applications. i.MX RT1180 MCU supports EtherCAT slave stack.

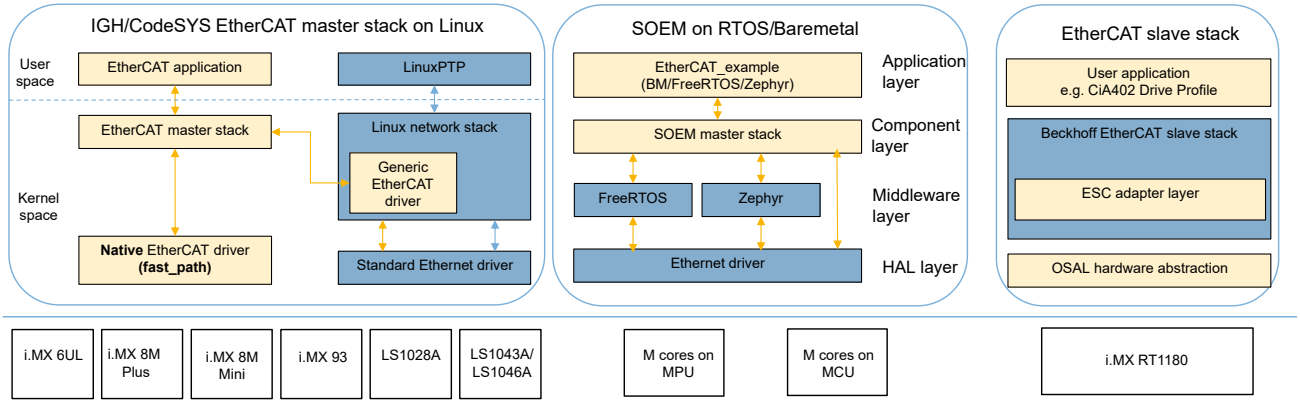


Figure 5. EtherCAT architecture

1.5.1.1 IGH EtherCAT

Real-time Edge integrates IGH EtherCAT master protocols.

The Generic driver uses the lower layers of the Linux network stack to connect to the hardware, independently of the actual hardware driver. So it can be used by all the hardware platforms that Real-time Edge supports. However, the performance by using generic Ethernet Device driver is a bit worse than the native driver.

To improve IGH performance, the native Ethernet Device dirvers are added. Native Ethernet Device Drivers allow the EtherCAT master direct and exclusive access to the Ethernet hardware. This implies that the network device must not be connected to the kernel's stack as usual. In Real-time Edge software, there are three native Ethernet drivers:

1. ec_fec: the native driver ec_fec can be used for the FEC MAC on i.MX 8DXL LPDDR4 EVK, i.MX 8M Mini LPDDR4 EVK, i.MX 8M Plus LPDDR4 EVK, and i.MX 93 EVK.
2. ec_enetc: the native driver "ec_enetc" is used for ENETC MAC on the LS1028ARDB platform.
3. ec_dpaa1: the native driver "ec_dpaa1" is used for DPAA1 MAC on the LS1043ARDB and LS1046ARDB.

1.5.1.2 User Space IGH EtherCAT

To further improve performance, user space IGH EtherCAT stack is introduced. The default IGH EtherCAT stack has both code in the kernel space and the user space. In the kernel space, it integrates multiple drivers for different networking devices. In the user space, it supplies a library (libetherat.so/.a) for the user's application. Users can set/get the running parameters of the device using the API of this library. The API reads or writes data via the ioctl mechanism of the Linux kernel.

The user space IGH EtherCAT stack runs wholly in user space. Therefore, it does not need ioctl to call the kernel part. Users can invoke the functions of the master module directly. This can avoid system call, it can decrease jitter of the system obviously.

From the perspective of threads, there is only one main thread in whole system, which avoids context switching. This also improves the performance, such as jitter and latency and other such parameters.

User space IGH EtherCAT stack has no code that runs in the kernel space, which makes it entirely independent of the kernel version.

User space IGH EtherCAT supports the below board:

- i.MX 8M Mini LPDDR4 EVK
- i.MX 8M Plus LPDDR4 EVK
- i.MX 93 EVK

1.5.1.3 Real-time Edge Servo Stack

real-time-edge-servo is a CiA402 (also referred to as DS402) profile framework based on IGH CoE interface. It abstracts the CiA 402 profile and provides an easily-usable API for the Application developer.

The real-time-edge-servo project consists of a basic library *libnservo* and several auxiliary tools.

The application developed with *libnservo* is flexible enough to adapt to the changing of CoE network by modifying the *xml* config file, which is loaded when the application starts. The *xml* config file describes the necessary information, which includes EtherCAT network topology, slave and master configurations, and definitions of all the axles.

The stack has been tested on below CoE servo production: DELTA ASDA-B3, HCFA SV-X6EB, SV-X3EB, Just Motion Control 2HSS458-EC, and INOVANCE InoSV680N.

1.5.1.4 SOEM EtherCAT

The SOEM is a library that provides the user application the means to send and receive EtherCAT frames. The application provides for:

- Reading and writing process data to be sent/received by SOEM
- Keeping local IO data synchronized with the global IO map
- Detecting errors reported by SOEM
- Managing errors reported by SOEM

On Real-time Edge software, SOEM is supported on Cortex-M core on the below platform:

- i.MX 8M Plus LPDDR4 EVK
- i.MX 8M Mini LPDDR4 EVK

And SOEM runs on FreeRTOS or without an operating system (baremetal).

There are two SOEM demos provided in this release. Both of them have the same function, but is based on different layer. Demo "`freertos_soem_gpio_pulse`" is based on FreeRTOS, while demo "`soem-gpio-pulse`" is based on bare metal (without an operating system).

1.5.1.5 CODESYS EtherCAT

Based on Real-time Edge yocto project, a new yocto distro named "`nxp-real-time-edge-plc`" is added, which is specific to the PLC use case.

Features are as follows:

- **Optimized native driver**

Typical industrial software, for example CODESYS or SOEM EtherCAT master stack, work on user space and communicate using Linux standard network interface. To reduce the latency when Ethernet raw packets pass from user space through Linux standard network, the network driver is optimized to avoid memory reallocation and copying, task rescheduling. The latency of the critical path is reduced for packet transmitting and receiving.

- **Light root filesystem**

Lighter root filesystem saves CPU cycles that could be used by the PLC user program.

- **Supported platforms**
  - imx6ull14x14evk
  - imx8mm-lpddr4-evk
  - imx8mp-lpddr4-evk
  - imx93evk

1.5.2 TSN

Time Sensitive Networking (TSN) is an extension to traditional Ethernet networks, providing a set of standards compatible with IEEE 802.1 and 802.3. These extensions intend to address the limitations of standard Ethernet in sectors ranging from industrial and automotive applications to live audio and video systems. Applications running over traditional Ethernet must be designed to be very robust in order to withstand corner cases such as packet loss, delay, or even reordering. TSN aims to provide guarantees for deterministic latency and packet loss under congestion. Therefore, it allows critical and non-critical traffic to be converged in the same network.

1.5.2.1 TSN hardware capability

Table 1. TSN hardware capability on different platforms

Platform	802.1Qbv (Enhancements for Scheduled Traffic)	802.1Qbu and 802.3br (Frame Preemption)	802.1Qav (Credit Based Shaper)	802.1AS (Precision Time Protocol)	802.1CB (Frame Replication and Elimination for Reliability)	802.1Qci (Per Stream Filtering and Policing)
ENETC (LS1028 A)	Y	Y	Y	Y	N	Y
Felix switch (LS1028A)	Y	Y	Y	Y	Y	Y
Stmac (i.MX 8DXL, i.MX 8M Plus, i.MX 93)	Y	Y	Y	Y	N	N

1.5.2.2 TSN configuration

Real-time Edge provides multiple confugretion tools to set TSN hardware and network.

The table below describes the TSN configuration tools support on different platforms.

Linux traffic control(tc), ethtool, tsntool are integrated into Real-time Edge to configure TSN device.

Table 2. TSN configuration tool support on different hardware platforms

Platform	802.1Qbv (Enhancements for Scheduled Traffic)	802.1Qbu and 802.3br (Frame Preemption)	802.1Qav (Credit Based Shaper)	802.1AS (Precision Time Protocol)	802.1CB (Frame Replication and Elimination for Reliability)	802.1Qci (Per Stream Filtering and Policing)
ENETC (LS1028 A)	tc-taprio tsntool	ethtool tsntool	tc-cbs tsntool	ptp4l	N/A	tc-flower tsntool
Felix switch (LS1028A)	tc-taprio tsntool	ethtool tsntool	tc-cbs tsntool	ptp4l, GenAVB/ TSN stack	tsntool	tc-flower tsntool
Stmac (i.MX 8DXL, i.MX 8M Plus, i.MX 93)	tc-taprio	ethtool	tc-cbs	ptp4l, GenAVB/ TSN stack	N/A	N/A

1.5.2.3 Remote configuration using NETCONF/YANG

NETCONF/YANG is also provided for remote configuration.

