

Introduction to IEEE 802.1

Focus on the Time-Sensitive Networking Task Group

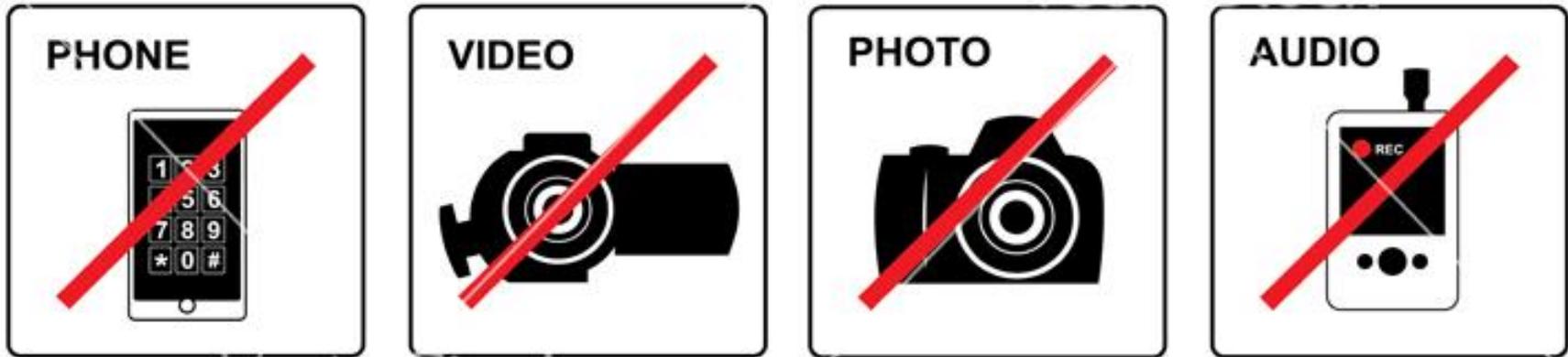
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March 5, 2018

Welcome!

Before We Start – Decorum



- › Press (i.e., anyone reporting publicly on this meeting) are to announce their presence (SASB Ops Manual 5.3.3.5)
- › Photography or recording by permission only (SASB Ops Manual 5.3.3.4)
- › Cell phone ringers off please

Before We Start – Security Issues

- › **Please wear your badge** when in the meeting areas of the hotel
- › This will help the hotel security staff to improve the general security of the meeting rooms
- › **PCs HAVE BEEN STOLEN** at previous meetings – **DO NOT** assume that meeting areas are secure

Before We Start – Patent Slides & Participation

- › <http://standards.ieee.org/about/sasb/patcom/materials.html>
- › <https://mentor.ieee.org/802-ec/dcn/17/ec-17-0093-05-0PNP-ieee-802-participation-slide-ppt.ppt>

Before We Start

- › This presentation should be considered as the personal views of the presenter/author not as a formal position, explanation, or interpretation of IEEE 802.1.

Let's get started!

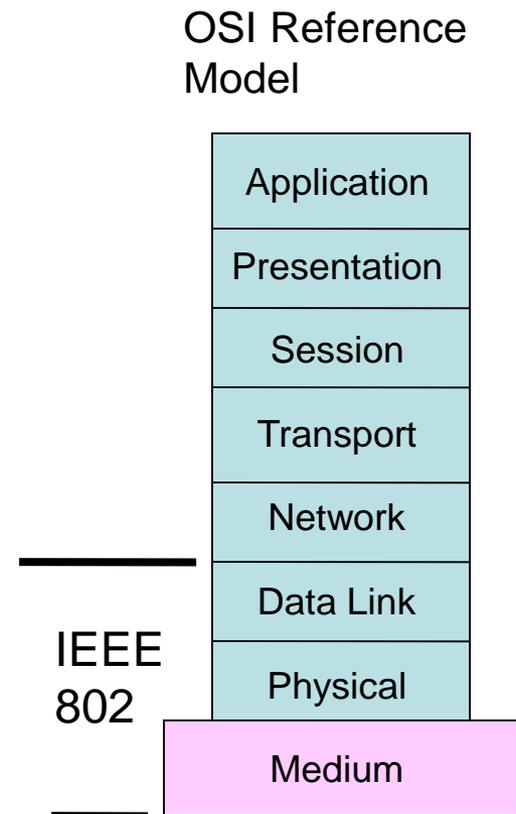
Agenda

- › IEEE 802.1 Overview
- › IEEE 802.1 Time-Sensitive Networking (TSN)
 - Audio Video Bridging (AVB) and TSN
 - AVB standards
 - TSN standards
 - TSN projects
- › Background
 - Bridge architecture

