

Initial solution for Nendica Study Item Forwarding of Fieldbus CPF 12 on 802.1 Bridges

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Objective

- According to the proposal for Nendica Study Item (Forwarding of Fieldbus CPF 12 on 802.1 Bridges), this presentation is to present the initial solution for this Study Item, including:
 - ❑ The forwarding rules and corresponding configuration
 - ❑ Some points to assure low latency
 - ❑ Orchestration policy to achieve bounded latency
 - ❑ High availability requirements
- Any comments are welcomed.

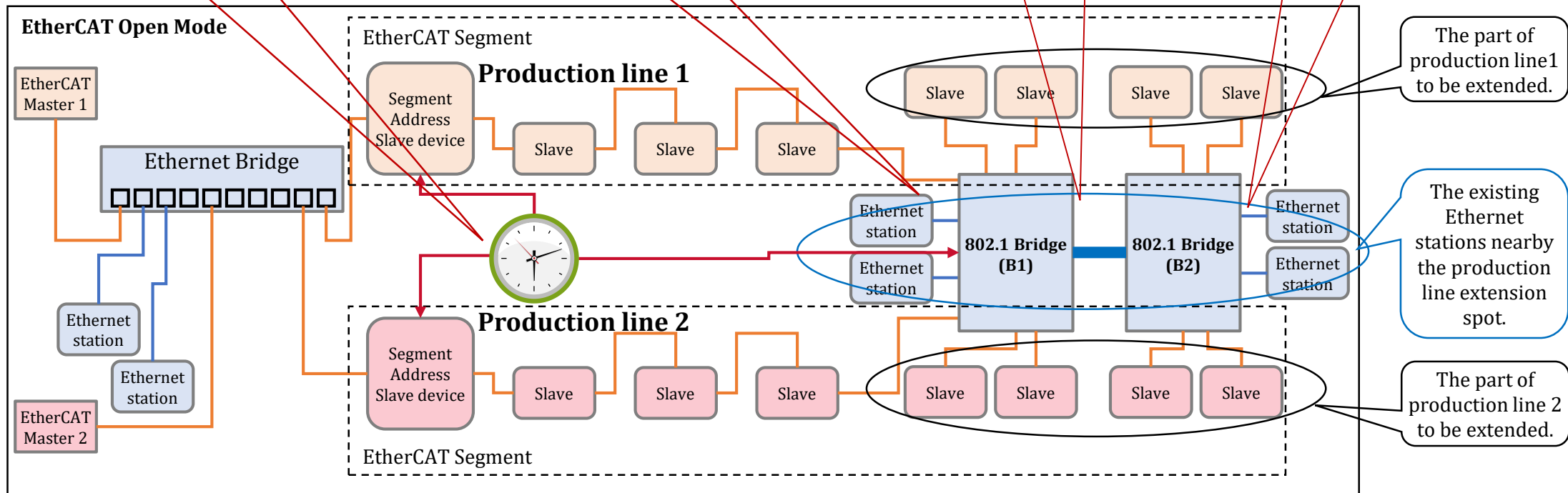
Initial Solution Points for the Use Case of EtherCAT Production Line Extension

① **Clock Synchronization:** clock synchronized to all of the two production lines and the 802.1 Bridges based on the current clock synchronization solution. (outside of current study item)