NETCONF protocol defines a mechanism for device management and configuration retrieval and modification. It enables a client to adjust to the specific features of any network equipment by using a remote procedure call (RPC) paradigm and a system to expose device (server) capabilities.

YANG is a standards-based, extensible, hierarchical data modeling language. YANG is used to model the configuration and state data used by NETCONF operations, RPCs, and server event notifications.

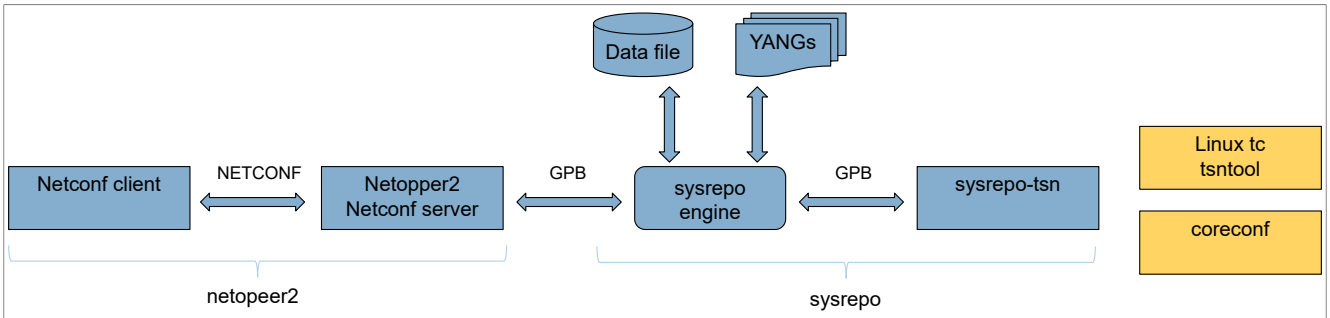


Figure 6. NetCONF/YANG

1.5.2.4 Web-based configuration

The Web UI allows the remote control of the YANG model and also get devices information by websockets.

The user can connect to the http server and input TSN parameters on the web UI. Click "Yes, confirm" button to send the parameters to the board.

The dynamic TSN configuration is used for the TSN configuration dynamically. Users do not need to log into each TSN node to specify the TSN parameters for TSN configuration. They only need to select the path, the base time, and then specify the cycle time. Then, the schedule mapping component calculates the TSN

configuration parameters according to the user input and the path selected. The configuration parameters are delivered to each node by YANG models.

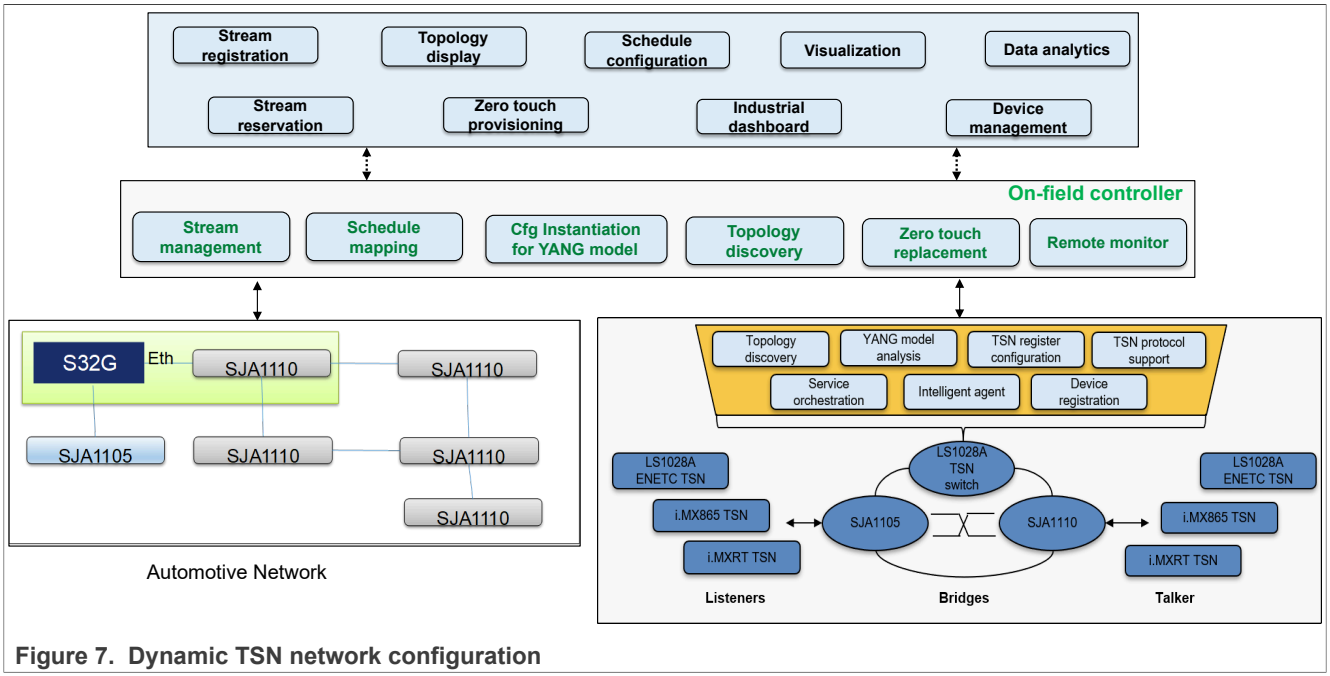


Figure 7. Dynamic TSN network configuration

1.5.3 GenAVB/TSN stack

The GenAVB/TSN Stack provides advanced implementation for Audio Video Bridging (AVB) and Time-Sensitive Networking (TSN) functionalities on NXP SoCs and hardware platforms, for both Endpoints and Bridges. This section provides information on how to set up and evaluate the GenAVB/TSN Stack. In that context, it provides information on the supported SoCs and boards, compile time software package configuration, and runtime configuration settings.

The GenAVB/TSN stack supports the following roles:

- **TSN Endpoint**: The TSN Endpoint functionality requires TSN hardware support.
- **TSN Bridge**: TSN Bridge functionality requires TSN hardware support.
- **AVB Endpoint:** AVB Endpoint functionality uses hardware support if available.
- **AVB Bridge**: AVB Bridge functionality requires AVB hardware support.
- **AVB Hybrid (Endpoint + Bridge functionalities)**: AVB Hybrid functionality requires AVB hardware support.

1.5.4 IEEE 1588/802.1AS

IEEE 1588 is the IEEE standard for a precision clock synchronization protocol for networked measurement and control systems. IEEE 802.1AS is the IEEE standard for local and metropolitan area networks – timing and synchronization for time-sensitive applications in bridged local area networks.

NXP's i.MX and Layerscape platforms provide hardware assist for 1588 compliant time stamping with the 1588 timer module. The software components provided to run IEEE 1588/802.1AS protocol utilizing the hardware feature are listed below:

- Linux PTP Hardware Clock (PHC) driver
- Linux Ethernet controller driver with hardware timestamping support
- A software stack application for IEEE 1588/802.1AS

1.5.5 Network redundancy

Real-time Edge supports the below protocols to achieve network redundancy.

