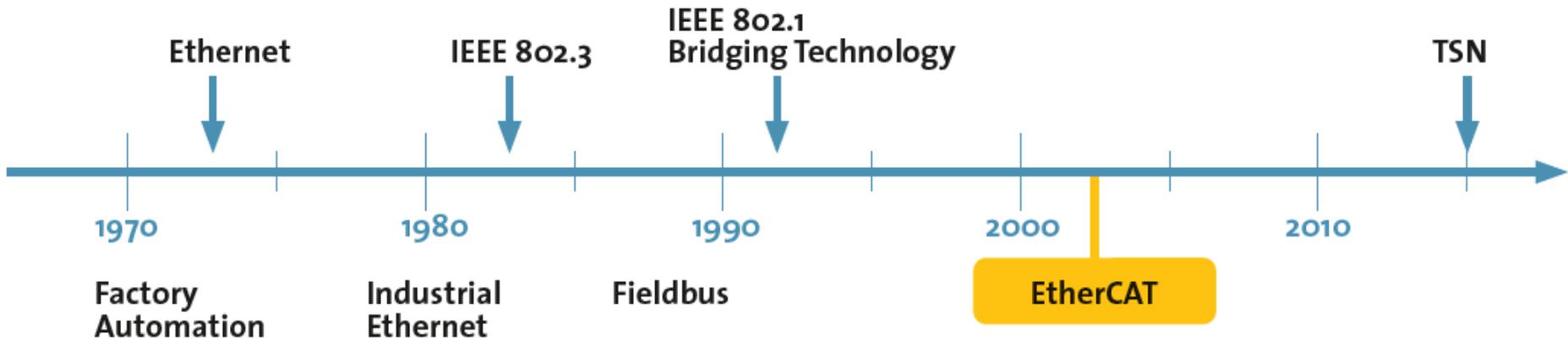


What is TSN – Time Sensitive Networking?



- Ethernet with switches
 - **best effort** approach
 - Use case: work stations, PCs
- **Use cases** with real-time requirements
 - Audio/ Video, Mobile Base Stations, Automotive, Automation, ...
- New approach for switching: TSN – **Time Sensitive Networking** allows combination with best effort traffic (if bandwidth is high enough)



- Many different standards

1. 802.1Qbu
2. 802.1Qbv
3. 802.1Qca
4. 802.1CB
5. 802.1Qcc
6. 802.1AS-REV
7. 802.1Qch
8. 802.1Qci
9. 802.1Qcj
10. 802.1CM
11. 802.1Qcp
12. 802.1Qcr
13. 802.1CS
- 14ff.

addressing different problems

“**tool box**” of different features

User has to choose “tools”



Standard	Title	Status	
IEEE 802.1AS-Rev	Timing and Synchronization for Time-Sensitive Applications	Performance improvement, support of multiple time domains and redundancy included. Can synchronize Layer 3 networks. (2019)	W
IEEE 802.1Qbu	Frame Preemption	Use of Ethernet Mechanism, requires new MAC	P
IEEE 802.1Qbv	Enhancements for Scheduled Traffic	So called Time Aware Shaper (TAS) = mainstream technology.	P
IEEE 802.1Qca	Path Control and Reservation	Not longer in scope as too much data and service interaction needed to specify a schedule	P
IEEE 802.1CB	Frame Replication and Elimination for Reliability (Seamless Redundancy)	Support of seamless media redundancy. Allows multiple paths for streams.	P
IEEE 802.1Qcc	Stream Reservation Protocol (SRP) Enhancements and Performance Improvements	SRP is not suited to run a schedule with several hundreds of streams. New config model selected as a result. (2017?)	S
IEEE 802.1Qch	Cyclic Queuing and Forwarding	Streams received in previous cycle forwarded in next cycle	P
IEEE 802.1Qci	Per-Stream Filtering and Policing	Packets accepted if the port-, time- and rate-constraints met	P
IEEE 802.1CM	Time-Sensitive Networking for Fronthaul	Telecom TSN profile	W
IEEE 802.1Qcr	Asynchronous Traffic Shaping	Shaper that operates on non synchronized streams	T
IEEE 802.1Qcp	802.1Q YANG data model	Provider bridging configuration using LLDP	W
IEEE 802.1Qcj	Auto Attach to PBB	Needed for .1Qcc services. YANG textual encoding should replace MIB/SNMP. (2019)	T
IEEE 802.1CS	LRP (new link-local registration protocol)	Procedures to replicate a registration database and changes to parts from one end to the other of a point-to-point link. (2021)	T

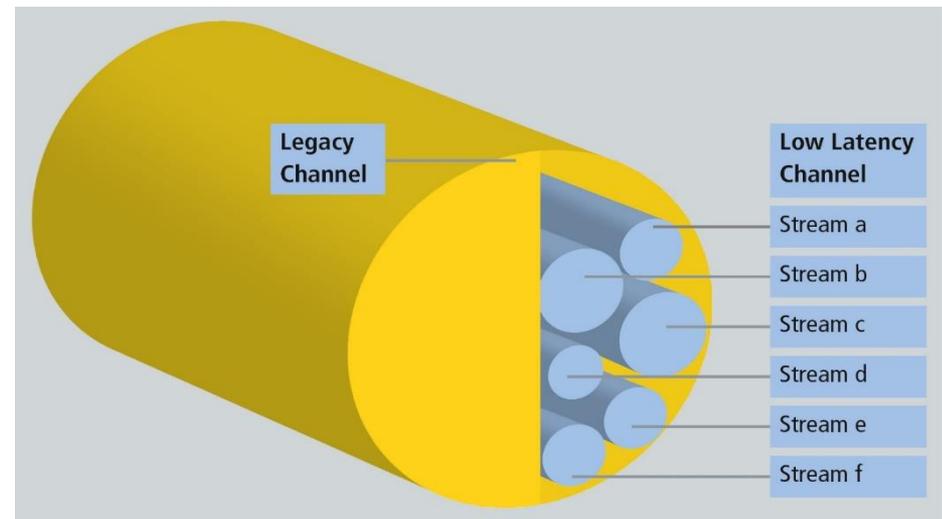
E=EditorDraft, T=TSNballot, W=802.1ballot, S=sponsorBallot, R=RevCom, P=published

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Several parts released: **P = published**