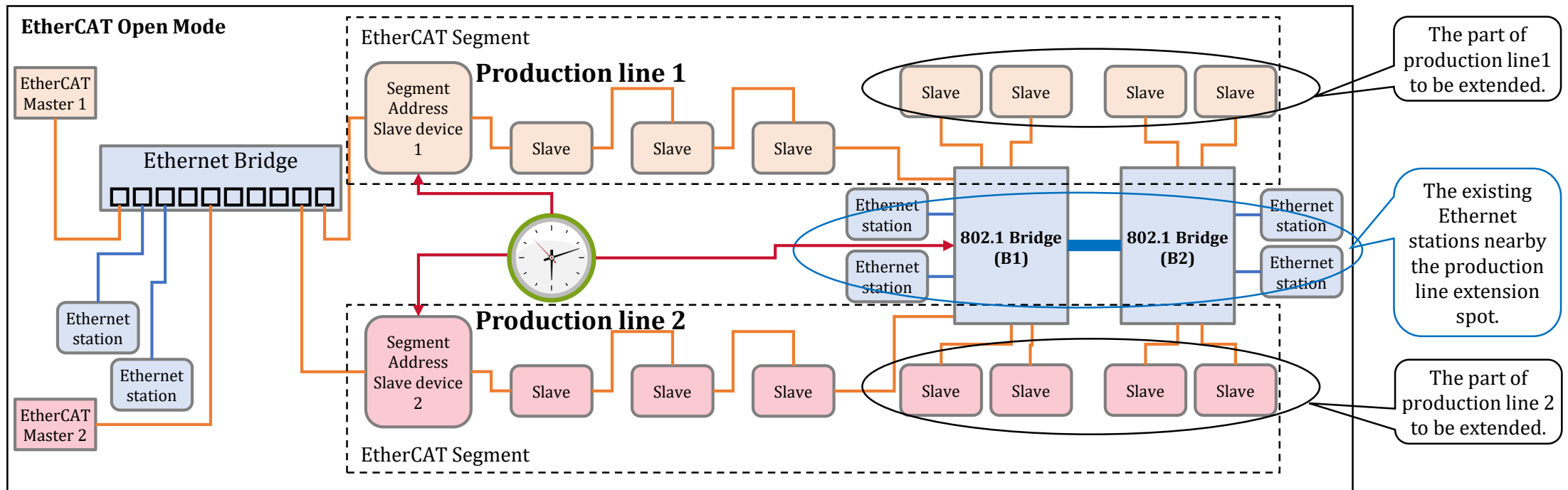
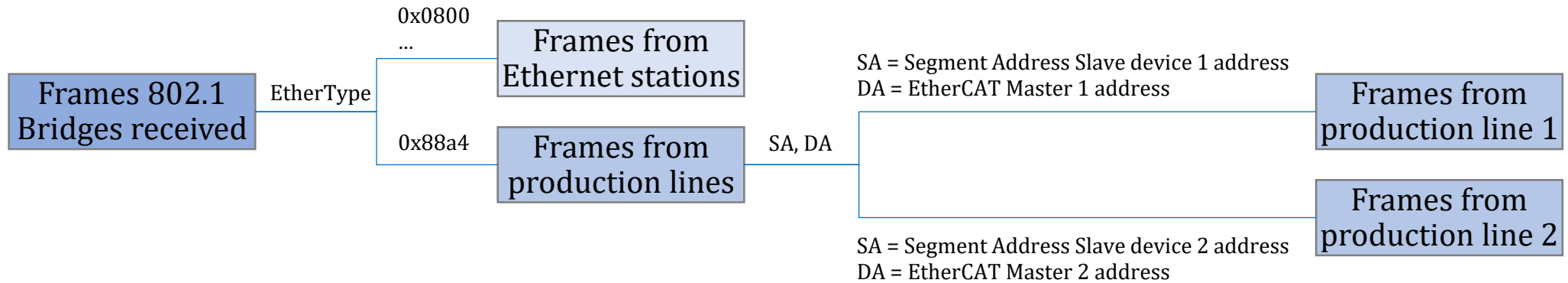
② **Identify different kinds frames, and forward to specific ports or devices according to EtherCAT**

③ **Improve the latency / jitter, assure the low latency / jitter according to independent of EtherCAT network**

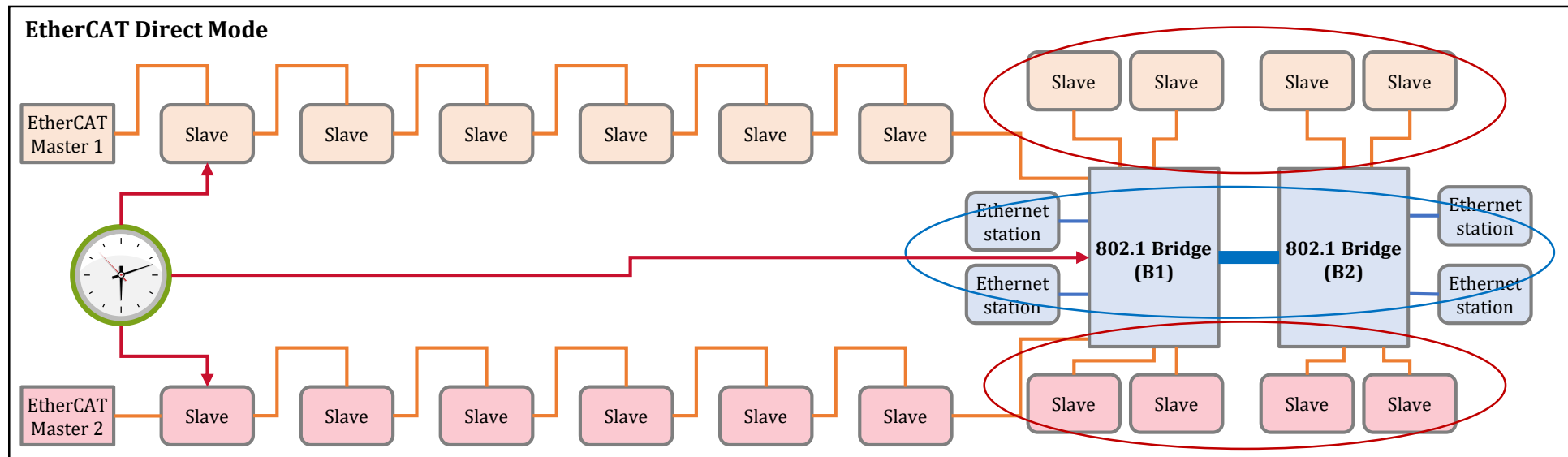
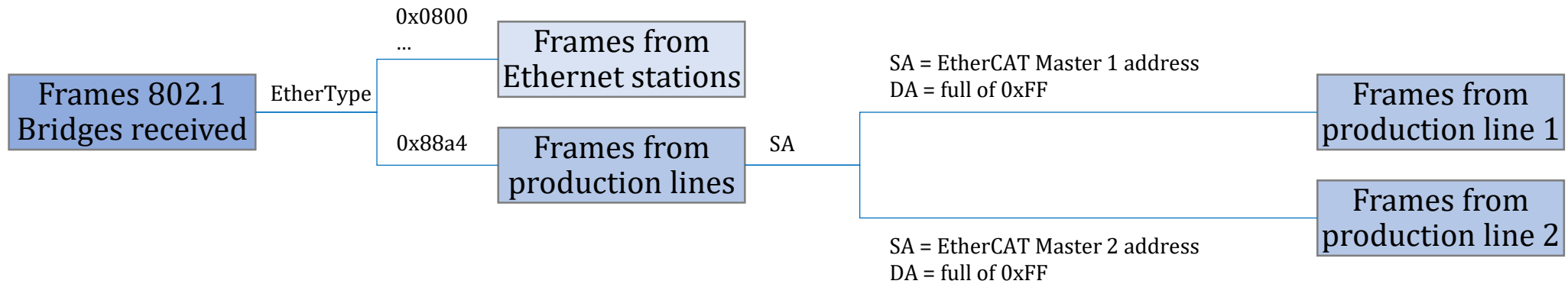
④ **Build reliable capability, assure the high reliability according to independent of EtherCAT network**