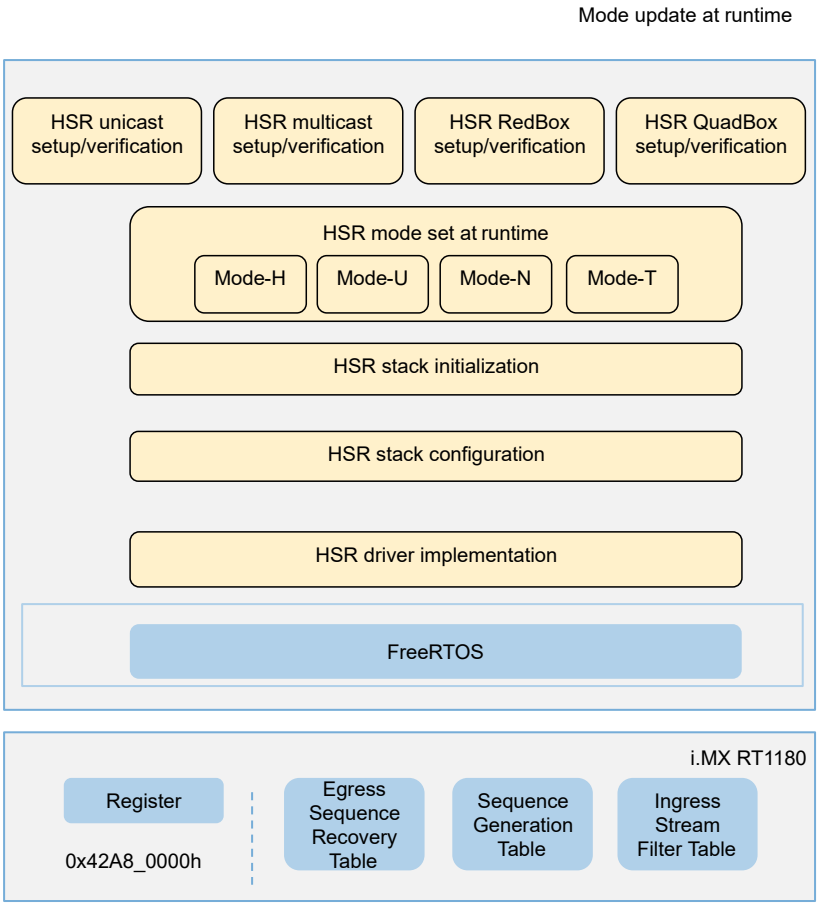
Table 3. Network redundancy

Parameter name	STP	RSTP	ERPS	FRER (802.1 CB)	HSR
Recovery time	30-60 s	1-2 s	50 ms	Zero-delay recovery (seamless redundancy)	Zero-delay recovery (seamless redundancy)
Hardware support	No	No	No	Yes	Yes
Network topologies	Ring, mesh	Ring, mesh	Ring	Stream based	Ring
Protocol	IEEE 802.1D	IEEE 802.1w	ITU G.8032	IEEE 802.1CB	IEC 62439-3:2016
Layer 2	Yes	Yes	Yes	Yes	Yes
SoC capability	SoC with Ethernet ports	SoC with Ethernet ports	SoC with Ethernet ports	LS1028A, i.MX RT1180	i.MX RT1180

i.MXRT TSN bridges can be configured to enable High-availability Seamless Redundancy (HSR). It can be used as HSR DANH, REDBOX. Once HSR is enabled, a duplicated stream flows in the opposite direction on the ring. Communication can be maintained by disconnecting any link on the ring. It supports unicast, multicast, Redbox

and quadbox for setup/verification. It also supports the mode-H, mode-N, mode-U, mode-T and mode-M HSR modes at runtime.

Figure 8. HSR Architecture



Two i.MXRT TSN bridges can be coupled as an HSR Quadbox. The Quadbox can connect two peer HSR rings, which behaves as an HSR node in each ring and is able to filter the traffic and forward it from ring to ring.

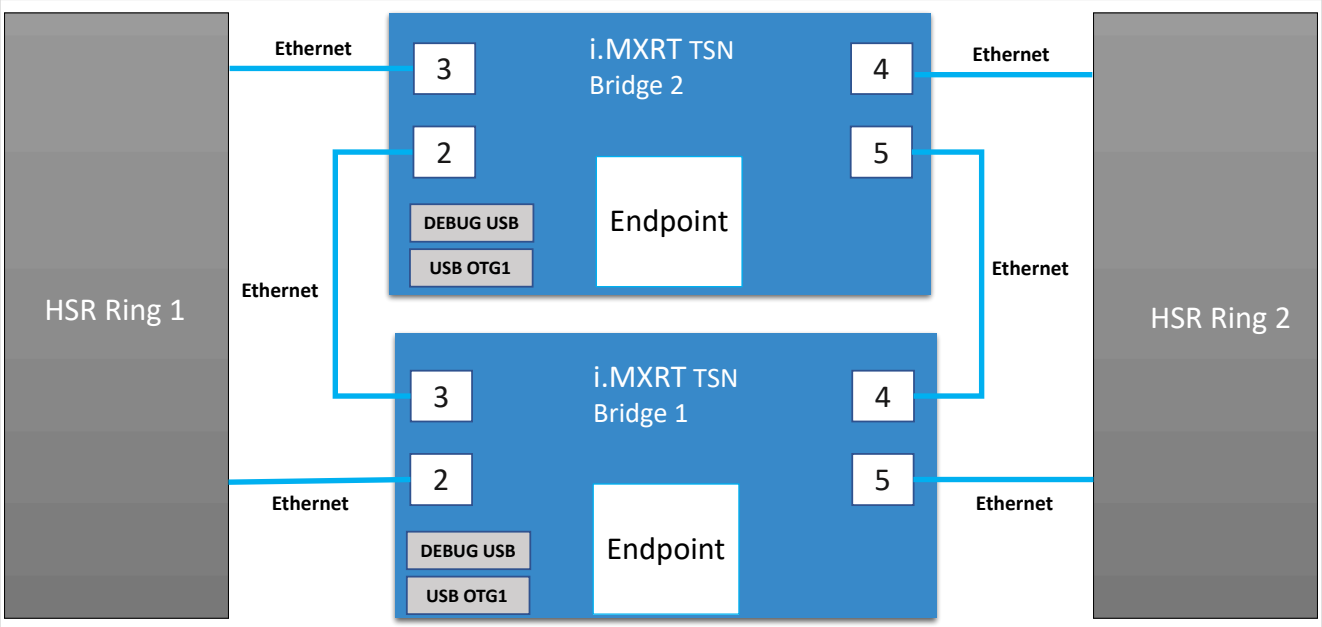


Figure 9. HSR Quadbox formed by coupling two i.MXRT TSN bridges

1.5.6 OPC-UA

OPC UA is a platform-independent standard through which various kinds of systems and devices can communicate by sending request and response Messages between Clients and Servers or Network Messages between Publishers and Subscribers over various types of networks. Multiple samples are provided by Real-time Edge software.

The typical case is two i.MX 8M Plus LPDDR4 EVK boards connected to LS1028ARDB TSN switch.