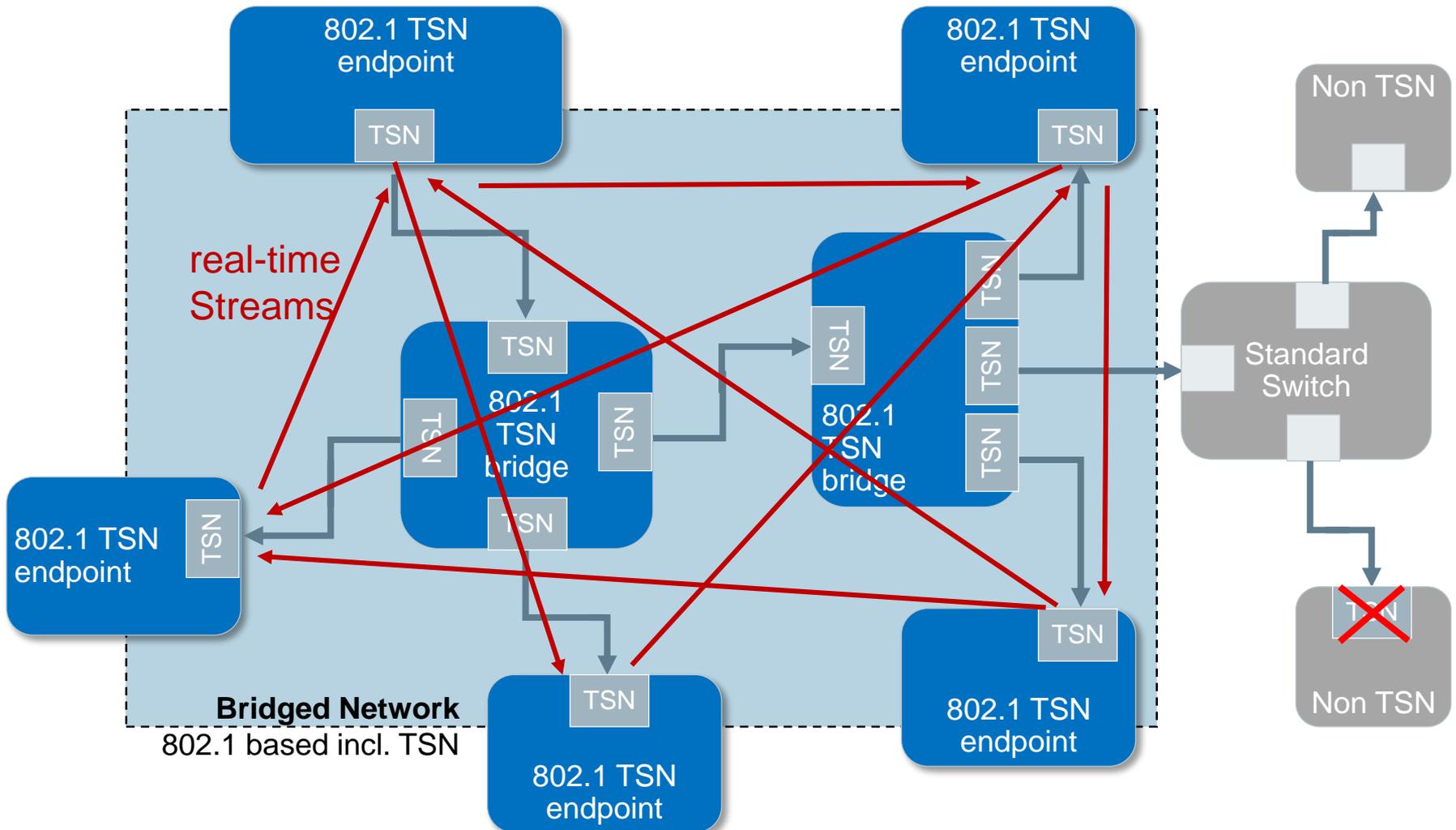
- TSN is a paradigm shift in the IEEE 802 world
 - Addresses **real time needs** of various industries
 - Moving away from the best effort approach
 - Forward frames as fast as possible in the IEEE802.1 context
 - Without losses due to congestion (reservation calculates buffers)

- Part of the bandwidth is reserved for **time sensitive streams**
- Other part of bandwidth remains for legacy traffic (higher frame drop rate, possibly higher delays)



→ TSN intends to reserve a fraction of the bandwidth for time sensitive traffic

Real time streams within TSN network – non-TSN devices can be connected outside



- TSN communication is done by so called **streams**
- IEEE 802.1 standard terms
 - “**Talker**” = the sender of a stream
 - “**Listener**” = the receiver of a stream
- A stream is an **unidirectional** flow of data from a talker to one or more listeners
- A stream transmits a **number of frames** with a **number of data bytes** within a given **interval**

TSN: set of standards relevant for Streaming with EtherCAT

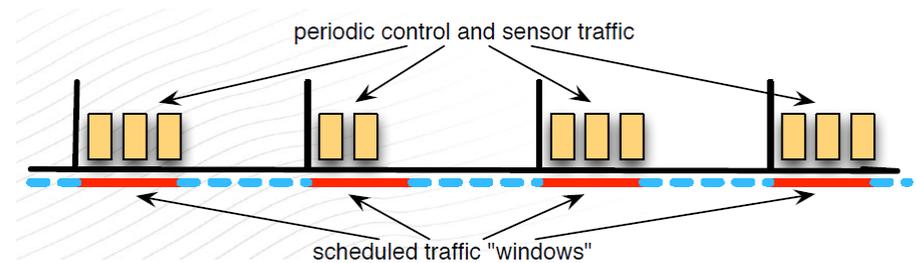
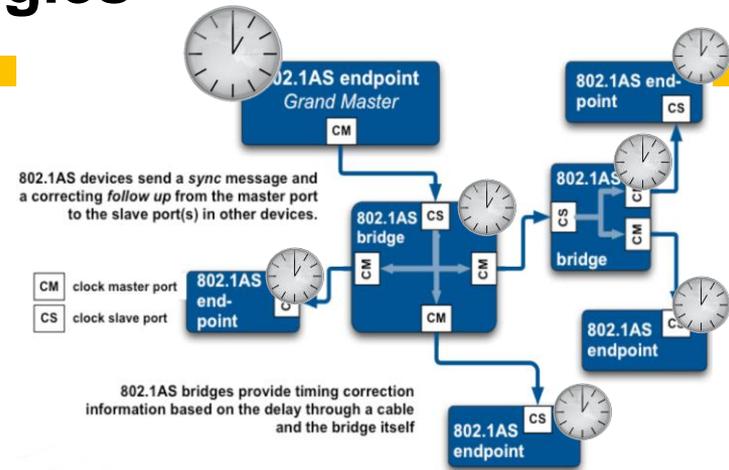
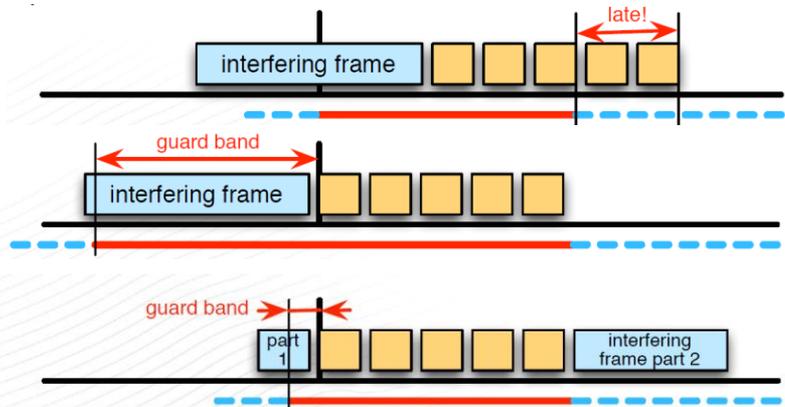
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- IEEE 802.1AS-REV Time Synchronization
 - Profile of 1588