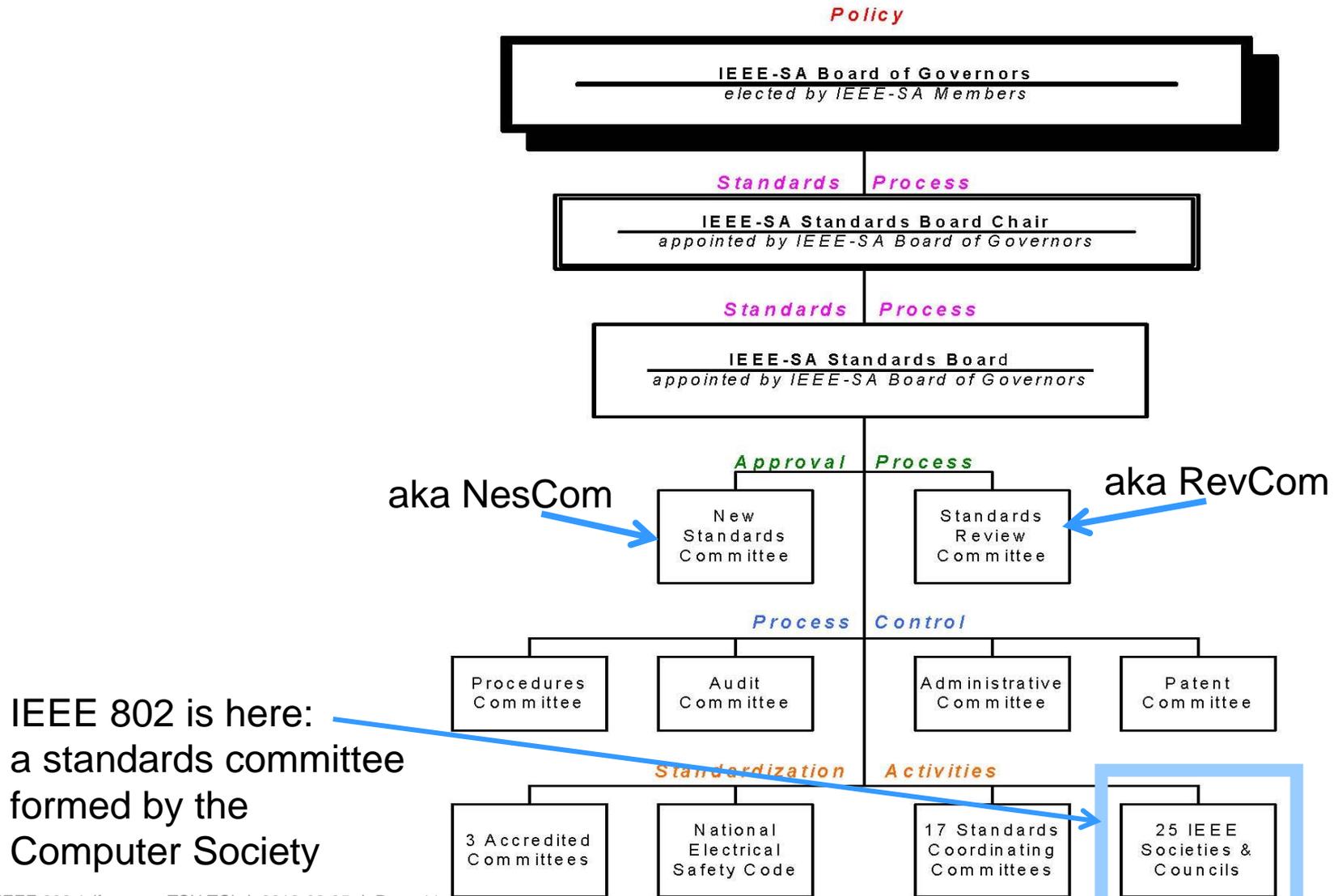
IEEE 802.1 Overview

IEEE 802 LAN/MAN Standards Committee (aka IEEE 802 or LMSC)

- › Develop LAN and MAN standards
- › Mainly for link and physical layers of the network stack
- › In operation since March 1980



IEEE Standards Organization



Some Terms

- › PAR – Project Authorization Request – the document that authorizes work on a project.
- › CSD – Criteria for Standards Development – the basis for determining whether to forward a PAR.
- › WG – Working Group – responsible for developing standards in an area
- › TAG – Technical Advisory Group – experts on a topic area that crosses working groups – may develop a recommended practice.
- › Task Group (TG) or task force – a part of a Working Group which focuses on a particular subject.