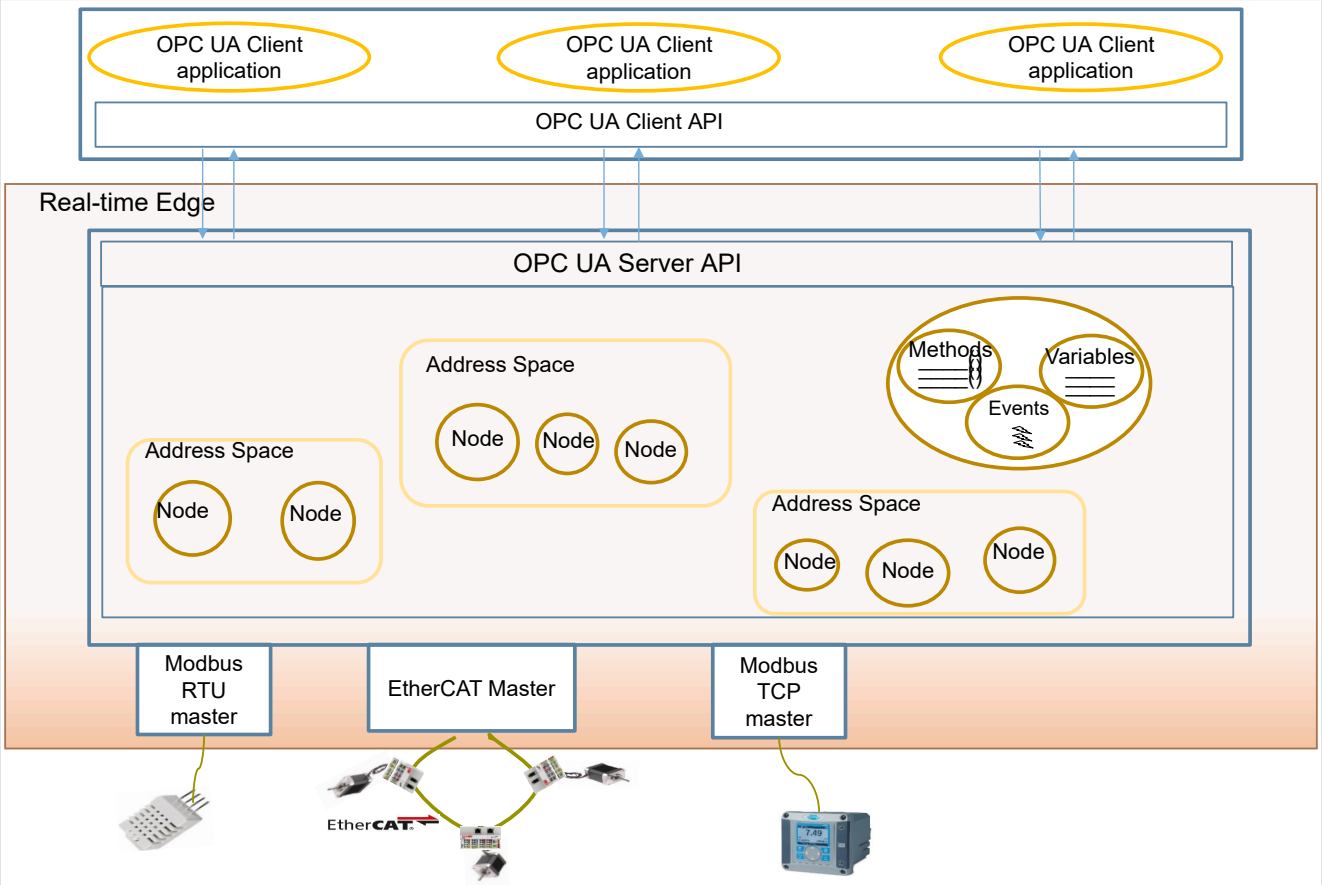


Figure 10. OPC UA

1.5.6.1 Open62541

Real-time Edge integrates the Open62541 software stack (https://open62541.org/). This supports both server-side and client-side API for OPC UA applications. Only server-side capabilities of open62541 are shown here.

Open62541 is distributed as a C-based dynamic library (`libopen62541.so`). The services run on pthreads, and the application code runs inside an event loop.

Enable open62541 in Real-time Edge file ./recipes-nxp/packagegroups/packagegroup-real-time-edge-industrial.bb":

```
libopen62541 \
```

In order to install Open62541 example application, file "`meta-real-time-edge/conf/distro/include/libopen62541.inc`" is included in the distro configuration.

The following Open62541 example applications are included in the target image:

- open62541_access_control_client
- open62541_access_control_server
- open62541_client
- open62541_client_async
- open62541_client_connect
- open62541_client_connectivitycheck_loop

- open62541_client_connect_loop
- open62541_client_subscription_loop
- open62541_custom_datatype_client
- open62541_custom_datatype_server
- open62541_server_ctt
- open62541_server_inheritance
- open62541_server_instantiation
- open62541_server_loglevel
- open62541_server_mainloop
- open62541_server_nodeset
- open62541_server_repeated_job
- open62541_tutorial_client_events
- open62541_tutorial_client_firststeps
- open62541_tutorial_datatypes
- open62541_tutorial_server_datasource
- open62541_tutorial_server_firststeps
- open62541_tutorial_server_method
- open62541_tutorial_server_monitoreditems
- open62541_tutorial_server_object
- open62541_tutorial_server_variable
- open62541_tutorial_server_variabletype

1.5.6.2 OPC UA PubSub over TSN

In general, OPC UA operates at the upper layers of the OSI reference model for networking, whereas TSN is a Layer 2 protocol. TSN adds real-time capability to standard Ethernet. Operating at different layers, TSN and OPC UA PubSub complement each other, yielding a complete communication stack for the industrial Internet of Things. OPC UA standardizes the protocols that applications use to exchange data and TSN enables this exchange to meet timing requirements of factories.

One of the key things is to define a mechanism for OPC UA nodes to tell the TSN layers how to prioritize data streams. This cross-layer control is essential to enabling operations technology (OT) using the OPC UA framework to get the data they need when they need it. It also enables time-sensitive OT to coexist on the same network as information technology (IT) functions. In this section, standard Linux tools (that is, tc) are used to map packets from different sources to different traffic classes in order to use TSN features like IEEE 802.1AS and IEEE 802.1Qbv.

The performance: 1 ms cycle time, 500 µs for OPC-UA pub packets, 500 µs for PTP packets and best effort packets.

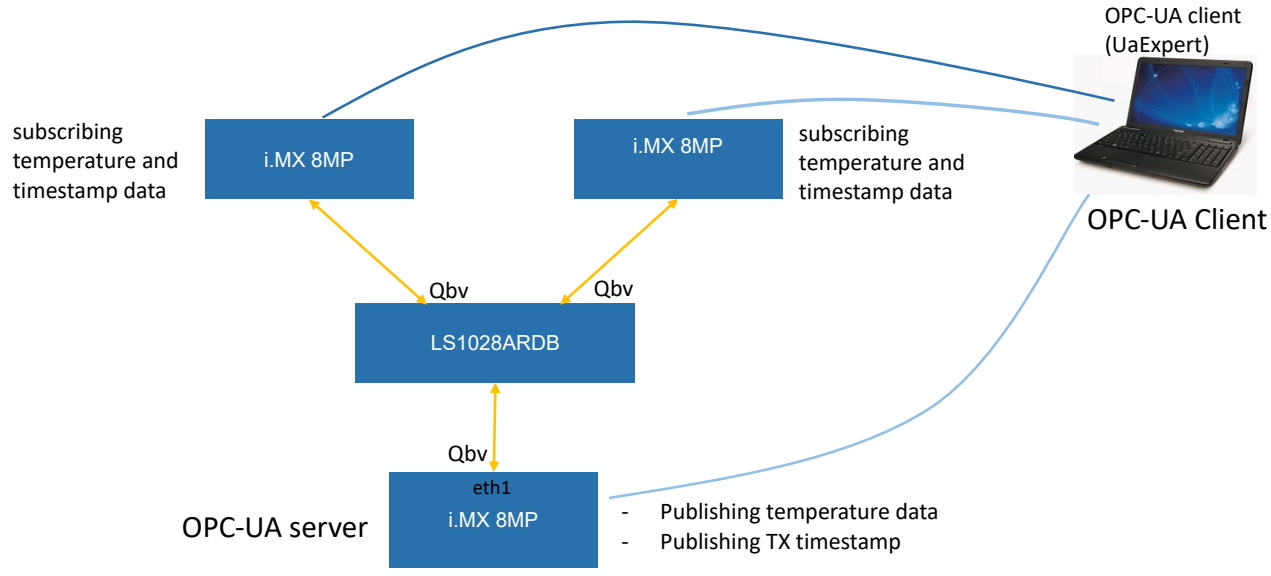


Figure 11. OPC-UA Pub/Sub in Real-time Edge

1.5.7 MODBUS

MODBUS is an application layer messaging protocol positioned at level 7 of the OSI model. It provides client/server communication between devices connected on different types of buses or network.

1.5.7.1 Libmodbus

Real-time Edge integrates libmodbus library. Libmodbus is a free software library used to send or receive data with a device that conforms to the Modbus protocol. It contains various backends to communicate over different networks (for example, serial in RTU mode or Ethernet in TCP IPv4/IPv6).

All the i.MX series and Layerscape series of boards support modbus. It can be used to write both:

- Client applications that reads/writes data from various devices.
- Server applications that provide data to several clients.

1.5.7.2 Libmodbus introduction

Modbus-Simulator is a Modbus tool based on libmodbus library. And it contains a modbus client and a modbus device simulator.

Modbus-device-Simulator supports both **TCP** and **RTU** modes, and each mode supports the following functions.

Features supported by TCP:

- Gets CPU temperature of a device
- Gets the status of the LED light of a device
- Modifies the status of the LED light of a device

Features supported by RTU:

- Gets CPU temperature of a device
- Gets the status of the LED light of a device
- Modifies the status of the LED light of a device
- Modifies the slave address of the device

- Modifies the baud rate of the device

Note: *Only the i.MX 8M Mini and i.MX 8M Plus boards support LED light function and CPU temperature function, other boards define a dummy variable. By default Modbus-Simulator is disable except i.MX 8M Mini and i.MX 8M Plus, taking I.MX 93 as an example, add the following line to* `meta-real-time-edge/conf/distro/include/real-time-edge-base.inc` *to enable it.*

```
DISTRO_FEATURES:append:mx93-nxp-bsp = " modbus-simulator"
```

1.5.8 FlexCAN and CANopen

The FlexCAN module is a communication controller implementing the CAN protocol according to the CAN 2.0 B protocol specification. The main sub-blocks implemented in the FlexCAN module include an associated memory for storing message buffers, Receive (RX) Global Mask registers, Receive Individual Mask registers, Receive FIFO filters, and Receive FIFO ID filters. The LS1028ARDB board has the FlexCAN module.