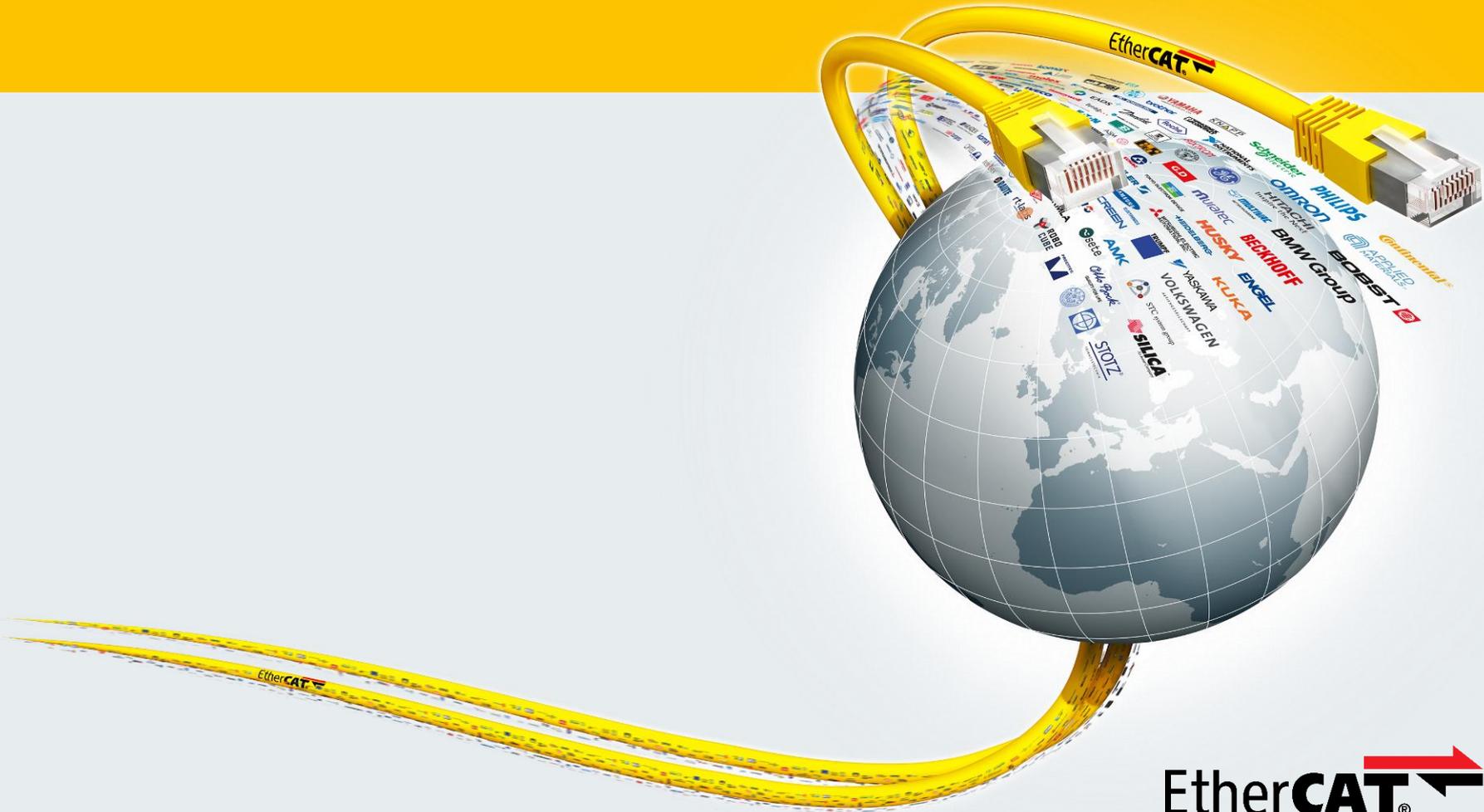
- IEEE 802.1Qbv: Scheduled Traffic Windows

- “Time Aware Shaper” TAS
- Interfering frames before start of time-sensitive time period
→ guard band



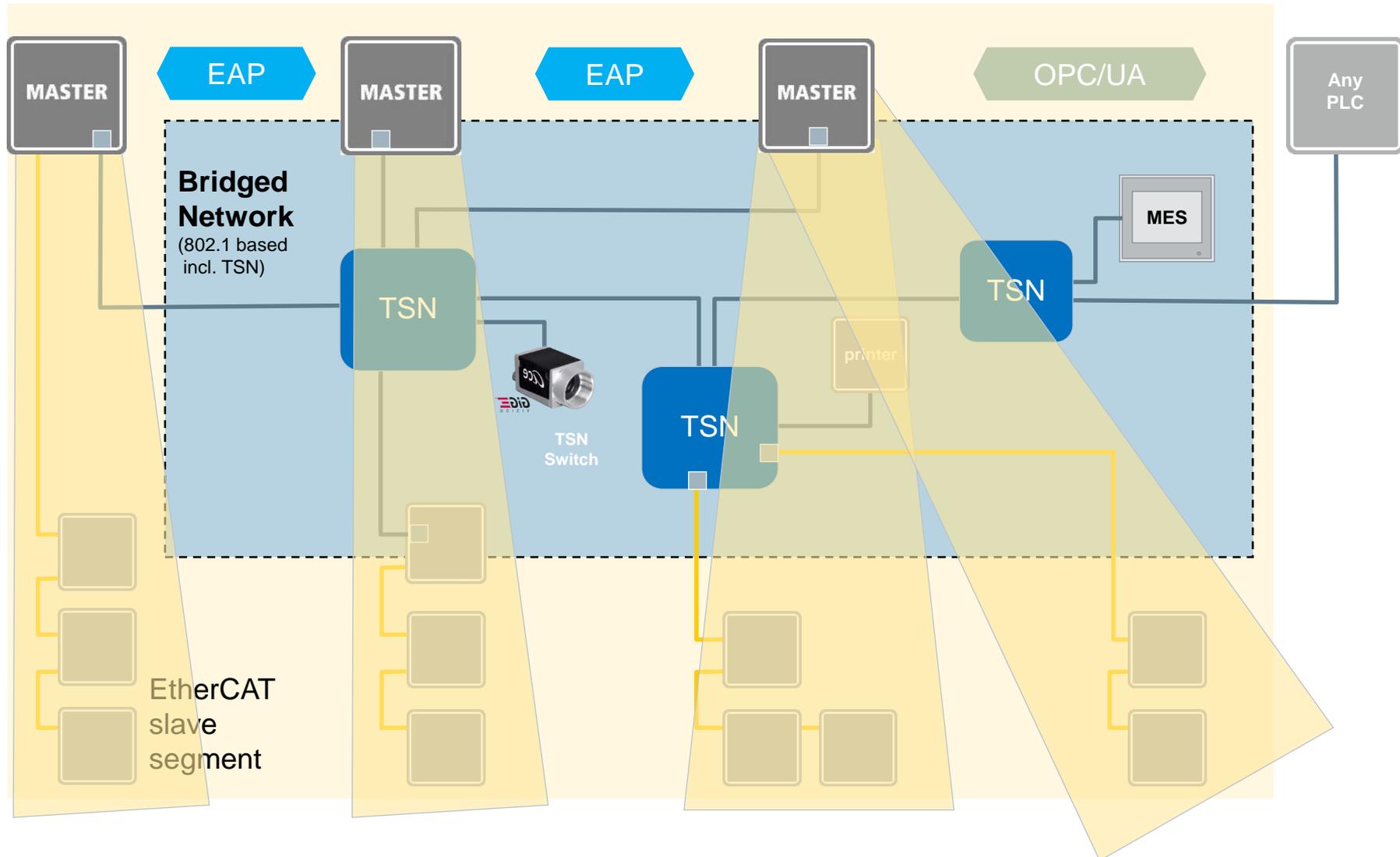
- IEEE 802.1Qbu: Frame Pre-emption
 - Reduces guard band