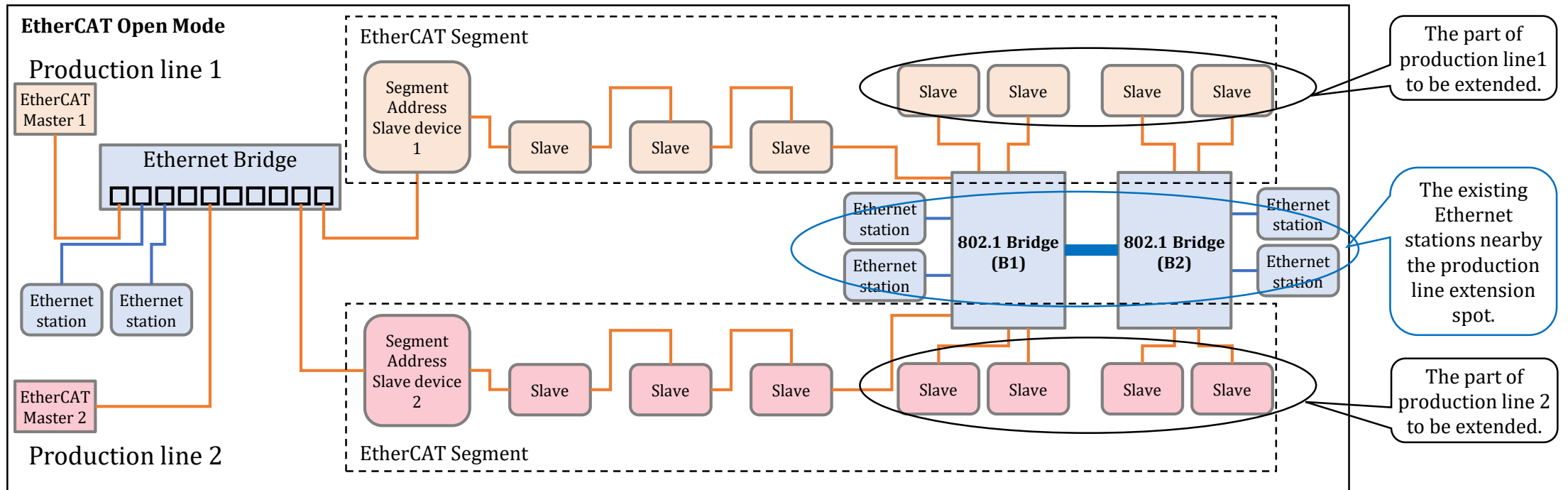
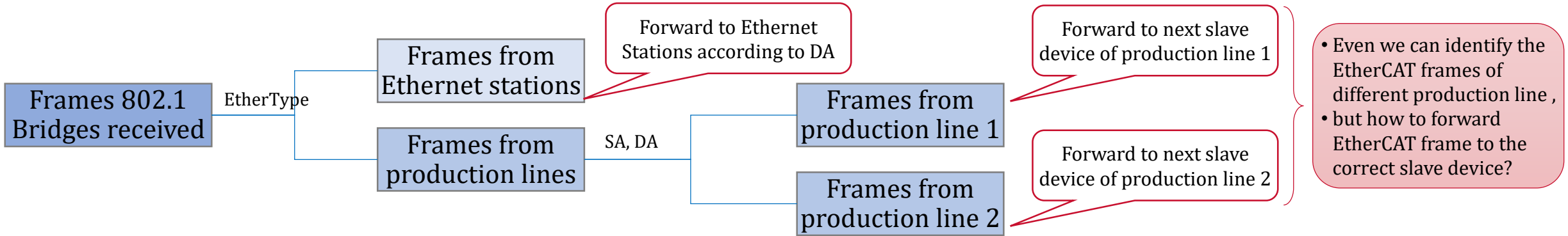
Identify Different Kinds Frames in EtherCAT Open Mode



