# Brief Introduction of Nendica Study Item Report (Forwarding of Fieldbus CPF 12 on 802.1 Bridges)

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Huajie Bao (Huawei, baohuajie@huawei.com)

Objective

➢ This presentation is to introduce the Nendica Study Item report briefly, and help to get the key point of the informal report.

➢ Generally, the fieldbus type 12 known as EtherCAT could be deployed in Open Mode or Direct Mode, that is an EtherCAT Mdevice and a group SubDevices are connected by a bridged LAN or directly. Both of the modes still keep the isolation paradigm for such a group of SubDevices which are deployed in the separated network.

➢ This Study Item studies a use case that tries to deploy the Ethernet network into the separated network connecting EtherCAT SubDevices, and the Ethernet network forwards the EtherCAT frames (from SubDevices) and Ethernet frames (from general Ethernet Stations) simultaneously.

➢ To some extent, this use case is similar with EtherCAT Open Mode, also, the Ethernet networks should assure the QoS for EtherCAT frames, as using the TSN technologies such as 802.1Qbv, 802.1CB etc. in EtherCAT Open Mode.

➢ And this Study Item analyzes these existing technologies, and focuses on the technical requirements including determinism (with complexity mitigation) & high reliability (without frame replication) for EtherCAT frames, then provides possible optimization direction points.
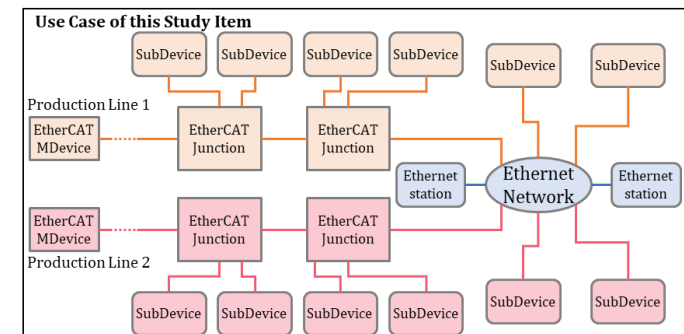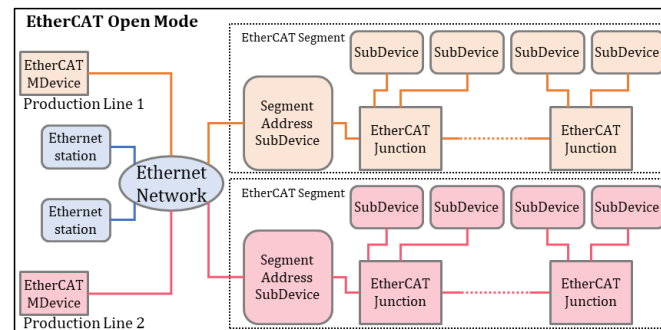
Some Explanations for the Convenience of Readers

➤ Generally, the terms mentioned in this document comply with the definition of 802.1Q, EtherCAT specifications or other standard specifications. In order to avoid confusion or misunderstanding, the following points are explained.

- ☐ **EtherCAT MDevice**: means the EtherCAT Main Device, it's a EtherCAT PLC or controller and includes only one MDevice instance in this document generally unless explicit notes.

- ☐ **EtherCAT SubDevice**: means the EtherCAT Subordinate Device, it's controlled by the EtherCAT MDevice.

- ☐ **EtherCAT frame**: the frame sent by EtherCAT MDevice and forwarded by EtherCAT SubDevice or 802.1 Bridges, and the EtherType of the frame equals 0x88a4.

- ☐ **Ethernet frame**: the frame sent by general Ethernet Stations in this document, and the EtherType of the frame doesn't equal 0x88a4.

- ☐ **EtherCAT topological forwarding mode**: the EtherCAT frames received from specific ingress port are being forwarded to specific egress port according to specific configuration regardless of MAC address of the EtherCAT frames.

- ☐ **MAC address forwarding mode**: the 802.1 Bridge forwards the frames to the specific port according the destination MAC address of the frame and the MAC address table which is mapping the MAC address to the port.