EtherCAT and TSN

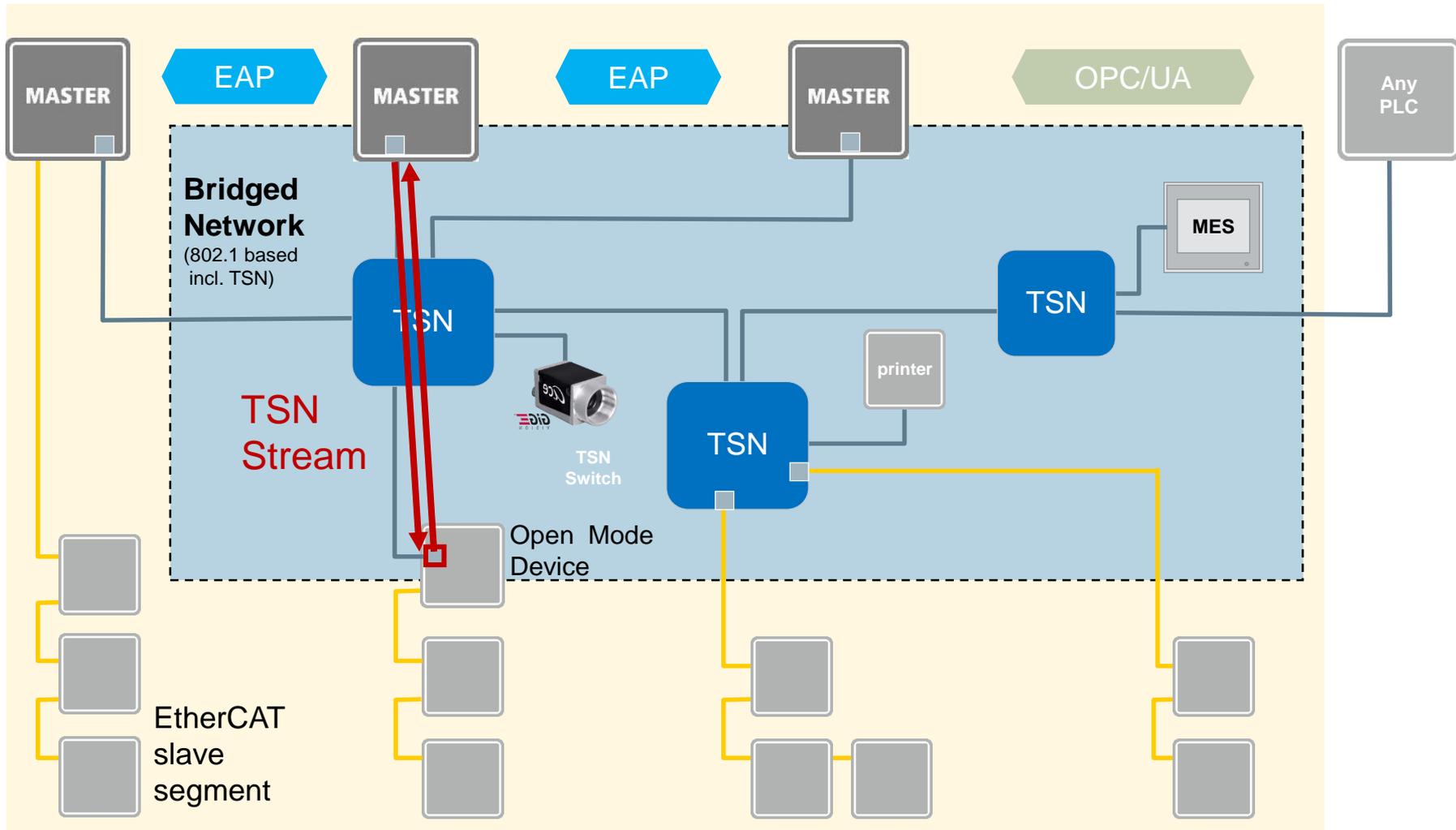


- EtherCAT master and EtherCAT segment connected **via heterogeneous switch-based** network
- Improve real-time capabilities of **EAP** in switched-based networks

