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

2022-12-8

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 is 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 of 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. for EtherCAT Open Mode.

➢ And this Study Item analyzes these existing technologies, and focuses on the issues including **determinism (with complexity mitigation)** & **high reliability (without double bandwidth usage)** for EtherCAT frames, then provides corresponding possible optimization direction points.

Requirement for 802.1 Bridge to Support to Extend New EtherCAT SubDevices of Production Lines

➤ 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 extend 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 extension 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.
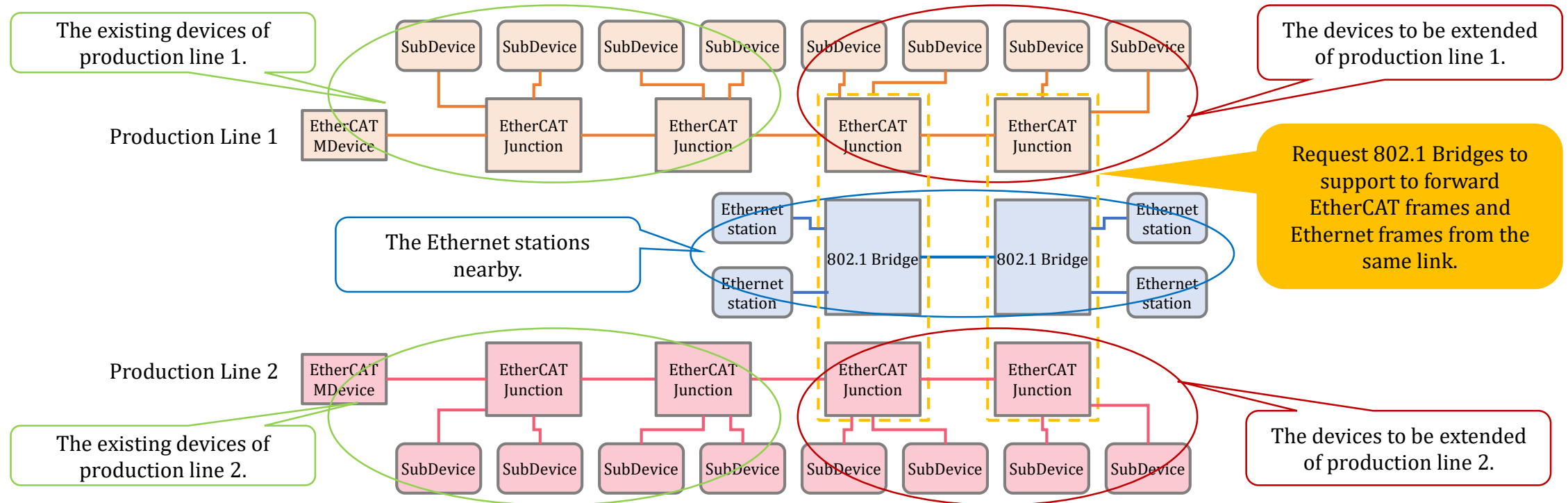
Use Case for 802.1 Bridges to Mix-Transfer Different Kind of Frames (EtherCAT Frames from Different Production Lines & Ethernet Frames)