Production Lines Request 802.1 Bridge to Support to Expand New EtherCAT SubDevices

➢ The two production lines are built based on EtherCAT devices in the factory, and the Mdevices and SubDevices are connected by EtherCAT Junctions respectively.

➢ The production lines requests to expand new devices including some new SubDevices and some new Junctions, and the production lines requests the network KPI: cycle time 4ms, jitter < 10%.

➢ Near the expansion spot, there are some Ethernet Stations and Bridges.

➢ Considering the space and cost, the factory request 802.1 Bridges to support to forward EtherCAT frames and Ethernet frames simultaneously, that is no need to deploy new EtherCAT Junctions.
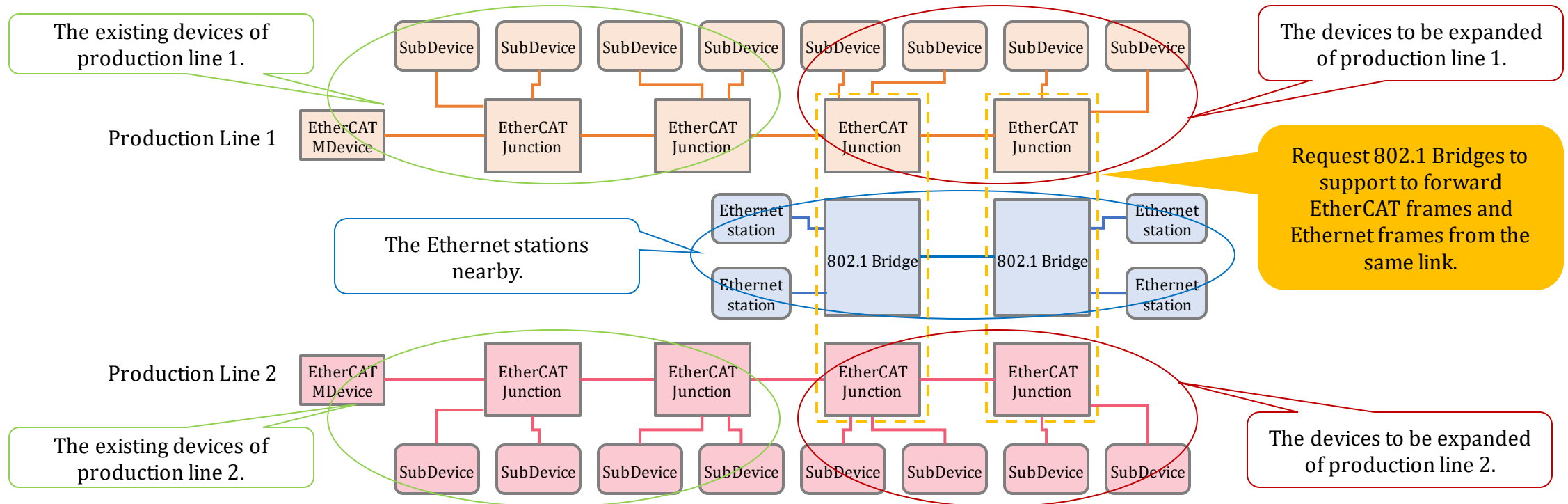
Use Case for 802.1 Bridges to Mix-Transfer Different Kind of Frames

➢ The existing production lines built based on EtherCAT might be Open Mode as the figure below, and request to expand some new SubDevices.

➢ The new expanded EtherCAT SubDevices, the existing EtherCAT devices and some other Ethernet stations are connected by Ethernet network of 802.1 Bridges.