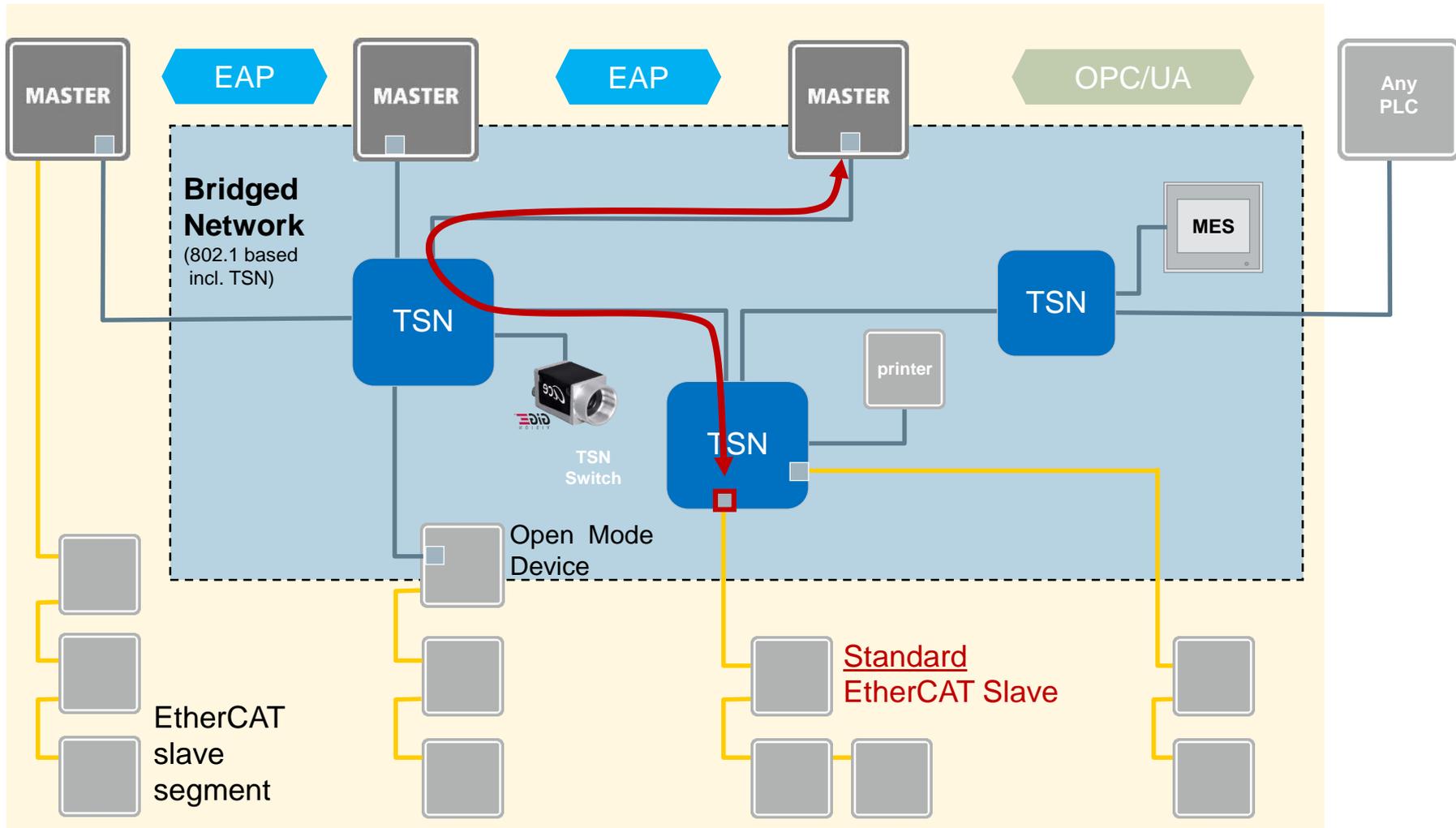
TSN network between master and EtherCAT segment



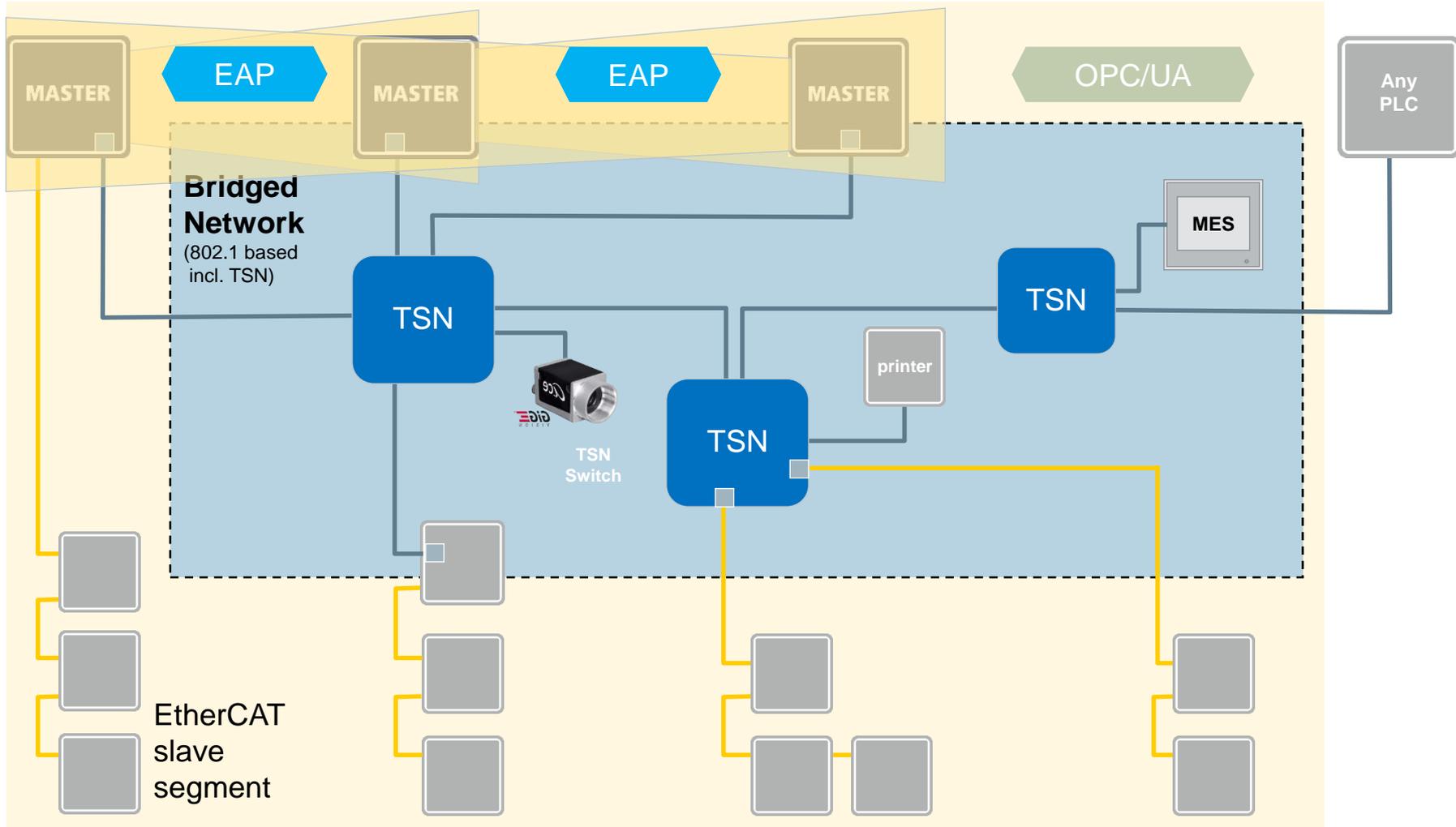
Adaptation of **TSN stream** to EtherCAT segment in first EtherCAT slave