Identify Different Kinds Frames in EtherCAT Direct Mode

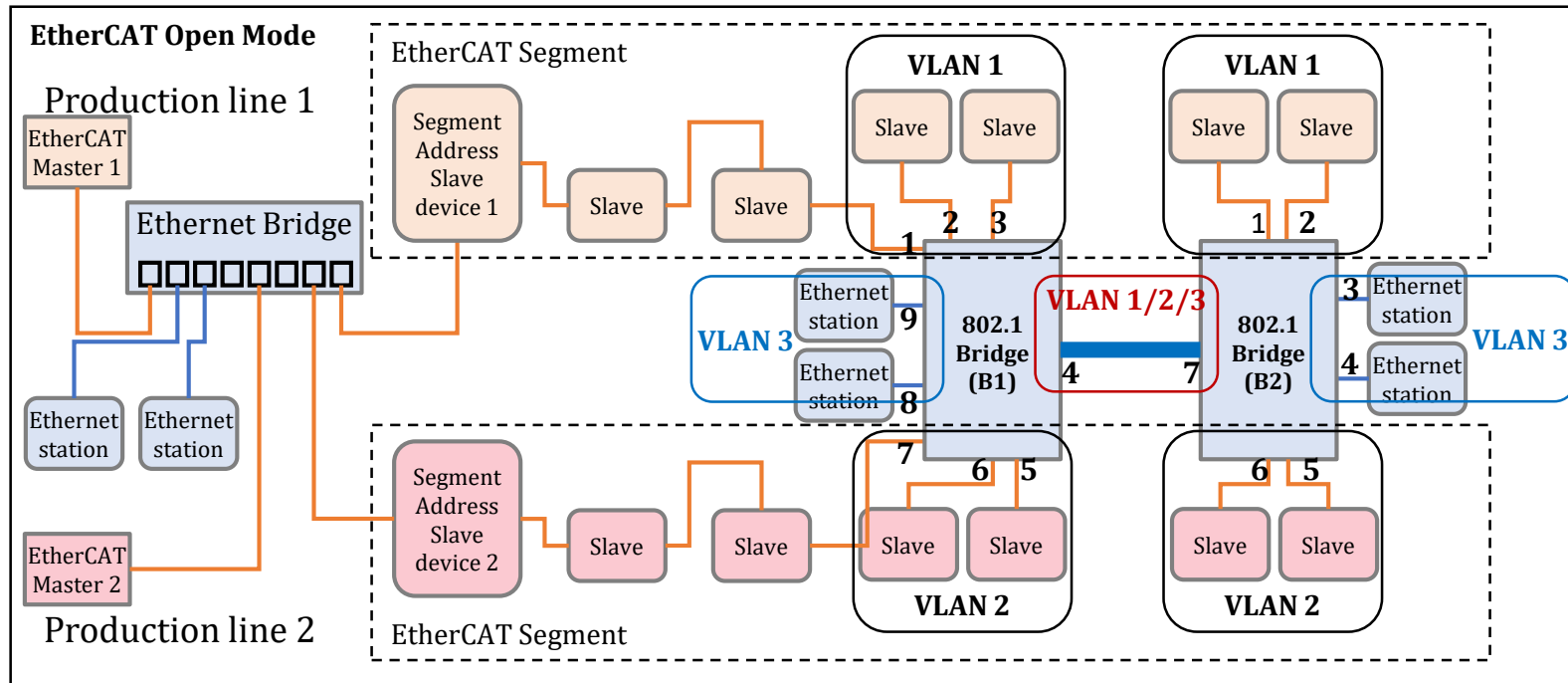


Forward the EtherCAT Frame to Specific Port



Identify the Next Slave Device of the Current Production Line in EtherCAT Open Mode

- Set 3 VLANs for 802.1 bridges B1 & B2
 - ❑ Set the ports connecting production line 1 devices into VLAN 1 as access type
 - ❑ Set the ports connecting production line 2 devices into VLAN 2 as access type
 - ❑ Set the ports connecting Ethernet stations into VLAN 3 as access type
 - ❑ Set the ports inter-connecting the 802.1 Bridges into VLAN 1 / 2 / 3 as trunk type
- The frames received from the port connecting to production line devices will be forwarded to next port as the right table.