➢ No matter the Open Mode or Direct Mode, there will be different kind of frames to be mix-transferred in the Ethernet network of 802.1 Bridges, and frame identification and QoS assurance should be studied.
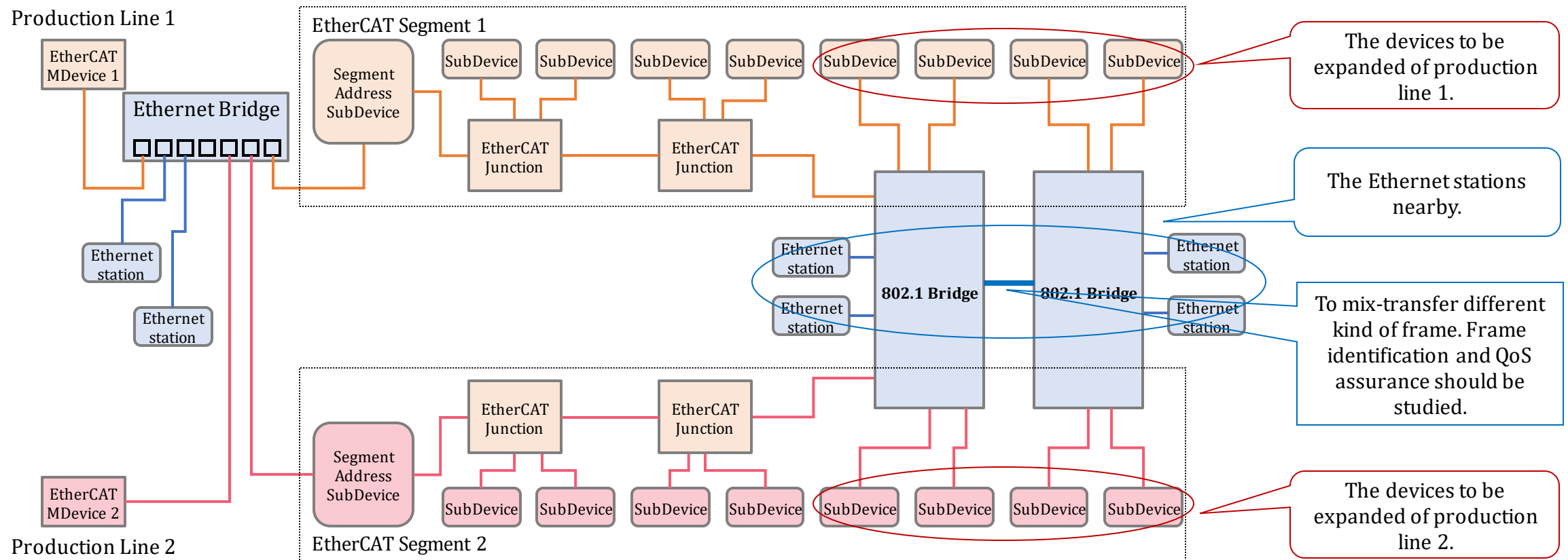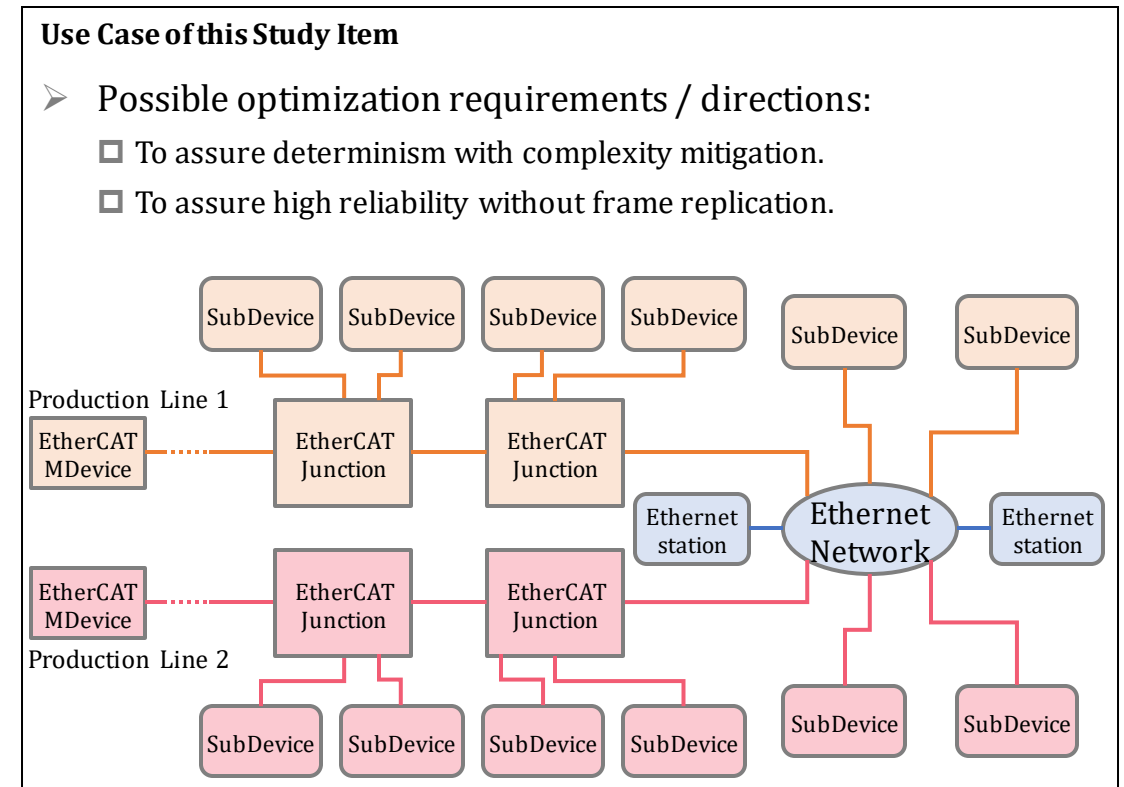
The Basic Simultaneous Forwarding Functionality Is Feasible
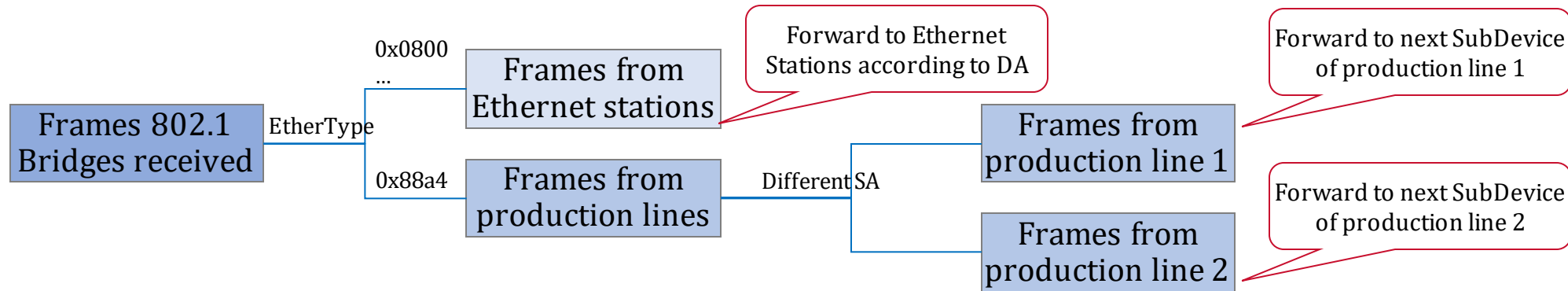
- ➤ No matter the Open Mode or Direct Mode, the frames could be identified by EtherType value and MAC address.
- ➤ The frames from production lines could be forwarded to next specific SubDevice of the production line respectively according to specific forwarding table, other than forwarding according to the destination MAC address.
- ➤ The frames from Ethernet stations should be forwarded according to the destination MAC address.