1.5.9 UART 9-bit Multidrop mode (RS-485) support

The UART provides a 9-bit mode to facilitate multidrop (RS-485) network communication. When 9-bit RS-485 mode is enabled, UART transmitter can transmit the ninth bit (9th bit) set by TXB8. The UART receiver can differentiate between data frames (9th bit = 0) and address frames (9th bit = 1).

Two examples are provided to demo UART RS485 9-bit multidrop support:

- `9bit-iuart-interrupt-transfer` for interrupt mode
- `9bit-iuart-polling` for polling mode.

These two demos support i.MX 8M Mini LPDDR4 EVK board.

2 Yocto Building

All the images including Linux, U-Boot, Rootfs, RTOS, Baremetal are built by Real-time Edge Yocto.

Real-time Edge Yocto Project Release directory contains a `sources` directory. This directory contains the recipes used to build one or more build directories, and a set of scripts used to set up the environment.

The following example shows how to download the Real-time Edge recipe layers. For this example, a directory called `yocto-real-time-edge` is created for the project. Any other name can also be used, instead of this name.

```
$ mkdir yocto-real-time-edge
$ cd yocto-real-time-edge
$ repo init -u https://github.com/nxp-real-time-edge-sw/yocto-real-time-edge.git \
-b real-time-edge-mickledore \
-m real-time-edge-2.8.0.xml
$ repo sync
```

When this process is completed, the source code is checked out into the directory `yocto-real-time-edge/sources`. You can perform repo synchronization, with the command `repo sync`, periodically to update to the latest code.

Real-time Edge provides the script `real-time-edge-setup-env.sh`, which simplifies the setup for both i.MX and Layerscape boards. To use the script, the name of the specific machine to be built for and the desired distro must be specified. The script sets up a directory and the configuration files for the specified machine and distro.

Each build folder must be configured in such way that it uses only one distro. Each time the variable `DISTRO_FEATURES` is changed, a clean build folder is needed. Distro configurations are saved in the `local.conf` file in the `DISTRO` setting and are displayed when the `bitbake` command is run. Here is the list of `DISTRO` configurations:

- `nxp-real-time-edge`: This is the normal image including Real-time and industrial package without BareMetal support.
- `nxp-real-time-edge-baremetal`: This is the BareMetal image (some boards do not support this distro).
- `nxp-real-time-edge-emmc`: This is the normal image to be deployed in eMMC device (for ls1028ardb and ls1046ardb only).

The syntax for the `real-time-edge-setup-env.sh` script is shown below:

```
$ DISTRO=<distro name> MACHINE=<machine name> source real-time-edge-setup-env.sh
 -b <build dir>
```

For example:

```
$ DISTRO=nxp-real-time-edge MACHINE=imx8mp-lpddr4-evk source real-time-edge-
setup-env.sh -b build-imx8mpevk-real-time-edge
```

- `DISTRO`=<distro configuration name> is the distro that configures the build environment.
- `MACHINE=<machine configuration name>` is the machine name that points to the configuration file in `conf/machine` in `meta-freescale` and `meta-imx`.
- `-b <build dir>` specifies the name of the build directory created by the `real-time-edge-setup-env.sh` script.

When the script is run, it prompts the user to accept the End User License Agreement (EULA). Once the EULA is accepted, the acceptance is stored in the `local.conf` file within each build folder. The EULA acceptance query is no longer displayed for that build folder.

Yocto Project build uses the `bitbake` command. For example, `bitbake <component>` builds the named component. Each component build has multiple tasks, such as fetching, configuration, compilation, packaging, and deploying to the target rootfs. The `bitbake` image build gathers all the components required by the image and builds in the order of the dependency per task. The first build is the toolchain along with the tools required for the components to build.

The following command is an example of how to build an Real-time Edge image:

```
$ bitbake nxp-image-real-time-edge
```

3 What's new

The following sections describe the new features for each release.

3.1 What's new in Real-time Edge software v2.8

- **Real-time System**
  - Preempt-RT Linux 6.1.55-rt16
  - eMMC boot support on i.MX 8M Mini/ i.MX 8M Plus/ i.MX 93
  - Harpoon 3.0
- **Heterogeneous multcore Framework**
  - lwIP on Cortex-A Core (ENET on i.MX 93 and i.MX 8M Mini)
  - RPMSG performance evaluation tools (on i.MX 8M Plus)
  - Native Zephyr on Cortex-A Core
- **Heterogeneous Multi-SoC Framework**
  - Software virtual switching stack on i.MX RT1180
  - NETC DSA switch configuration on both i.MX RT1180 and MPU
    - Using ENETC port as DSA CPU port
- **Protocols**
  - EtherCAT master
    - User space IGH EtherCAT master stack and user space native driver on i.MX 8M Mini, i.MX 8M Plus and i.MX 93.
  - AVB/TSN
    - Bridge and hybrid mode (endpoint + bridge) on i.MX93 14x14 / SJA1105 using external port
- **NPI**
  - i.MX93 A1 14x14 (PRC)
- **Based on lf-6.1.55-2.2.0**
  - U-Boot v2023.04
  - LTS 6.1.55
  - MCUX SDK 2.14.0
  - Yocto mickledore 4.2
- **Documentation**
  - Real-time Edge RN (Release Notes)

3.2 What's new in Real-time Edge software v2.7

- **Real-time System**
  - Preempt-RT Linux 6.1.36-rt12
  - BareMetal: math library extended to all platforms
  - Harpoon 2.5
- **Heterogeneous multcore Framework**
  - lwIP on Cortex-A Core (ENET on i.MX8MP)
  - RPMSG between two FreeRTOS
  - RPMSG performance evaluation tools
  - RAM console on FreeRTOS
  - Flexible bootstraps with application
- **Heterogeneous Multi-SoC Framework**
  - NETC DSA switch driver on Linux

  - Device driver of DSA control interface on Linux DSA
  - Service driver of DSA control interface on i.MX RT1180
  - NETC DSA switch configuration on i.MX RT1180
- **Protocols**
  - AVB bridge with SJA1105
- **Benchmarking**
  - Heterogeneous Multicore VirtIO performance optimization
- **NPI**
  - i.MX93 A1 9*9
    - Preempt RT, BareMetal, Jailhouse, Heterogeneous Multicore (RPMSG, UART sharing), TSN web-UI configuration
- **Based on lf-6.1.36-2.1.0**
  - U-Boot v2023.04
  - LTS 6.1.36
  - MCUX SDK 2.13.1
  - Yocto mickledore 4.2
- **Documentation**
  - Real-time Edge QRG (Quick Reference Guide)

3.3 What's new in Real-time Edge software v2.6

- **Real-time system**
  - Preempt-RT Linux 6.1.22-rt8
  - Baremetal
    - LS1028A
      - Preempt-RT Linux + Baremetal
      - All Cortex-A running under Baremetal
      - Math library support
    - DM mode for Baremetal example and driver: I2C, QSPI
  - Harpoon 2.4.0
- **Heterogeneous multcore framework**
  - VirtIO Ethernet sharing RFP
- **Protocols**
  - EtherCAT master CodeSYS networking optimization
    - i.MX 8M Plus, i.MX 8M Mini, i.MX93, i.MX 6ULL
  - TSN
    - Enhancements for Avnu Alliance Conformance Test for IEEE802.1Qbu/IEEE802.3br
  - AVB Milan 1.1 Test Suite conformance
- **Benchmark**
  - Heterogeneous multicore performance: networking
  - CodeSYS EtherCAT master stack benchmarking
- **NPI**
  - i.MX93 A0 9*9
    - Preempt RT, TSN, TSN stack, and config tool
  - i.MX8DXL: AVB Media Clock Recovery
- **Based on lf-6.1.22-2.0.0**
  - U-Boot v2023.04
  - LTS 6.1.22