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

➢ The new extended 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.
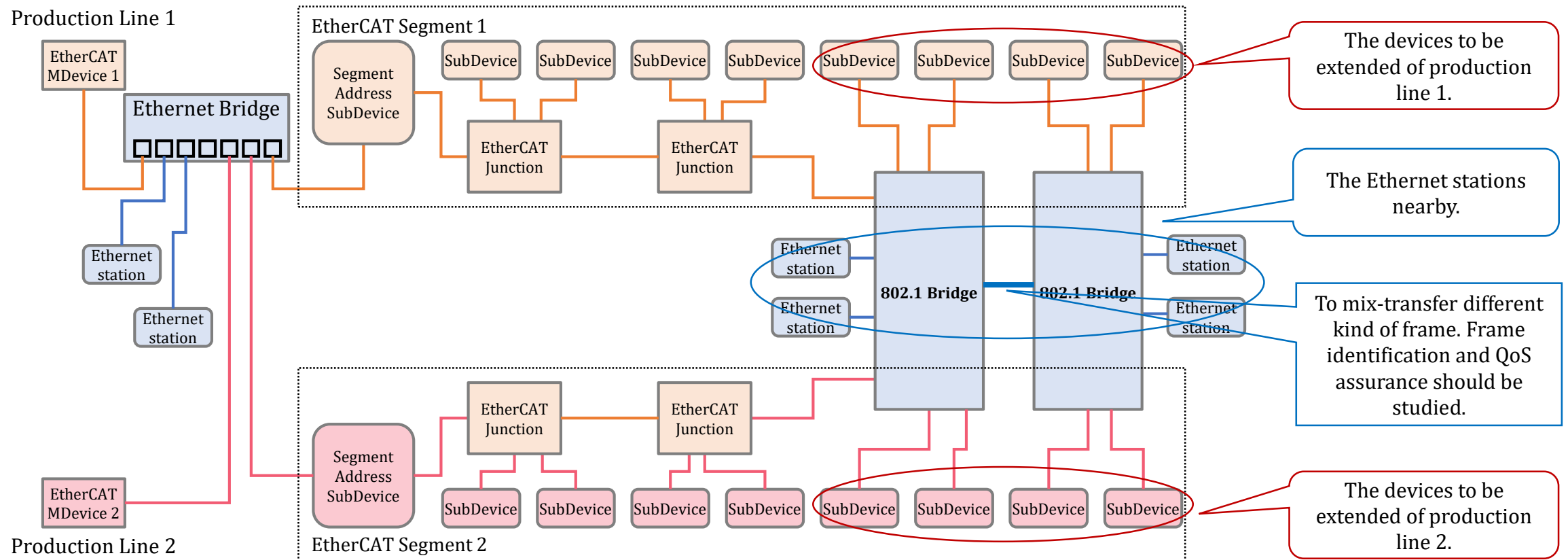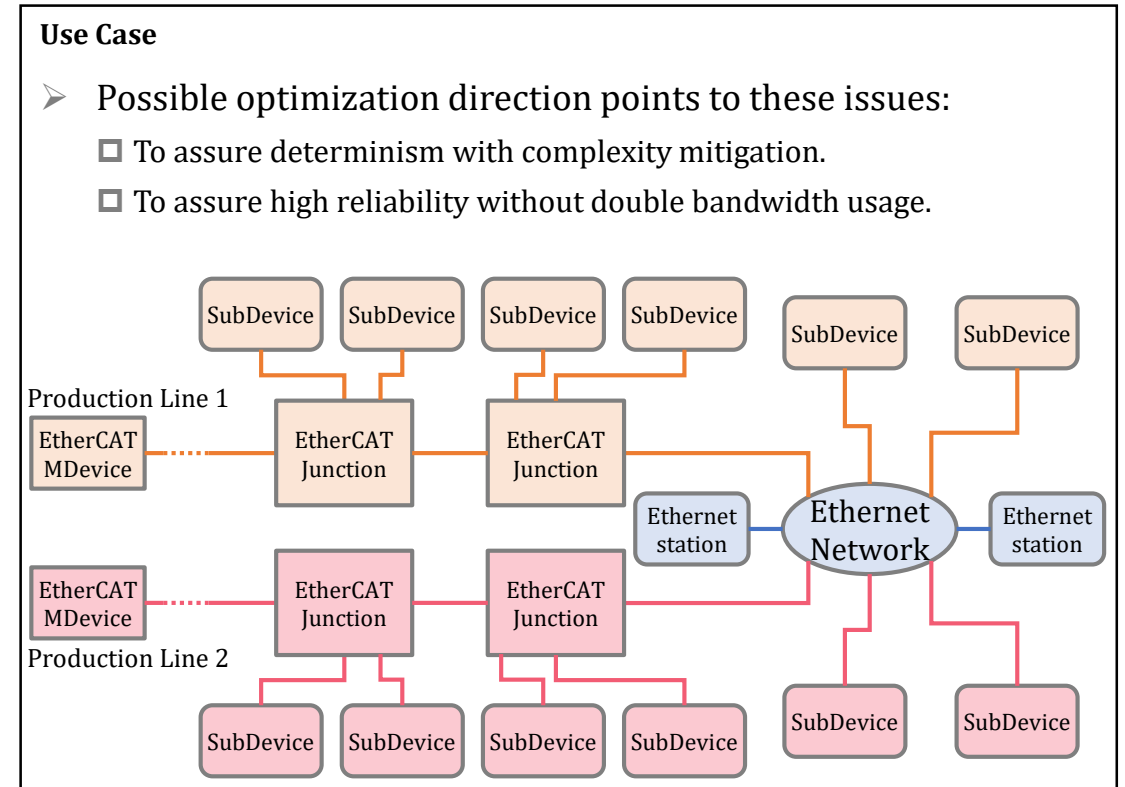
The Basic Simultaneous Forwarding Functionalities Are Feasible
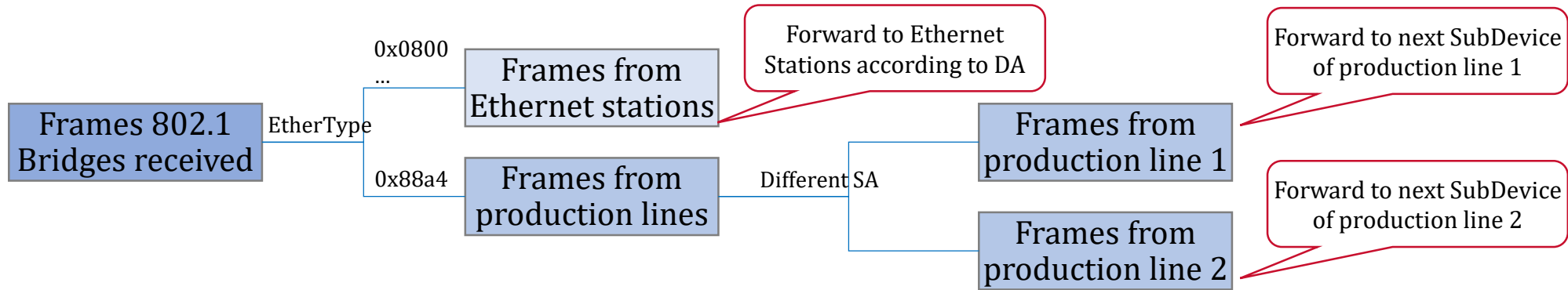
- ➢ No matter the Open Mode or Direct Mode, the frames could be identified by EtherType value and MAC address.
- ➢ The frames from production lines could be forwarded to next specific SubDevice of the production line respectively according to specific forwarding table, other than forwarding according to the destination MAC address.
- ➢ The frames from Ethernet stations should be forwarded according to the destination MAC address.