The QoS Assurance Requirements of the Use Case

➢ As compared with Open Mode, the Use Case deploys the Ethernet network into the EtherCAT separated sub-network.

➢ No matter where the Ethernet network deploys, the Ethernet network has to assure the QoS requirements of EtherCAT services.

➢ The main QoS assurance scenarios and requirements of determinism and high reliability of the Use Case are same as Open Mode, and corresponding technologies & optimizations are consistent.

EtherCAT Open Mode

➢ The existing technologies and corresponding issues:
- ☐ 802.1Qbv to assure determinism, but complicated to implement.
- ☐ 802.1CB, etc. to assure the high reliability, but with frame replication.

Use Case of this Study Item

➢ Possible optimization requirements / directions:
- ☐ To assure determinism with complexity mitigation.
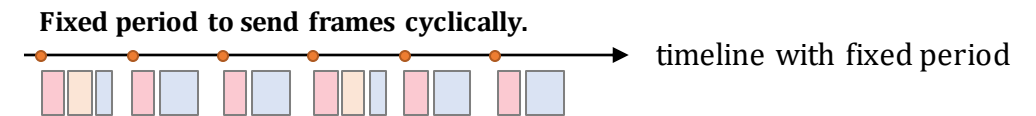- ☐ To assure high reliability without frame replication.
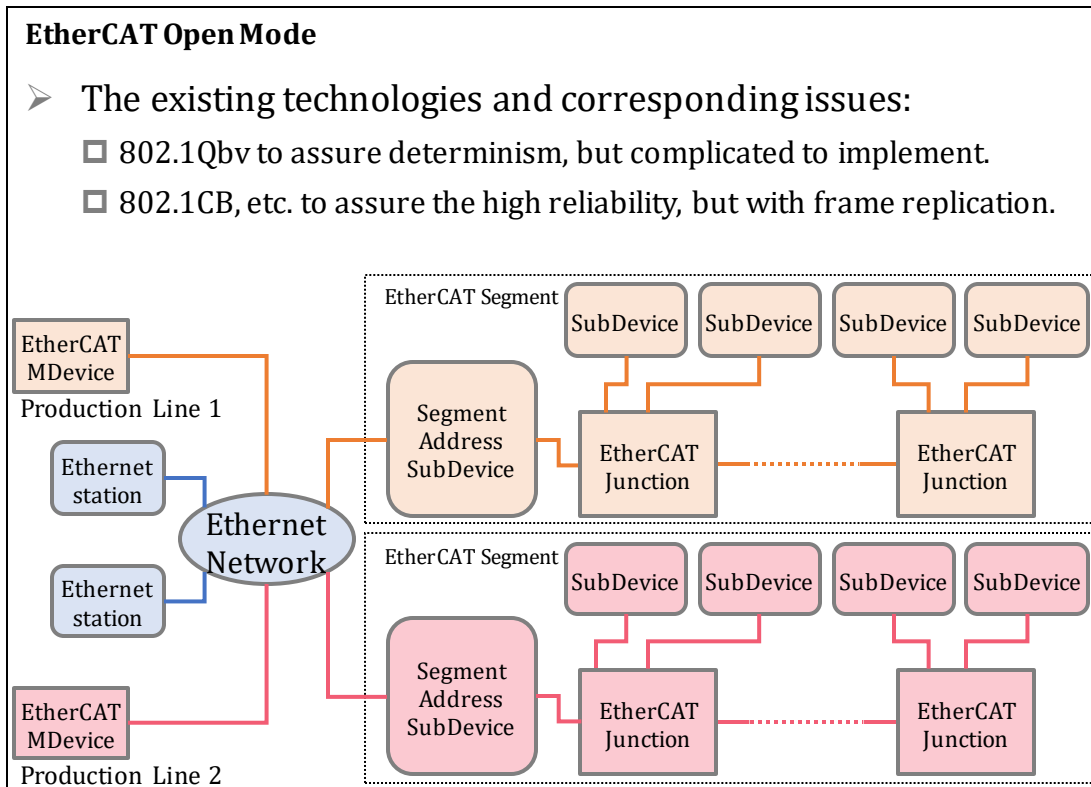
Possible Optimization Directions to Assure Determinism with Complexity Mitigation

➢ **The complication of 802.1Qbv strict orchestration including following factors:**
- ☐ The periods between the two adjacent time points are **different**.
- ☐ The action of sending out frames has to be done **as per the timeline** with strict time synchronization, no earlier and no later than the time point.