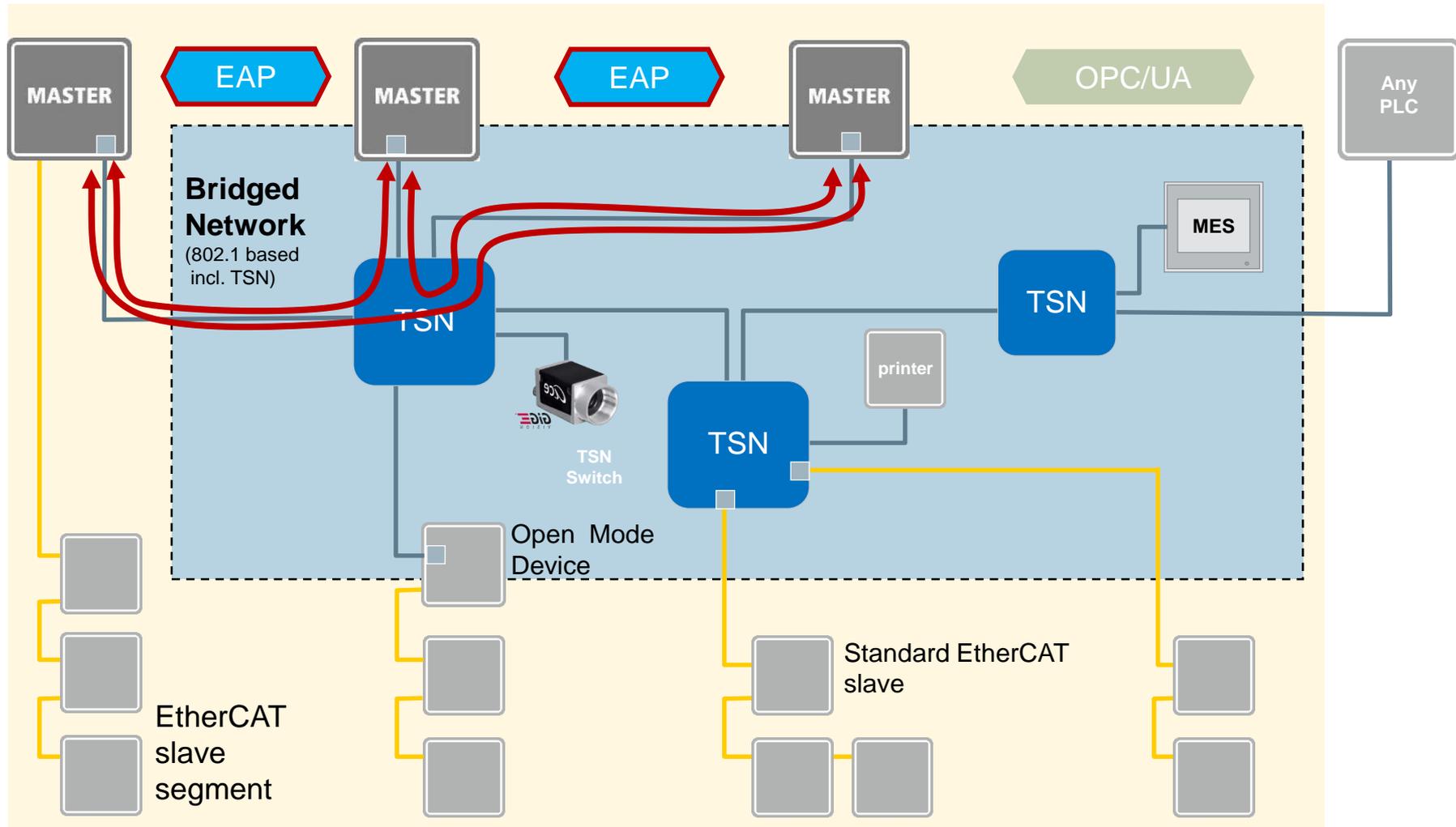
Adaptation of TSN stream to EtherCAT segment in Switch



TSN network between EtherCAT Masters



EAP transferred on TSN-enhanced 802.1 network



- ETG defines **profile specification** for usage of EtherCAT with TSN with focus on
 - Time based sending
 - Synchronization
- **Adaptation** of TSN streams to EtherCAT segment
- Includes
 - **Handling of MAC** addresses
 - **Synchronizing** .AS and DC time
 - Set (VLAN) Identifier as base for unique **Stream addresses**
 - Can be either feature of **switch** or of EtherCAT **device** (1st device)