All Those Dots

- › 802.1 Bridging and Architecture
 - generally the top of the link layer
- › 802.3 Ethernet
- › 802.11 Wireless LAN (WLAN)
- › 802.15 Wireless Personal Area Network (WPAN)
- › 802.16 Broadband Wireless Access (BWA)
- › 802.18 Radio Regulatory TAG
- › 802.19 Coexistence TAG
- › 802.21 Media Independent Handover
- › 802.22 Wireless Regional Area Networks (WRAN)
- › 802.24 Smart Grid TAG

Principles of the IEEE Standards Process

- › **Due process** – procedures are publicly available and followed consistently
- › **Consensus** – requiring agreement of a majority or supermajority – for technical decisions here $\geq 75\%$
- › **Openness** – ensuring materially interested and affected parties can participate
- › **Balance** – representation from all interested parties without overwhelming influence from any one party
- › **Right of appeal** – process to ensure due process

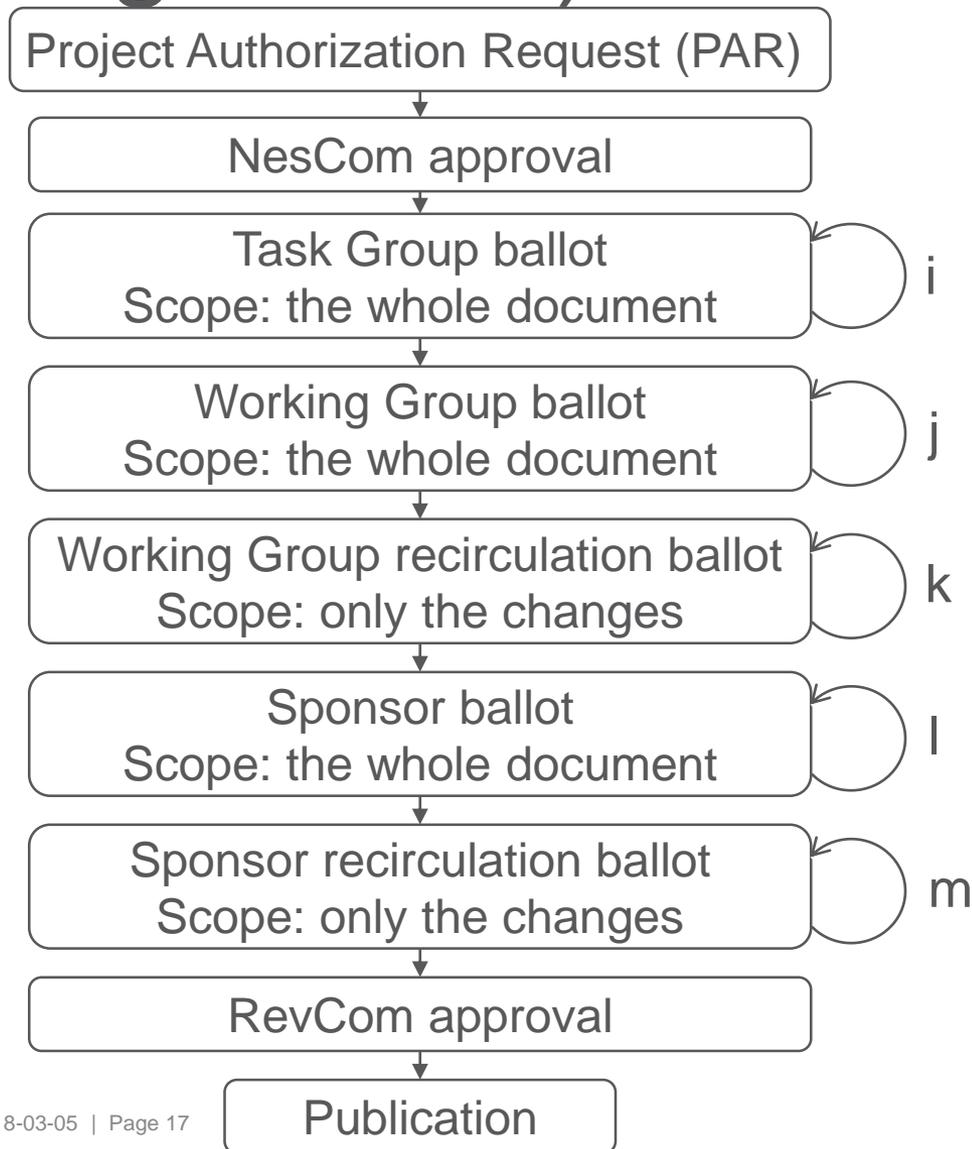
IEEE 802.1 Working Group

- › Chair: Glenn Parsons
- › Vice-chair: John Messenger
- › Addressing and Data Center Bridging (DCB) TG
 - Chair: Patricia Thaler
- › Maintenance TG
 - Chair: John Messenger
- › OmniRAN TG
 - Chair: Maximilian Riegel
- › Security TG
 - Chair: Michael Seaman
- › Time-Sensitive Networking (TSN) TG
 - Chair: János Farkas

IEEE 802.1 Standards

- › The ones with capital letters, e.g. 802.1Q or 802.1AX are independent standards
- › Amendments to these standards are identified by lower case letters e.g. 802.1ah, 802.1Qbg or 802.1AEbn
- › Periodically the amendments get merged into a revision of the main standard, e.g. 802.1ah and 802.1Qay are part of 802.1Q-2014
- › 802.1Q can be considered as many individual standards integrated into a single document