- MCUX SDK 2.13.1
- Yocto mickledore 4. 2

3.4 What's new in Real-time Edge software v2.5

- **Real-time system**
  - Heterogeneous multi-core
    - RPMSG Vring buffer increasing from 256 KB to 8 MB
    - VirtIO network sharing with performance optimization
  - Baremetal improvements on LS1046A
    - All Cortex-A cores running under Baremetal
    - Flextimer
    - Baremetal example and driver change to DM mode: GPIO
  - Integration of Harpoon 2.3
    - Support for AVB Talker in FreeRTOS audio app
    - Support for RPMsg control (FreeRTOS, all boards)
    - Support for Virtual Ethernet
    - Basic support for i.MX 93 ("hello world")
- **Protocols**
  - EtherCAT master
    - Basic CodeSYS PLC control support and native driver optimization
    - i.MX 8M Plus, i.MX 8M Mini, i.MX 93, i.MX 6ULL
- **NPI**
  - i.MX93 A0 11*11
    - Baremetal, RPMSG based UART sharing
    - AVB Media Clock Recovery
  - i.MX8DXL: AVB audio talker/listener
- **Platform**
  - eMMC booting on LS1028ARDB and LS1046ARDB
  - Removal of testing and documentation support, keeping code inclusion for:
    - LS1021AIOT, LS1021ATSN, LS1021ATWR, LS1012ARDB
  - Based on lf-5.15.71-rt-2.2.0
    - LTS 5.15.71
    - Yocto Kirkstone 4.0
    - U-Boot v2022.04

3.5 What's new in Real-time Edge software v2.4

- **Real-time system**
  - Preempt-RT Linux-5.15.52-rt
  - Heterogeneous multi-core
    - Inter-core communication between Cortex-A core and Cortex-A/Cortex-M core on i.MX 8M Plus and i.MX 8M Mini
      - UART 9-bit Multidrop mode (RS-485) support
      - RPMSG between Cortex-A cores
        - Linux SGI mailbox driver on Linux
        - RPMSG Lite with SGI mailbox on RTOS

    - Loading binaries on i.MX 8M Mini and i.MX 8M Plus to the Cortex-M from Linux
  - Baremetal extensions on LS1046A
    - Single hardware interrupt routed to multiple cores
    - Newlib math library
  - Integration of Harpoon 2.2
  - Audio SMP pipeline (Zephyr)
  - RPMsg-based IPC through Linux control application
  - audio AVB pipeline (FreeRTOS)
  - Support for AVB Listener in FreeRTOS audio app
- **Real-time Networking**
  - TSN
    - Dynamic TSN configuration of Qci for bandwidth limitation
    - Qbu: added preemption TLV on LLDP package and preemption verification support
  - AVB
    - AVB integration improvements
- **Protocols**
  - AVB Milan extensions
  - EtherCAT master stacks
    - EtherCAT master multiple axes control system
  - HMI: LS1028A and i.MX 8M Plus
    - HTML5/chromium
  - Modbus
    - Libmodbus package integration
    - Modbus-simulator client and server
  - WiFi enabled on i.MX 8DXL
- **Reference design**
  - EtherCAT master multiple axes control system
    - HCFA 60-axes servo using CSP mode
- **NPI**
  - i.MX93 A0 11*11: Preempt-RT, EtherCAT master, AVB/TSN, TSN stack and config tools, TSN performance, OPC-UA Pub/Sub
  - i.MX8DXL: Preempt-RT, EtherCAT master, TSN stack and config tools, OPC-UA Pub/Sub
- **Based on lf-5.15.52-2.1.0**
  - LTS 5.15.52
  - Yocto Kirkstone 4.0
  - U-boot v2022.04

3.6 What's new in Real-time Edge software v2.3

- **Real-time Networking**
  - TSN
    - Dynamic TSN configuration (EAR)
      - Qci configuration
      - CAF configuration based on 802.1 Qch

  - YANG modules updating to latest version
- AVB
  - Endpoint support on i.MX 6ULL, i.MX 8M Plus, and i.MX 8M Mini
- **Real-time System**
- PREEMPT-RT Linux-5.15.5-rt22
- Heterogeneous AMP software
  - Yocto based unified delivery for Cortex-A and Cortex-M
  - Resource sharing
    - RPMSG-based UART sharing
      - Virtual UART to physical UART 1:1 mapping
      - Virtual UART to physical UART n:1 mapping
      - Virtual UART to physical UART flexible mapping
- Harpoon (RTOS on Cortex-A)
  - Zephyr integration on i.MX 8M Plus and i.MX 8M Mini
  - Audio Application
    - Sine wave playback
    - Record and playback (loopback)
    - Audio pipeline
  - Industrial applications:
    - TSN over Ethernet test application
    - CAN test application
- **Protocols**
- EtherCAT master stack
  - IGH EtherCAT master native driver on LS1043A and LS1046A
    - Multiple EtherCAT masters
    - Flexible port selection for EtherCAT and Ethernet
  - SOEM EtherCAT master stack enablement (PRC):
    - RTOS on Cortex-M on i.MX 8M Plus
    - RTOS on Cortex-M on i.MX 8M Mini
    - FreeRTOS or without an operating system
- Benchmark
- Scheduling latency on Preempt_RT and Harpoon RTOS
- Inter-core communication bandwidth of Baremetal
- Packet processing time of TSN
- Packet processing time of EtherCAT
- Based on lf-5.15.5-1.0.0
- Linux 5.15.5-rt22
- U-Boot v2021.04
- Yocto Honister 3.4

3.7 What's new in Real-time Edge software v2.2

- Real-time Networking
- TSN
  - 802.1AS: PHY delay correction calibration
  - AF_XDP performance improvements

  - IEEE 1588 PTP UDP on LS1028ARDB TSN switch
- Real-time system
  - PREEMPT-RT Linux-5.10.72-rt53
  - Harpoon (RTOS on Cortex-A)
    - Integration of Harpoon on i.MX 8M Plus and i.MX 8M Mini
- Protocols
  - EtherCAT master stack
    - IGH EtherCAT master native driver on LS1043A and LS1046A
      - Multiple EtherCAT masters
      - Flexible port selection for EtherCAT and Ethernet
    - SOEM EtherCAT master stack enablement (EAR):
      - RTOS on Cortex-M on i.MX 8M Plus
      - FreeRTOS or without an operating system
- Based on lf-5.10.72-2.2.0
  - Linux 5.10.72-rt
  - U-Boot v2021.04
  - Yocto Hardknott 3.3

3.8 What's new in Real-time Edge software v2.1

What’s New:

- Real-time Networking
  - TSN
    - 802.1AS-2020
      - CMLDS (generic interface to PTP stack)
    - TSN application
      - TSN application with AF_XDP data path
    - TSN configuration
      - Path selection for Qbv
      - Schedule mapping for Qbv
- Real-time system
  - PREEMPT-RT Linux-5.10.52-rt47
  - Jailhouse
    - GPIO in non-root cell Linux support on LS1028ARDB
    - ENETC in non-root cell Linux support on LS1028ARDB
- Protocols
  - Native EtherCAT-capable network driver module on ENETC (LS1028ARDB)
  - Native EtherCAT-capable network driver module on FEC (i.MX 8M Plus EVK)
  - EtherCAT: CoE 6-8 axis control
  - OPC UA PubSub
  - OPC UA PubSub over TSN
- Based on i.MX L5.10.52_2.1.0
  - Linux 5.10.52-rt
  - U-Boot v2021.04
  - Yocto Hardknott 3.3

3.9 What's new in Real-time Edge software v2.0

- **Based on Yocto project 3.2 (Gatesgarth)**
- **Real-time System**
  - PREEMPT-RT Linux
  - Heterogeneous architecture
    - Baremetal: PREEMPT-RT Linux on A core + Baremetal architecture on A core
      - i.MX 8M Plus EVK, i.MX 8M Mini EVK, LS1028ARDB, LS1046ARDB, LS1043ARDB, LS1021A-IoT
    - Jailhouse: PREEMPT-RT Linux on A core + Jailhouse + PREEMPT-RT Linux on A core
      - i.MX 8M Plus EVK, LS1028ARDB, LS1046ARDB
- **Real-time Networking**
  - TSN
    - TSN Standards
      - IEEE 802.1Qav
      - IEEE 802.1Qbv
      - IEEE 802.1Qbu
      - IEEE 802.1Qci
      - IEEE 802.1CB
      - IEEE 802.1AS-2020 (gPTP)
      - IEEE 802.1Qat-2010 (SRP)
    - TSN Configurations
      - Linux tc command and tsntool
      - NETCONF/YANG
      - Dynamic TSN configuration - web-based TSN configuration, dynamic topology discovery
    - TSN Applications
      - Example for real-time traffic processing
  - Networking
    - 802.1 Q-in-Q
    - VCAP tc flower chain mode
      - Priority set, VLAN tag push/pop/modify, Policer Burst and Rate Configuration, drop/trap/redirect
- **Industrial**
  - EtherCAT master
    - IGH EtherCAT master stack
    - Native EtherCAT-capable network driver module (i.MX 8M Mini EVK)
  - FlexCAN
    - SocketCAN on Linux kernel
  - CANOpen
    - CANOpen master and slave example code
  - CoE: CANOpen over EtherCAT
    - CiA402(DS402) profile framework based on IGH CoE interface
    - EtherCAT CoE 6-8 axis control (i.MX 8M Mini EVK)
  - OPC UA/OPC UA PubSub
    - open62541
  - Modbus
    - Modbus master and slave
    - Modbus-RTU
    - Modbus-TCP