➢ It's being more complicated while increasing the network scale and stream quantity.

Specific timepoint to send specific frame.

timeline with unfixed period
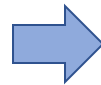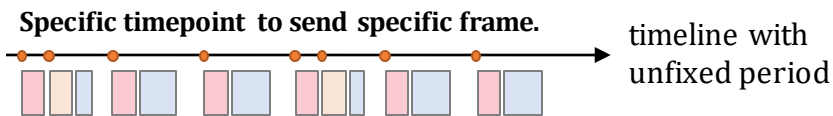
➢ **The mitigation is to use 802.1Qch and the Bridges send the frames according to a same rhythm cyclically other than a strict timeline.**
- ☐ Each bridge use the **same period** to send the frames cyclically, and the EtherCAT frame is sent out as the cyclic shuttle.
- ☐ No matter the routine is long or short, the corresponding transmission time of the shuttle along the link is different, but in a Bridge, the departure time of shuttle is **cyclically fixed**, likewise the adjacent Bridge.
- ☐ That is, the adjacent Bridges build the period mapping relationship, and the end to end transmission latency of frame is anticipated and bounded.

➢ But, in order to satisfy the determinism requirement of EtherCAT service in the Ethernet network which mix-transfers different kind of frames, the following optimization points could be considered:
- ☐ To make full use of the network bandwidth to avoid using big period.
- ☐ Also to use small period to minimize the wait duration for departure time.
- ☐ To minimize the end to end transmission latency of EtherCAT frames to build the explicit & tight period mapping relationship between the adjacent Bridges.

Fixed period to send frames cyclically.

timeline with fixed period

| Frames from Production Line 1 |
| Frames from Production Line 2 |
| Frames from Ethernet Stations |

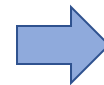# Possible Optimization Directions to Assure High Reliability without Frame Replication

➢ As specified in IEC 61784-2, the redundancy recovery time of EtherCAT is micro-second level.

➢ The high reliability should achieve micro-second level of recovery time first, then to improve other aspects.

➢ The existing reliable capabilities, most of them, the recovery time is milli-second level.

➢ But, 802. 1CB and IEC 62439-3, occupy twice of network bandwidth to implement the zero recovery time level.

NO.	Redundancy / Reliable Capability	Topology Supported	Recovery Time Level
1	Rapid Spanning Tree Algorithm and Protocol (802.1w)	Ring, Mesh	Hundreds of milliseconds
2	Medium Redundancy Protocol (IEC 62439-2)	Ring	Dozens - hundreds of milliseconds
3	Distributed Redundancy Protocol (IEC 62439-6)	Ring	Hundreds of milliseconds
4	Spatial Reuse Protocol (RFC 2892)	Ring	Hundreds of milliseconds
5	Cross-network Redundancy Protocol (IEC 62439-4)	Mesh	Hundreds of milliseconds
6	Ethernet Ring Protection Switching (ITU-T G.8032)	Ring	Dozens milliseconds
7	Ethernet Linear Protection Switching (ITU-T G.8031)	Linear	Dozens milliseconds
8	Frame Replication and Elimination for Reliability (802.1CB)	Ring, Mesh	Zero
9	Parallel Redundancy Protocol and High-availability Seamless Redundancy (IEC 62439-3)	Mesh	Zero

Milli-second level recovery time.

Zero recovery time with frame replication.

➢ Based on Ethernet network of 802.1 Bridges, with the aim to achieve micro-second level recovery time and avoid frame replication, the possible optimization directions are followings:

☐ To make use of Ethernet network ring topology, detect the link fault and activate the backup link.

☐ To build the network fault detection capability in low layer other than layer 2 or high layer.

☐ To build the network recovery capability in low layer to achieve quick deliver the fault point information and trigger to activate the backup link.

☐ To build the high reliable capability in network level completely to avoid additional co-operation of end device.

☐ To avoid the influence to data frames, it's better for the fault detection and notification frame to use no more than 1% of the network bandwidth.