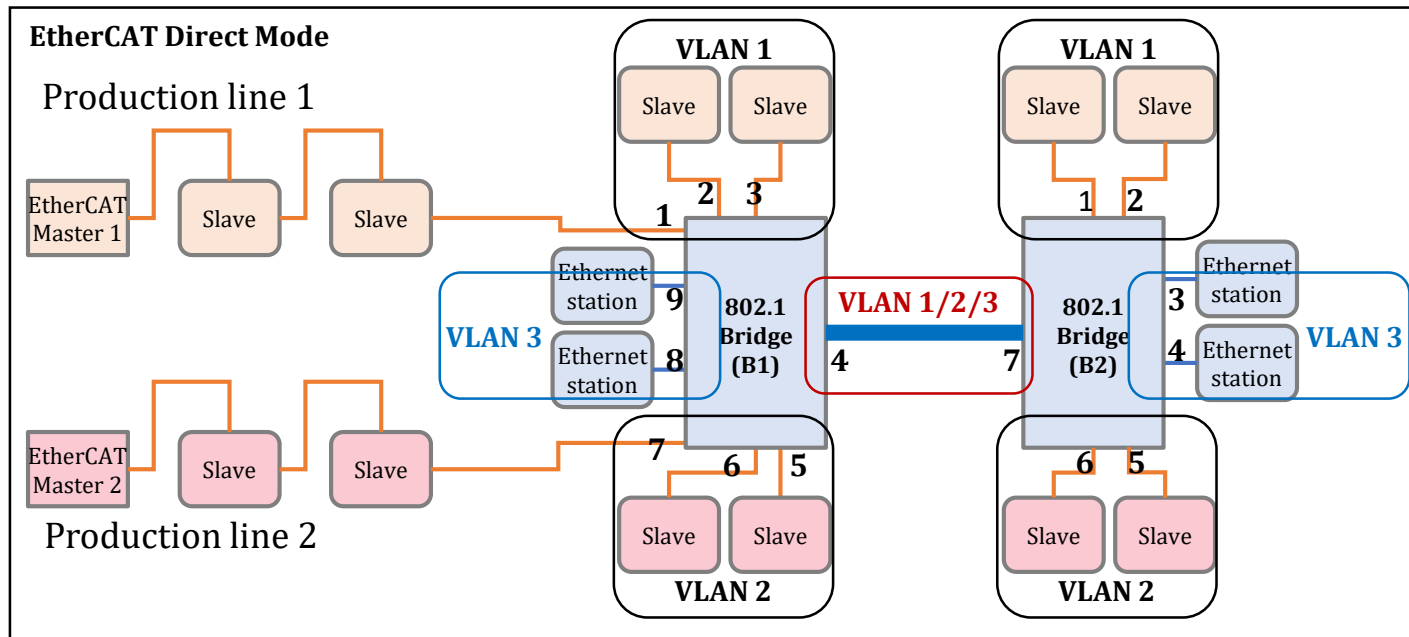


Bridge	Frames Received from	Frames Tagged VLAN	DA of Frames	Frames Forwarded to Port
B1	Port 1	VLAN1	Master 1	Port 2
	Port 2	VLAN1	Master 1	Port 3
	Port 3	VLAN1	Master 1	Port 4
	Port 4	VLAN1	Master 1	Port 1
	Port 7	VLAN2	Master 2	Port 6
	Port 6	VLAN2	Master 2	Port 5
	Port 5	VLAN2	Master 2	Port 4
	Port 4	VLAN2	Master 2	Port 7
	Port 4	VLAN3	N/A	According to DA
Port 8	VLAN3			
Port 9	VLAN3			
B2	Port 7	VLAN1	Master 1	Port 1
	Port 1	VLAN1	Master 1	Port 2
	Port 2	VLAN1	Master 1	Port 7
	Port 7	VLAN2	Master 2	Port 6
	Port 6	VLAN2	Master 2	Port 5
	Port 5	VLAN2	Master 2	Port 7
	Port 7	VLAN3	N/A	According to DA
	Port 3	VLAN3		
	Port 4	VLAN3		

The table background color represents the frame type corresponding to the figure left.

Identify the next slave device of the current production line in EtherCAT Direct Mode

- Set 3 VLANs for 802.1 bridges B1 & B2
 - ❑ Set the ports connecting production line 1 devices into VLAN 1 as access type
 - ❑ Set the ports connecting production line 2 devices into VLAN 2 as access type
 - ❑ Set the ports connecting Ethernet stations into VLAN 3 as access type
 - ❑ Set the ports inter-connecting the 802.1 Bridges into VLAN 1 / 2 / 3 as trunk type
- The frames received from the port connecting to production line devices will be forwarded to next port as the right table.