  - Modbus-ASCII
- **New Added Platform**
  - i.MX 6ULL EVK

3.10 What's new in OpenIL v1.11

What's New:

- **TSN**
  - 802.1AS-2020
    - Initial support for multi-domain on i.MX 8M Plus and LS1028A
- **Hardware**
  - i.MX 8M Plus silicon A1
- **Linux Kernel**
  - LTS 5.4.70 for i.MX 8 Series
- **U-Boot**
  - v2020.04 for i.MX 8 Series
- **Baremetal**
  - v2020.04 for Layerscape and i.MX 8 Series
  - i.MX 8M Plus EVK

3.11 What's new in OpenIL v1.10

What's New:

- **TSN**
  - VCAP chain mode
  - GenAVB/TSN stack
- **Real-time**
  - PREEMPT-RT 5.4 on i.MX 8M Mini
    - Ethernet
    - PCIe
    - GPIO
    - DSI
- **Baremetal**
  - i.MX 8M Mini EVK (A core to A core)
    - ICC
    - Ethernet
    - GPIO
- **OpenIL framework**
  - Board
    - i.MX 8M Mini platform
      - GPU: OpenGL ES
      - Display: OpenGL ES, Weston, DSI-MIPI, CSI-MIPI

3.12 What's new in OpenIL v1.9

What's New:

- **TSN**
  - tc flower support for Qbu and Qci
  - 802.1 QinQ
  - Multi-ports TSN switch solution
  - i.MX 8M Plus - TSN
- **Real-time**
  - PREEMPT-RT 5.4 on i.MX 8M Plus
- **Baremetal**
  - LX2160ARDB rev2 support and ICC
- **OpenIL framework**
  - linuxptp uprev to 3.0
  - Board
    - i.MX 8M Plus EVK
      - TSN: Qbv, Qbu, Qav
      - GPU: OpenGL ES, OpenCL
      - Display: OpenGL ES, Weston
    - LS1028ARDB
      - Display: OpenGL ES, Weston
      - GPU: OpenGL ES, OpenCL
    - LX2160ARDB Rev2

3.13 What's new in OpenIL v1.8

What’s New:

- TSN
  - tc VCAP support for VLAN-retagging
  - tc VCAP support for police
  - tc support for Qav and Qbv
  - SJA1105 DSA Support and clock synchronization
  - YANG modules for network config (IP, MAC, and VLAN)
- Real time
  - PREEMPT-RT 5.4
- Baremetal
  - LX2160A rev1 ICC
- OpenIL framework
  - buildroot uprev to 2020.02
  - Kernel/U-Boot
    - Linux upgraded to LSDK20.04 - Linux-5.4.3
    - U-Boot upgraded to LSDK20.04 - U-Boot 2019.10
  - Board
    - i.MX 8M Mini
    - Foxconn LS1028ATSN board with SJA1105

3.14 What's new in OpenIL v1.7

What’s New:

- TSN
  - BC-based 802.1AS bridge mode
  - Netopper2 support based on sysrepo. Support Qbv, Qbu, Qci configuration
  - VLAN-based tc flower policer
  - Web-based TSN configuration tool - available for Qbv, Qbu, and Qci configuration
- Real time
  - Xenomai
    - Xenomai I-pipe uprev to 4.19
  - Baremetal
    - SAI support on LS1028
    - i.MX6Q Baremetal ICC
- Industrial protocols
  - CANopen over EtherCAT
- OpenIL framework
  - Kernel/U-Boot
    - Linux upgraded to LSDK1909 - 4.19
    - U-Boot upgraded to U-Boot-2019.04
  - Boards
    - LX2160ARDB SD boot
    - LX2160ARDB XSPI boot
    - LS1028ARDB XSPI boot
    - LS1046ARDB eMMC boot

3.15 What's new in OpenIL v1.6

What’s New:

- TSN
  - Web-based TSN configuration tool - available for Qbv and Qbu configuration
  - TSN driver enhancement
- Real time
  - Baremetal
    - i.MX6Q-sabresd Baremetal support
- NETCONF/YANG
  - NETCONF/YANG model for Qbu and Qci protocol
- Industrial protocols
  - LS1028A - BEE click board

3.16 What's new in OpenIL v1.5

What’s New:

- TSN
  - Web-based TSN configuration tool - available for Qbv and Qbu configuration

- 802.1AS endpoint mode for LS1028A TSN switch
- Real time
  - Xenomai
    - LS1028 ENETC Xenomai RTNET support
  - Baremetal
    - LS1028 Baremetal ENETC support
- NETCONF/YANG
  - NETCONF/YANG model for Qbv protocol
- Industrial protocols
  - LS1028A - BLE click board

3.17 What's new in OpenIL v1.4

What’s New:

- TSN
  - ENETC TSN driver: Qbv, Qbu, Qci, Qav
  - ENETC 1588 two steps timestamping support
  - SWTICH TSN driver: Qbv, Qci, Qbu, Qav, 802.1CB support
- Real time
  - Xenomai
    - LS1028ARDB
  - Baremetal
    - LS1021AIoT, LS1043ARDB, LS1046ARDB
    - LS1028 Baremetal basic Baremetal support
- Industrial protocols
- – LS1028A - NFC click board
  - QT5.11
- OpenIL framework
  - boards: LS1028ARDB

4 Supported NXP platforms

The Table 4 "Supported NXP platforms" lists the NXP hardware SoCs and boards that support the Real-time Edge software.

Table 4. Supported NXP platforms

Platform	Architecture	Boot
i.MX 6ULL EVK	Arm v7	SD
i.MX 8DXL LPDDR4 EVK	Arm v8	SD, eMMC
i.MX 8M Mini LPDDR4 EVK	Arm v8	SD, eMMC
i.MX 8M Plus LPDDR4 EVK	Arm v8	SD, eMMC
i.MX 93 EVK	Arm v8	SD, eMMC
i.MX 93 9x9 QSB	Arm v8	SD, eMMC
i.MX 93 14x14 EVK	Arm v8	SD, eMMC
LS1028ARDB	Arm v8	SD, eMMC
LS1043ARDB	Arm v8	SD
LS1046ARDB	Arm v8	SD, eMMC
LX2160ARDB Rev 2	Arm v8	SD

5 Feature support matrix

Table 5 "Key features" shows the features that are supported in this release.

Table 5. Key features

Feature				i.MX 6ULL 14x14 EVK	i.MX 8DXL LPDDR4 EVK	i.MX 8M Mini LPDDR4 EVK	i.MX 8M Plus LPDDR4 EVK	i.MX 93 EVK	i.MX 93 9x9 LPDDR4 QSB	i.MX 93 14x14 LPDDR4x EVK	i.MX RT1180 EVK	LS1028 ARDB	LS1043 ARDB	LS1046 ARDB	LX2160 ARDB
Boot mode	SD			Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y
	eMMC					Y	Y	Y	Y	Y		Y		Y	
Real-time System	Preempt-RT Linux			Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y
	BareMetal	ICC				Y	Y	Y	Y			Y	Y	Y	Y
		PCIe										Y	Y	Y	
		Ethernet				Y	Y	Y				Y	Y	Y	
		GPIO				Y	Y							Y	
		IPI				Y	Y	Y	Y			Y	Y	Y	Y
		UART				Y	Y	Y	Y			Y	Y	Y	Y
		USB											Y	Y	
		SAI										Y			
		CAN													
		I2C										Y	Y	Y	
		QSPI												Y	
		IFC												Y	
		Flextimer												Y	
		Linux (communi-cation with Baremetal)	ICC			Y	Y	Y	Y			Y	Y	Y	Y
			IPI			Y	Y	Y	Y			Y	Y	Y	Y
		Single HW Interrupt to multiple cores												Y	
		Newlib Math library				Y	Y	Y	Y			Y	Y	Y	Y
		All Cortex-A cores running under Baremetal										Y		Y	
	Native RTOS on Cortex-A	FreeRTOS				Y	Y	Y							
		Zephyr				Y	Y	Y							
	Jailhouse					Y	Y		Y			Y	Y	Y	
	Harpoon RTOS	FreeRTOS				Y	Y	Y							
		Zephyr				Y	Y	Y							
Heterogen-eous Multicore Framework	Flexible Real-time System	Flexible Realtime System	Free RTOS			Y	Y	Y							
			Zephyr			Y	Y	Y							
		RAM Console	Free RTOS			Y	Y	Y							
			Zephyr			Y	Y	Y							
		Networking stack on A-Core RTOS	Free RTOS			Y	Y	Y							
	Unified Life Cycle Management	U-Boot booting Native RTOS A-Core Image	Free RTOS			Y	Y	Y							
			Zephyr			Y	Y	Y							
		U-Boot booting Native RTOS M-Core Image	Free RTOS			Y	Y	Y	Y						