The QoS Assurance Issues 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 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 it's complicated to implement.
  - ☐ 802.1CB, etc. to assure the high reliability, but more bandwidth are occupied.

Use Case

➢ Possible optimization direction points to these issues:
  - ☐ To assure determinism with complexity mitigation.
  - ☐ To assure high reliability without double bandwidth usage.

Possible Optimization: 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 making the Bridges to 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, and corresponding transmission time of the shuttle along the link is different, but in a Bridge, the departure time of shuttle is **cyclically fixed**.
  - ✓ That is, even the shuttle arrives at a Bridge earlier, but the next departure time has to wait until the timepoint of next cycle, and absolute latency value of frame is increased.
  - ✓ The stream meter & self-studying capabilities could be built to get the features of streams, and make the adjacent Bridges to work in a same rhythm.
  - ✓ So, from the view of the whole network, the end to end network transmission latency is anticipated and bounded.

➢ If the network bandwidth is enough, even the frame has to wait until the complete cycle in each Bridge, the end to end transmission latency of frame could afford the specific EtherCAT service requirement, and the complexity of orchestration could be mitigated.

Fixed period to send frames cyclically.

timeline with fixed period
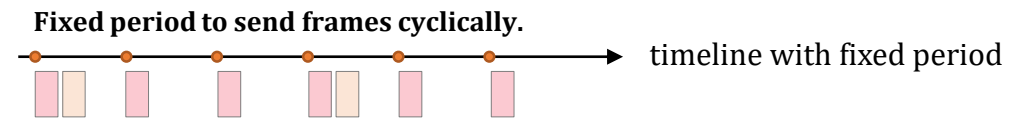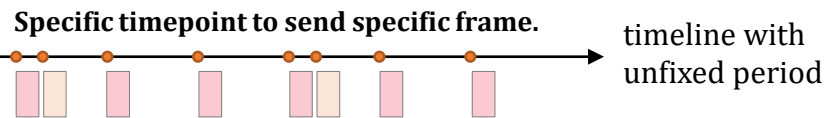
Frames from Production Line 1

Frames from Production Line 2

# Possible Optimization: to Assure High Reliability without Double Bandwidth Usage

➢ 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 (IEC 62439-3)	Mesh	Zero

Milli-second level recovery time.

Zero recovery time, but network bandwidth doubled.
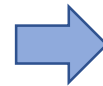
➢ Based on Ethernet network of 802.1 Bridges, with the aim to achieve micro-second level recovery time and avoid double network bandwidth usage, the possible optimization directions are followings:

☐ 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 (TSN 802.1Qbv, 802.1CB etc.) and provides some optimizations points for further analysis.

➢ 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 points of QoS assurance technology are consistent.

➢ We would like to raise the following points to ask for comments from ETG:

❑ The first point is about the determinism, the possible optimization point in this Study Item is to mitigate the complexity caused by determinism implementation & management. From the view of industrial service level, is it a possible optimization direction for determinism or is there any other factors to be considered?

❑ The second point is about the high reliability, the existing high reliable technologies could afford the requirement of EtherCAT but with double bandwidth usage, the optimization point in this Study Item is to consider to build the Ethernet network (of ring topology) high reliability on lower level to support the EtherCAT services without frame replication. From the view of factual industrial environment, is it a possible optimization direction or is there any other factors to be considered?

Thank you.