Bridge	Frames Received from	Frames Tagged VLAN	DA of Frames	Frames Forwarded to Port
B1	Port 1	VLAN1	Master 1	Port 2
	Port 2	VLAN1	Master 1	Port 3
	Port 3	VLAN1	Master 1	Port 4
	Port 4	VLAN1	Master 1	Port 1
	Port 7	VLAN2	Master 2	Port 6
	Port 6	VLAN2	Master 2	Port 5
	Port 5	VLAN2	Master 2	Port 4
	Port 4	VLAN2	Master 2	Port 7
	Port 4	VLAN3	N/A	According to DA
B2	Port 7	VLAN1	Master 1	Port 1
	Port 1	VLAN1	Master 1	Port 2
	Port 2	VLAN1	Master 1	Port 7
	Port 7	VLAN2	Master 2	Port 6
	Port 6	VLAN2	Master 2	Port 5
	Port 5	VLAN2	Master 2	Port 7
	Port 7	VLAN3	N/A	According to DA
	Port 3	VLAN3	N/A	According to DA
	Port 4	VLAN3	N/A	According to DA

The table background color represents the frame type corresponding to the figure left.

The Main Latency Related with 802.1 Bridges

➤ The main latency related with 802.1 bridges includes three parts:

1. Forwarding latency

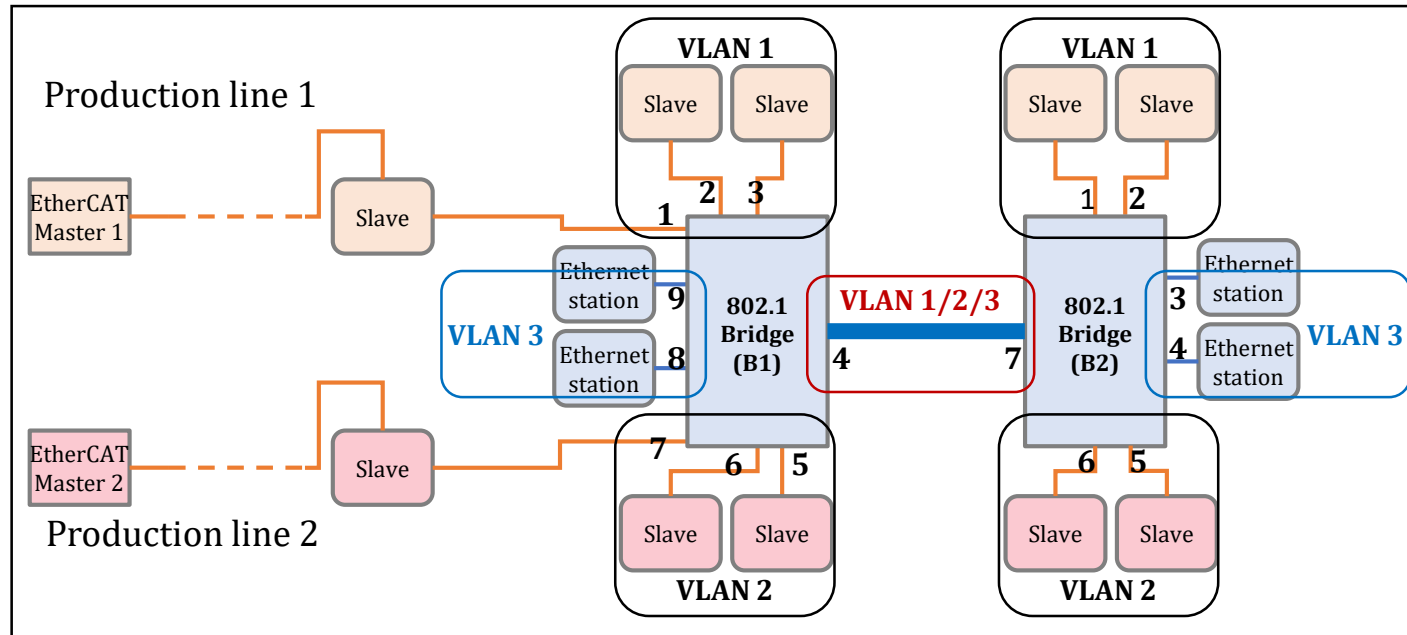
- ✓ The delay to query the specific table get the egress port via ingress port & VLAN ID, it's fixed delay and hard to reduce.
- ✓ The delay to forward the frame to egress port, it's possible to reduce the delay via cut-through forwarding.