 - Clauses 6 through 9 give a general overview of the 802.1Q bridge architecture
 - To get oriented on an additional area, it's best to read the Clause titled the "Principles of <area>"
 - Once oriented, references in the subclause of Clause 5 Conformance for the relevant device can be helpful

Standard Development Process (High Level)



Balloting Hints

- › Please follow the instructions provided in the ballot invitation
 - Goal of the ballot
 - Ballot email body and subject (e.g., “Comments (with abstain)” from non-voting contributor)
 - xls for ballot comments:
<http://www.ieee802.org/1/files/private/commenting-tool/MyBallot-tools>
- › In the xls
 - Please fill in “First name”, “Surname”, and “Affiliation”
 - Please fill in each column including “Must Be Satisfied”
 - Please leave each cell empty in rows without comment
 - Please do not use anything else than the binary choices for “Category” and “Must Be Satisfied” (e.g., a dot at the end stops it working)
 - Please do not go fancy with the line number, the Editor will figure it out
 - › Single number is enough
 - › Although, entries with two numbers seem to be OK, e.g., “19-25”, “19-25”, or “19, 25”
 - › Entries with more than two numbers do not work, e.g., “17-22, 29-42”
 - › The tool does not accept Figure number either in the Line or Sub-clause filed

› Thank you!

Meetings

› Face-to-face

- 802.1 face-to-face meetings: <https://1.ieee802.org/meetings>
 - › Plenary: <http://802world.org/plenary>,
 - › Interim: https://1.ieee802.org/meetings/#Interim_Meetings
- 802 Plenary agenda (meeting rooms): <http://schedule.802world.com>
- attendance: <https://imat.ieee.org>
- TSN agenda: <https://1.ieee802.org/tsn-task-group-agenda>