Summary

➢ The use case is based on the production line expansion with EtherCAT SubDevices, it tries to connect the new expanded EtherCAT SubDevices and the existing Ethernet Stations with the Ethernet network of 802.1 Bridges, and different kind of frames will be mix-transferred on 802.1 Bridges.

➢ This Study Item initially analyzes the existing technologies and provides some optimization directions to assure QoS of EtherCAT frames.

  ❑ **Mix-transfer latency / jitter:** as analyzed, the 802.1Qbv could satisfy the low latency / jitter, but it's complicated to implement. The 802.1Qch could mitigate the complexity but it will increase the latency. In order to combine the complexity mitigation and low latency / jitter, the following optimization directions could be considered to assure the determinism of EtherCAT frames based on 802.1Qch.
    ✓ To make full use of the network bandwidth to use small fixed period and minimize the wait duration for departure time of EtherCAT frame in each Bridge.
    ✓ To minimize the end to end transmission latency of EtherCAT frames to build the explicit & tight period mapping relationship between the adjacent Bridges.

  ❑ **High reliability:** As analyzed, the following optimization directions could be considered to achieve the high reliability without frame replication.
    ✓ To build the high reliability on lower layer of Ethernet network (of ring topology) to quickly detect link down and activate the backup link.
    ✓ To avoid influence to end devices, keep compatible device and minimize the bandwidth usage of detection frame (no more than 1 %).

➢ Any comments to the informal report of this Study Item are welcomed, you could your comments to Nendica document area or send an Email to baohuajie@huawei.com.

Intend to Ask for Comments from ETG

➢ Even the scenarios of this Use Case is not the universal scenarios of production line expansion with the EtherCAT devices, but the optimization technology of QoS assurance are consistent with EtherCAT Open mode.

➢ We would like to ask ETG to comment on the following points from the view of up-level application, to review these technical optimization directions are appropriate or not, or is there some other aspects should be considered?

▫ As analyzed, the 801.Qbv implement low latency / jitter based on strict timeline but leading to complexity of implementation, the 802.1Qch mitigate the complexity but increasing end to end latency / jitter, in order to combine the complexity mitigation and low latency / jitter, it's proposed to optimize based on 802.1Qch, to use small fixed period to minimize the wait duration for departure time of the EtherCAT frame, and build the explicit & tight period mapping relationship between the adjacent Bridges to minimize the end to end transmission latency.

▫ The 802.1CB could satisfy the requirement of EtherCAT but it has to replicate the frames. The technical optimization direction is based on the Ethernet network of ring topology, and to use less of network bandwidth (e.g. no more than 1%) to quickly detect link down and activate the backup link on the lower Ethernet network layer.
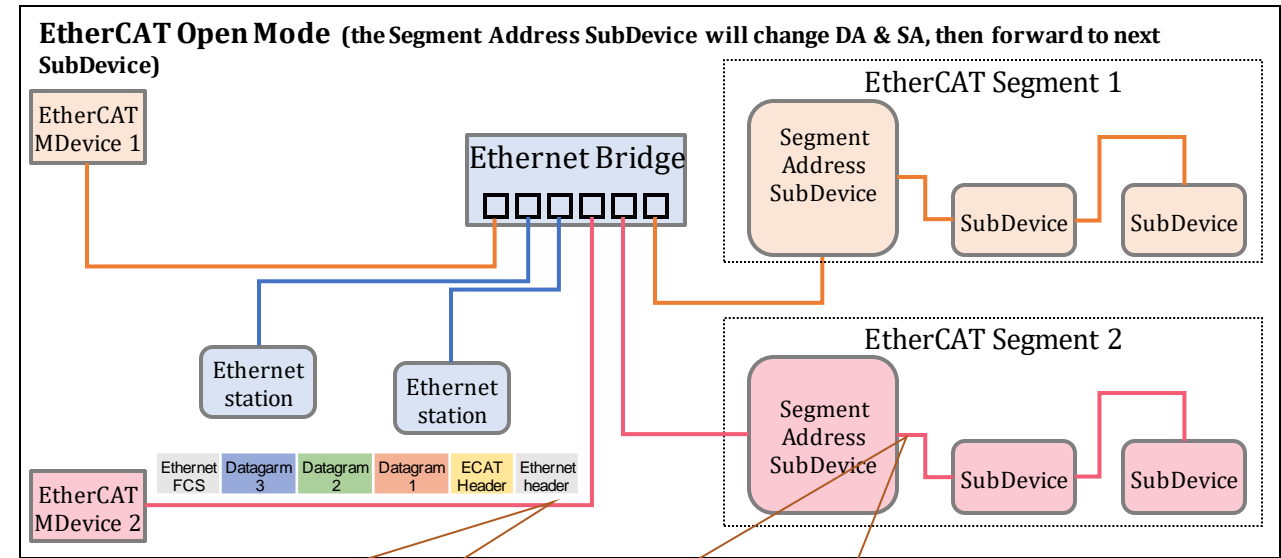
Thank you.