2. Schedule latency (mixed inter-link between 802.1 bridges)

- ✓ The streams from different EtherCAT master will be mix-transferred in the inter-link, so it's should be orchestrated based on application cycle, inter-link bandwidth and application frame size, and to avoid frame lost and get the bounded latency.
- ✓ The send queue for the egress port of the inter-link should be scheduled according to the orchestration results.

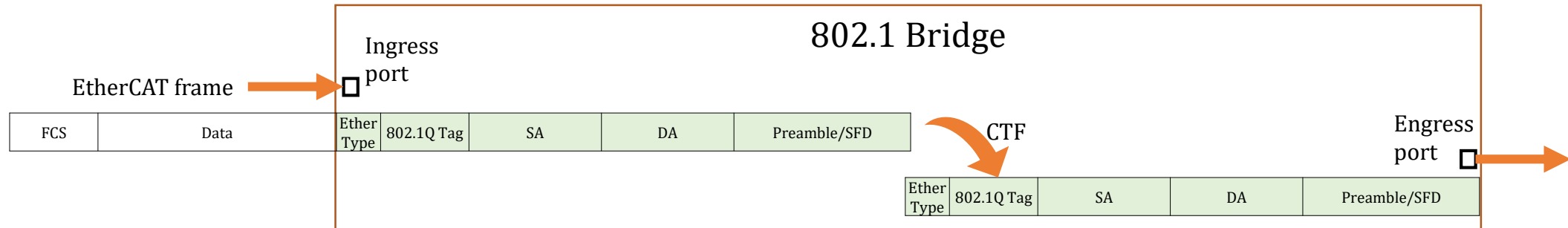
3. Interface / cable latency

- ✓ The latency is related with rate of interfaces and the corresponding interface connected. It's fixed delay and hard to reduce.



Cut-Through Forwarding to Reduce Forwarding Delay

- In order to minimize the forwarding delay, it's necessary to apply the cut-through forwarding.
- As for EtherCAT open mode or direct mode, it's necessary to get a common mechanism to query the table to get the egress port, and then trigger the cut-through forwarding immediately.
- The 802.1 bridges are configured to indicate that the EtherCAT frame from each ingress port will be forward to specific egress port, according to this forwarding rule configured, the cut-through forwarding could be applied.



➤ Next step

- ❑ Refine the forwarding table configure & common query mechanism to support the CTF.

Orchestrate to Achieve Bounded Latency

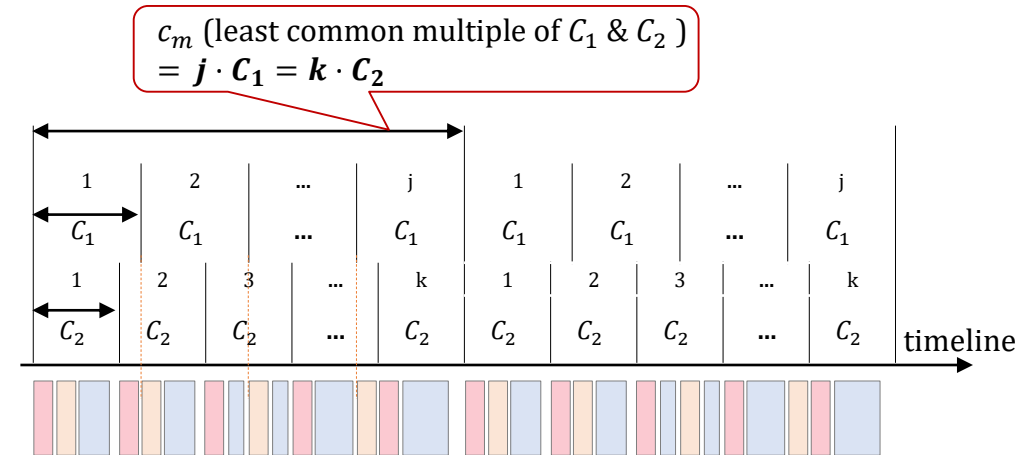
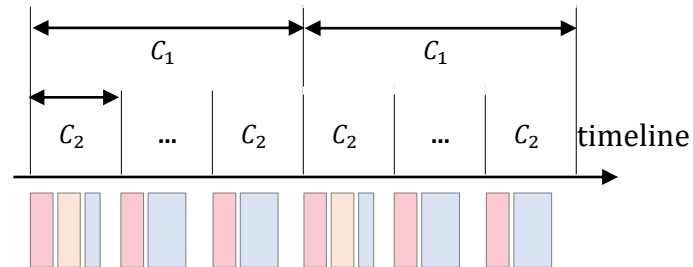
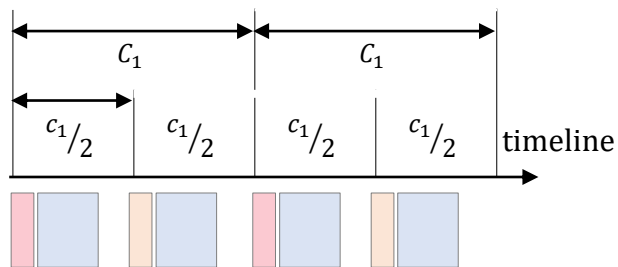
- Based on the clock synchronization to two production lines and the 802.1 bridges, the frames from EtherCAT master 1 / EtherCAT master 2 and the Ethernet stations will be mix-forwarded in the inter-link between the 802.1 bridges.
 - ❑ The inter-connection bandwidth between the 802.1 bridges should be evaluated according the EtherCAT frame size and application cycle.
 - ❑ The transfer delay from the EtherCAT master to 802.1 bridges should be evaluated based on the frame size and bandwidth.
 - ❑ All these parameters and evaluation results will be input as per 802.1Qbv, and orchestrate the streams to get the specific timeline.
 - ❑ Along the whole routine, the EtherCAT frames should be sent to and arrived at the nodes (slave devices or 802.1 bridges) as per the timeline.
 - ❑ Even if the frames of the two EtherCAT masters arrive at the egress port of inter-link simultaneously, one of them has to be delayed as the timeline.