Table 5. Key features*...continued*

Feature				i.MX 6ULL 14x14 EVK	i.MX 8DXL LPDDR4 EVK	i.MX 8M Mini LPDDR4 EVK	i.MX 8M Plus LPDDR4 EVK	i.MX 93 EVK	i.MX 93 9x9 LPDDR4 QSB	i.MX 93 14x14 LPDDR4x EVK	i.MX RT1180 EVK	LS1028 ARDB	LS1043 ARDB	LS1046 ARDB	LX2160 ARDB
		Linux booting Native RTOS M-Core Image	Free RTOS			Y	Y	Y	Y						
	RPMSG	RPMSG between A-Core Linux and M-Core RTOS	Free RTOS			Y	Y	Y	Y						
		RPMSG between A-Core Linux and A-Core RTOS	Free RTOS			Y	Y								
		RPMSG between 2 A-Core RTOS	Free RTOS				Y								
		RPMSG between A-core Linux and M-core RTOS with enhanced 8MB buffer	Free RTOS			Y									
		RPMSG Performance Evaluation	Free RTOS				Y								
		UART Sharing based on RPMSG	Free RTOS			Y		Y	Y						
	Heterogene-ous Multicore VirtIO	Heterogeneous Multicore VirtIO Performance Evaluation	Free RTOS			Y	Y								
		Heterogeneous Multicore VirtIO Network Sharing	Free RTOS			Y	Y	Y							
Heterogen-eous Multi-SoC Framework	NETC TSN Switch	DSA single port mode					Y	Y			Y				
		DSA bridge mode					Y	Y			Y				
		MTU configuration					Y	Y			Y				
		VLAN configuration					Y	Y			Y				
		FDB configuration					Y	Y			Y				
		Port statistics					Y	Y			Y				
	Virtual Switch						Y	Y			Y				
Real-time Networking	TSN Standards	Qbv			Y		Y	Y	Y	Y		Y			
		Qbu			Y		Y	Y	Y	Y		Y			
		Qci										Y			
		Qav			Y	Y	Y	Y	Y	Y		Y			
		802.1AS			Y	Y	Y	Y	Y	Y		Y	Y	Y	Y
		802.1CB										Y			
		VCAP chain mode										Y			
		802.1 Q-in-Q										Y			

Table 5. Key features*...continued*

Feature				i.MX 6ULL 14x14 EVK	i.MX 8DXL LPDDR4 EVK	i.MX 8M Mini LPDDR4 EVK	i.MX 8M Plus LPDDR4 EVK	i.MX 93 EVK	i.MX 93 9x9 LPDDR4 QSB	i.MX 93 14x14 LPDDR4x EVK	i.MX RT1180 EVK	LS1028 ARDB	LS1043 ARDB	LS1046 ARDB	LX2160 ARDB
	TSN Configurations	Linux tc command			Y		Y	Y	Y	Y		Y			
		TSN tool										Y			
		NETCONF/ YANG	Qbv		Y		Y	Y	Y	Y		Y			
			Qbu		Y		Y	Y	Y	Y		Y			
			Qci									Y			
			IP		Y		Y	Y	Y	Y		Y			
			MAC		Y		Y	Y	Y	Y		Y			
			VLAN config		Y		Y	Y	Y	Y		Y			
		Web-based configuration	Qbv		Y		Y	Y	Y			Y			
			Qbu		Y		Y	Y	Y			Y			
			Qci									Y			
		Dynamic topology discovery			Y		Y	Y	Y			Y			
		Dynamic TSN configuration	Qci									Y			
			CQF									Y			
			Qbv		Y		Y	Y	Y			Y			
	AVB standards	AVTP Talker/Listener		Y	Y	Y	Y	Y		Y					
		AVDECC		Y	Y	Y	Y	Y		Y					
		MAAP		Y	Y	Y	Y	Y		Y					
		Milan		Y	Y	Y	Y	Y		Y					
		Media clock recovery		Y	Y	Y [1]	Y	Y [1]		Y [1]					
	AVB Bridge on SJA1105Q-EVB				Y					Y					
	AVB Hybrid on SJA1105Q-EVB									Y					
	IEEE 1588/802.1AS				Y	Y	Y	Y	Y	Y		Y	Y	Y	Y
Industrial Protocol	EtherCAT master	IGH EtherCAT master stack		Y	Y	Y	Y	Y				Y	Y	Y	Y
		IGH native Ethernet device driver			Y	Y	Y	Y				Y	Y	Y	
		SOEM				Y	Y								
		CodeSYS EtherCAT master stack		Y		Y	Y	Y							
	FlexCAN											Y			
	CANopen														
	OPC UA	open62541		Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y
		OPC UA PubSub over TSN			Y		Y	Y	Y	Y		Y			
	BEE (Mikroe Click board)											Y			
	BLE (Mikroe Click board)											Y			
	NFC (Mikroe Click board)											Y			
	Modbus	Modbus-RTU		Y	Y	Y	Y	Y	Y	Y					
		Modbus-TCP		Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y

[1] Media clock recovery is implemented through a software-based sampling

6 Related documentation

All documentation related to Real Time Edge software is available on the link: REALTIME EDGE Documentation. The following documents are available:

- ***Real-time Edge Release Notes*** *(RN00161)* (provides release information)
- ***Real-time Edge User Guide*** *(REALTIMEEDGEUG)* (provides detailed user guide)
- ***Real-time Edge Yocto Project User Guide*** *(RTEDGEYOCTOUG)*(provides information for using Yocto build environment)
- ***GenAVB/TSN Stack Evaluation User Guide*** *(GENAVBTSNUG)*(provides information on how to set up Audio Video Bridging evaluation experiments of the GenAVB/TSN Stack on NXP platforms)
- ***Harpoon User's Guide****(HRPNUG)* (provides information to build Harpoon Yocto images)
- ***i.MX6ULL EVK GenAVB/TSN Rework Application Note*** (*AN13678*)
- For details about the graphics feature available in i.MX 8M Plus and i.MX 8M Mini boards, refer to the *i.MX Graphics User's Guide*

To boot up and set up the boards mentioned in this document, refer to the instructions available in the following user guides:

- *i.MX 6ULL EVK Quick Start Guide*
- *i.MX 8M Mini LPDDR4 EVK Quick Start Guide*
- *i.MX 8M Plus LPDDR4 EVK Quick Start Guide*
- *i.MX 8XLite EVK Quick Start Guide*
- *LS1028ARDB Quick Start Guide*
- *LS1043ARDB Getting Started Guide*
- *LS1046ARDB Getting Started Guide*
- *LX2160A/LX2160A-Rev2 RDB Quick Start Guide*
- *IMX93EVK Quick Start Guide*

7 Open, fixed, and closed issues

This section contains three tables that describe Open, Fixed, and Closed issues.

- Open issues do not currently have a resolution. Workaround suggestions are provided where possible. Refer Table 6 "Open issues in Real-time Edge software v2.8"
- Fixed issues have a software fix that has been integrated into the '*Fixed In*' Release. Refer Table 7 "Fixed Issues in Real-time Edge Software v2.8".
- Closed issues are issues where the root cause and fix are outside the scope of Real-time Edge Software. Disposition is to provide the explanation. Refer Table 8 "Closed Issues in Real-time Edge Software v2.8".

Table 6. Open issues in Real-time Edge software v2.8

ID	Description	Opened In	Workaround
INDLINUX-3750	logout after listing services by running 'service --status-all' on LS1028ARDB	Real-time Edge software v2.6	None

Table 7. Fixed Issues in Real-time Edge Software v2.8

ID	Description	Opened In	Fixed In
None			

Table 8. Closed Issues in Real-time Edge Software v2.8

ID	Description	Opened In	Disposition
None	-	-	-

8 Revision history

Table 9 "Document revision history" summarizes the revisions to this document.

Table 9. Document revision history

Document ID	Release date	Description
RN00161 v.1.0	29 March 2024	Initial release for Real Time Edge Software Rev 2.8

8.1 Note about the source code in the document

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