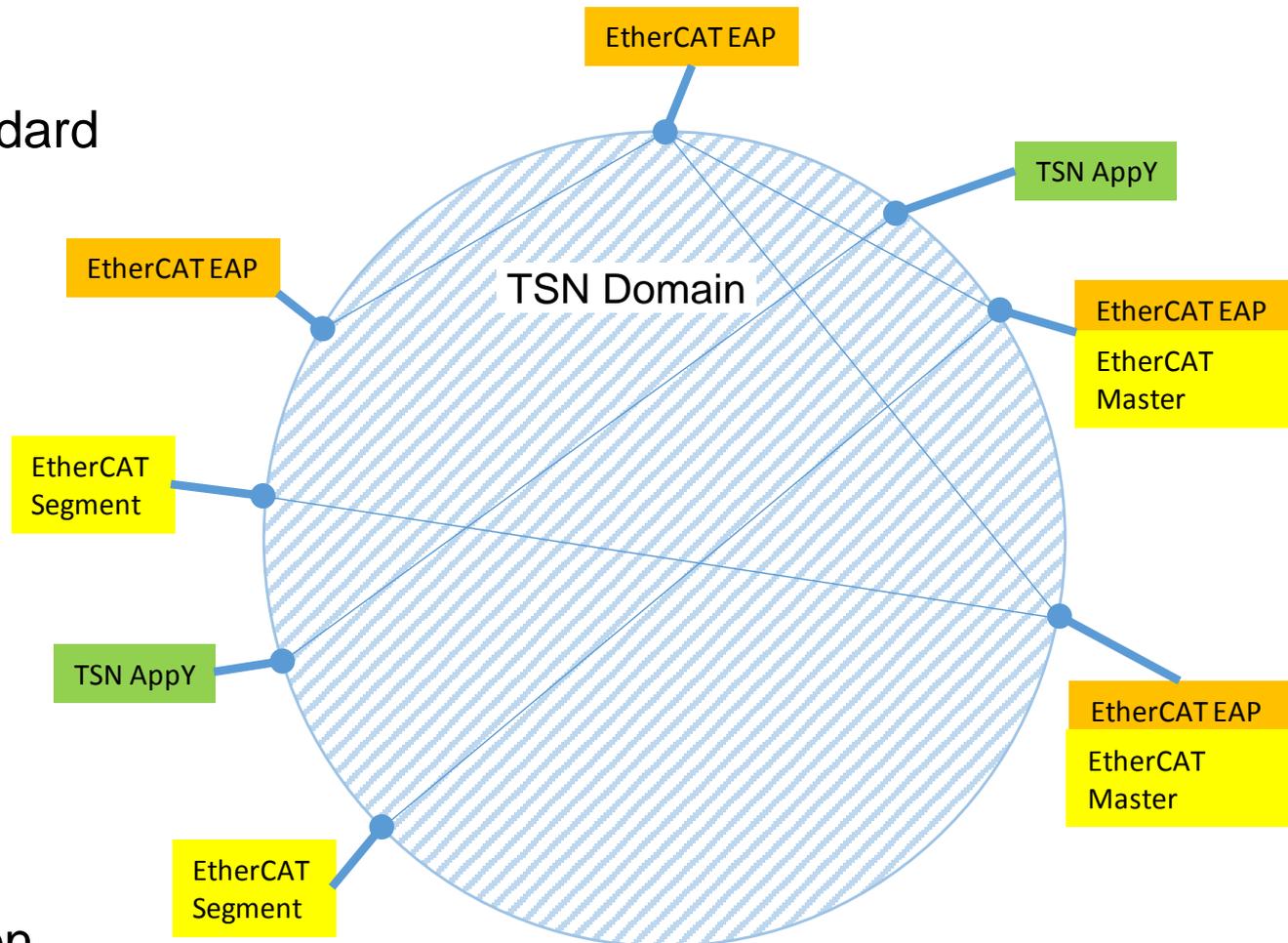
- References

- EtherCAT standard
- TSN standard

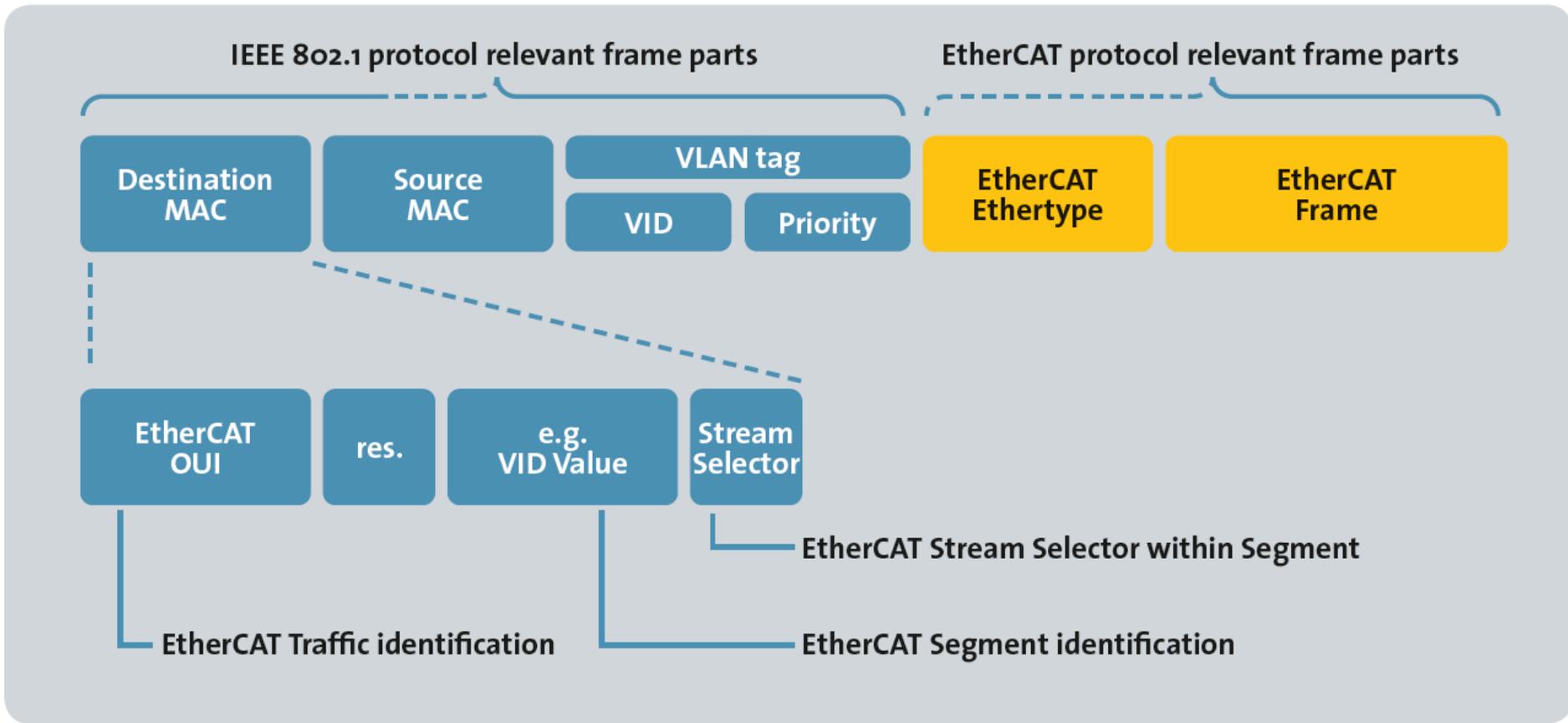
- Compatibility with other TSN Profiles

- Specifies adaptation

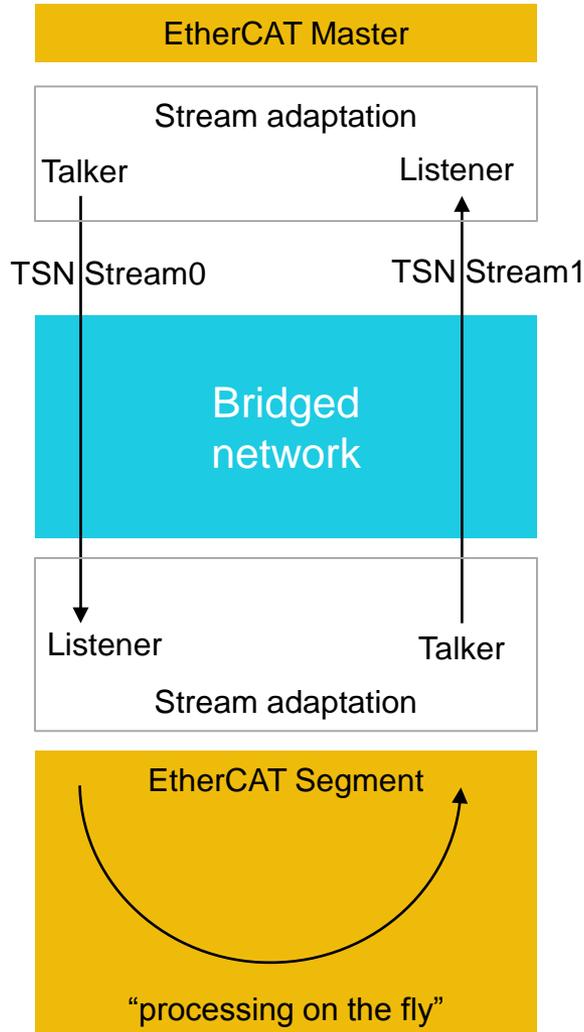
- Defines **how** to use standards – but **not** a new protocol
- Specifies **a generic interface** to TSN “tool box” (not a specific protocol)