• $C_1 = \text{Cycle of EtherCAT master 1}, C_2 = \text{Cycle of EtherCAT master 2}, C_1 \geq C_2$

1. $C_1 = C_2$

2. $C_1 = nC_2$ ($n > 1$ is an integer)

3. $C_1 = mC_2$ ($m > 1$ is not an integer)



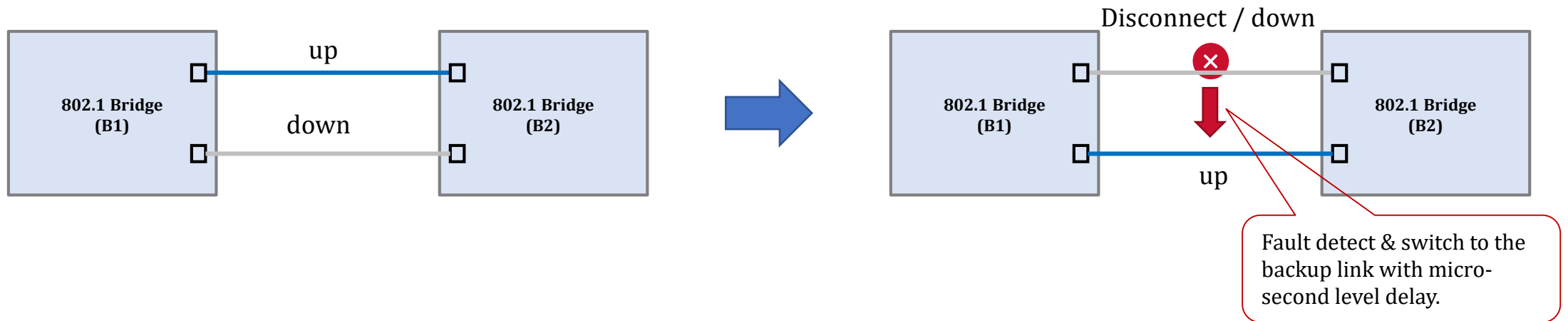
Frames from EtherCAT Master 1

Frames from EtherCAT Master 2

Frames from Ethernet Stations

High Reliability of the Inter-Connection between the 802.1 Bridges

- According to EtherCAT application cycle requirements, the inter-link between the 802.1 bridges should support , micro-second level to detect and notify the STP to switch to the backup link.
- Next step:
 - ❑ To study the possible high reliability solution according to EtherCAT application requirements.



Thank you.

Proposal for Nendica Study Item

- For Nendica to initiate a study item on **Forwarding of Fieldbus CPF 12 on 802.1 Bridges**

To be studied	<ul style="list-style-type: none">• Detail use case and practical requirements for intermixed EtherCAT and Ethernet forwarding• Feasibility of operation• Impact on functionality, including latency, compared to independent networks• Feasibility of assuring QoS for EtherCAT and Ethernet• This study item excludes aspects that are covered by project IEC/IEEE 60802
Deliverable	<p>An informal report documenting</p> <ul style="list-style-type: none">• Summary requirements according to industrial scenarios• Potential benefits• Summary of feasibility issues• Impact & optimization of evolving technologies• Possible standardization needs• Possible recommendation to initiate a work item
Leader	<ul style="list-style-type: none">• Huajie Bao (Huawei), or other volunteers
Timeline	<ul style="list-style-type: none">• Start in June 2022, finish in Nov 2022• Draft version Aug 2022• Call for comments Sept 2022• Complete Study Item Report Nov 2022
Work schema	<ul style="list-style-type: none">• Weekly meeting or on-demand meeting• Encourage all contributions• Provide ongoing reporting to IEC/IEEE 60802

Extension Use Case based on New Switch According to EtherCAT Open Mode & Direct Mode