EtherCAT Open Mode & Direct Mode

➢ The previous slides indicated EtherCAT direct mode. In the direct mode, the EtherCAT MDevice and the SubDevices are connected one by one, and the frames are forwarded in a logical ring, and the MAC address fields of the EtherCAT frames are not checked (the SA is the EtherCAT MDevice address, and the DA is the broadcast address).

➢ Using the EtherCAT open mode, one or several EtherCAT segments and respective EtherCAT MDevices can be connected via Ethernet Bridge. Each segment can be addressed using a "Segment Address SubDevice" (the head station of the segment).

  ☐ The EtherCAT MDevice sends the EtherCAT frame, and the DA is the MAC address of the Segment Address SubDevice.
  ☐ The Ethernet Bridge forwards the EtherCAT frame to Segment Address SubDevice.
  ☐ This Segment Address SubDevice replaces the DA with the SA (address of MDevice) and replaces the SA with its own MAC address.
  ☐ The EtherCAT frame loops as the rule of EtherCAT in the segment network.
  ☐ Finally, the EtherCAT frame is forwarded to MDevice by the Ethernet Bridge.
  ☐ Note that, in the figure right side, the EtherCAT MDevice just communicates with one segment only, that is, as the figure right, the EtherCAT MDevice 1 communicates with EtherCAT segment 1 only via orange link, and the EtherCAT MDevice 2 communicates with EtherCAT segment 2 only via light red link.

EtherCAT Direct Mode (the DA & SA will not be changed in the whole process)
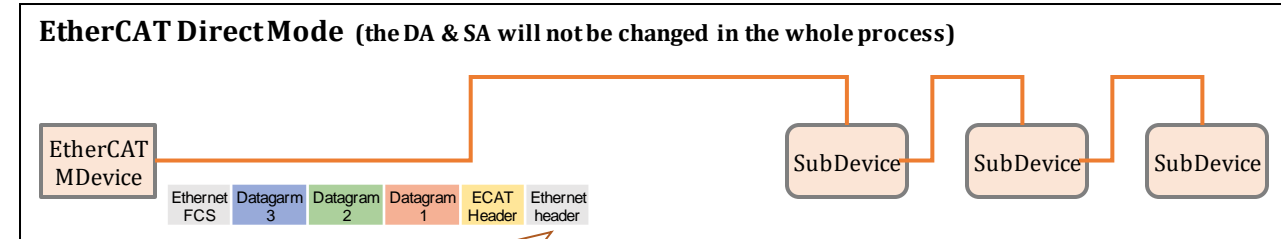
DA = Broadcast address
SA = EtherCAT MDevice MAC address

EtherCAT Open Mode (the Segment Address SubDevice will change DA & SA, then forward to next SubDevice)

DA = Segment Address SubDevice MAC address
SA = EtherCAT MDevice MAC address

Segment Address SubDevice change the DA & SA MAC
DA = EtherCAT MDevice MAC address
SA = Segment Address SubDevice MAC address