Not a new protocol: Separate protocol fields

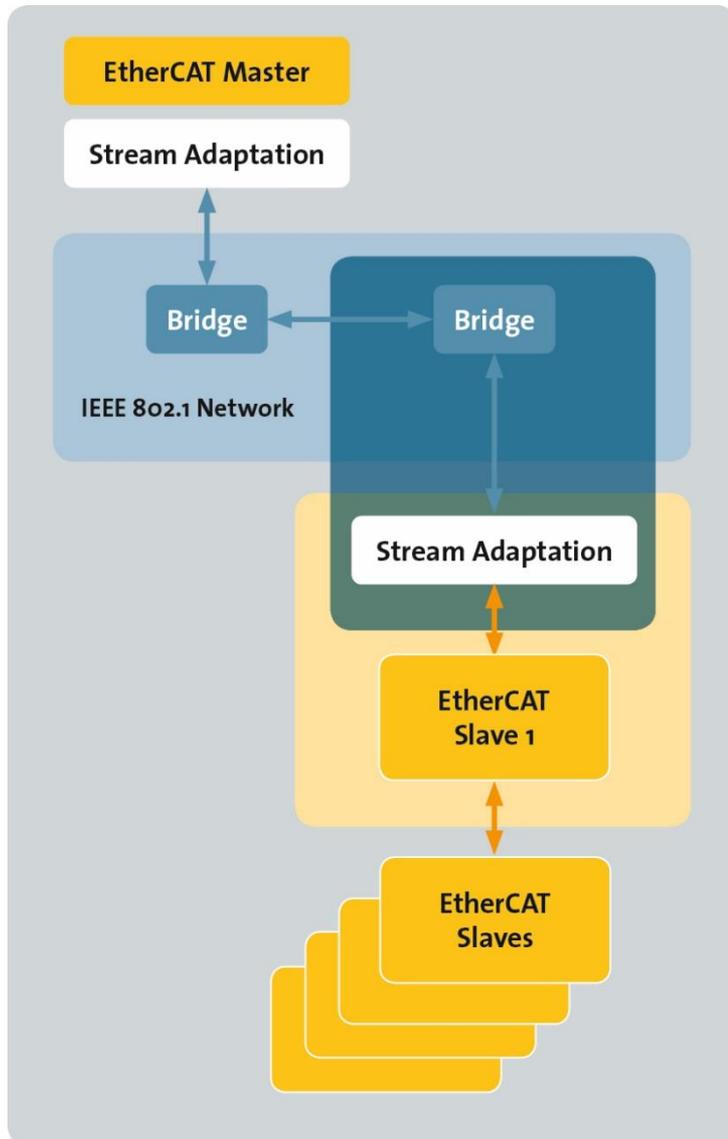


Stream Adaptation: Details



- Always a pair of streams is set up
- Minimum one pair, but more might be set up, e.g.
 - One for cyclic
 - One for acyclic (strict priority)
 - for additional transfers
- Traffic class for pair of stream always the same
- Maintain Traffic Class (VLAN Prio)
- Maintain length (EtherCAT Rx/TX frame length identical)

Adaptation provides virtual Ethernet channel



- Adaptation maps TSN stream to EtherCAT frame
- Adaptation is hardware independent
- Adaptation on
 - Master
 - Switch or first EtherCAT slave

- Slave
 - No change to EtherCAT implementations required
- Master
 - **Lean** stream **adaptation**
 - **Only TSN synchronization and stream announcement** required
 - Optional: Multiplexing Layer to connect multiple (TSN) functions or segments → multiple applications connected to one (GBit/s) port

EtherCAT TSN Adaptation can be done on either:

- Switch
 - incl. TSN features: IEEE802.1.AS/ .Qbu/.Qbv /...
- specific component between TSN network and EtherCAT segment

ETG is actively participating in the TSN Working Groups:
Dr. Karl Weber is an active member of IEEE 802.1



5.: 199 - 101, Dresden, Germany, May 2006.

3. Intiaz, Jahanzaib; Jasperneite, Jürgen; **Weber, Karl**: Approaches to reduce the Latency for High Priority Traffic in **IEEE 802.1 AVB Networks**. In: 9th **IEEE International Workshop on Factory Communication Systems (WFCS 2012)** Lemgo, Germany, May 2012.

4. Intiaz, Jahanzaib; Jasperneite, Jürgen: Performance impacts of different models. **IEEE 802.1 AVB Task Group Real Time communication Symposium**, Munich, Germany, Jan 2012.

5. Intiaz, Jahanzaib; Jasperneite, Jürgen; Schriegel, Sebastian: A Proposal to Integrate Process Data Communication to **IEEE 802.1 Audio Video Bridging (AVB)**. In: 16th **IEEE International Conference on Emerging Technologies and Factory Automation (ETFA 2011)** Toulouse, France, Sep 2011.

6. Goetz, Franz-Josef; **Weber, Karl**: Reduction of Impacts of Stream Latency. In: **IEEE 802.1 AVB Task Group Interim Meeting**, USA, May 2011, May 2011.

7. Jasperneite, Jürgen; **Weber, Karl**: Redundant Structures for a Factory Automation and Factory Automation, Bilbao, Spain Sep 2010.

8. Wisniewski, Lukasz; Jasperneite, Jürgen; **Weber, Karl**: A Forwarding Policy for a Generic Real-time Ethernet System. In: **International Workshop on Factory Communication Systems (WFCS 2010)** Nancy, France, May 2010.

EtherCAT[®] Technology Group

ETG Team Worldwide

May 2017

ETG Liaison, (technical) coordinated with IEEE 802.1

- Close cooperation of ETG and IEEE 802.1 working group for technical coordination
- Grants access to IEEE 802.1 documents working documents even if those are not yet released
- Ensures that TSN standards can be referenced within the ETG Profile specification in the right manner and as an early adaptation.
- Ensures access for all ETG members to related TSN documents for ETG profile review



available

- EtherCAT matches perfectly well with TSN Streams – EtherCAT segments can be updated with **one single EtherCAT frame**
- TSN offers real-time for **heterogeneous** networks
- EtherCAT offers fieldbus benefits
 - **Highest performance**
 - Complete **semantic** concept
 - Device **profiles**
 - Easy network configuration
 - Diagnosis

No replacement of each other - combine mutual benefits

If you have the choice, take both!

Stream adaptation uses **TSN** without modification!

+

Stream adaptation uses **EtherCAT** without modification!

- Whitepaper: EtherCAT and TSN – Best Practices for Industrial Ethernet System Architectures
[Download](#)
- Presentation: Layering with TSN and EtherCAT
[Download](#)
- Specification: ETG.1700 EtherCAT TSN Communication Profile
[Download](#)



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