› Virtual

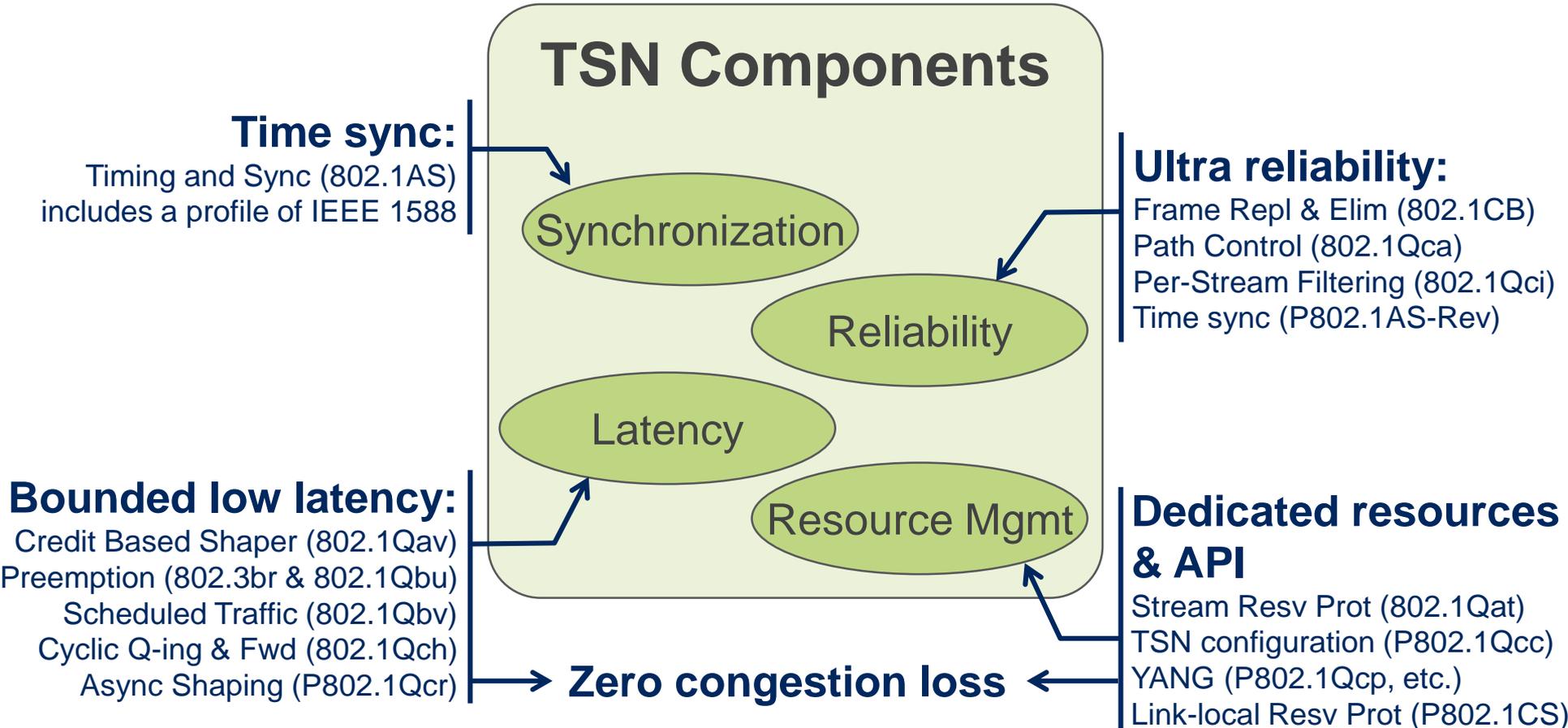
- TSN virtual meetings: https://1.ieee802.org/tsn-task-group-agenda/#Upcoming_conference_calls (<https://join.me/ieee802.1>)
 - › **Mondays: 8am PT: Generic TSN** – **9am PT: Synchronization**
 - › agenda request by **Thursday** the latest
- Virtual meetings of each Task Group are announced on the 802.1 email list
 - › TSN agenda items or cancellation on **Friday**

Further Navigation

- › <https://1.ieee802.org> (projects, drafts, everything)
 - TSN: <https://1.ieee802.org/tsn> (conference calls, etc.)
- › public folder: <http://www.ieee802.org/1/files/public>
- › file upload – at the bottom of <https://1.ieee802.org/filenaming-conventions>
 - Follow the file naming conventions please
- › email list: <https://1.ieee802.org/email-lists>
 - archive: <http://www.ieee802.org/1/private/email2>
- › ongoing ballots: <https://1.ieee802.org/active-ballots>
- › minutes & opening/closing plenary slides: <https://1.ieee802.org/category/minutes>
- › IEEE 802 “Get” program (free stds after 6 months): <http://ieeexplore.ieee.org/browse/standards/get-program/page>

IEEE 802.1 Time-Sensitive Networking (TSN)

TSN Overview



Guaranteed data transport with bounded low latency, low delay variation, and extremely low loss

From AVB to TSN

- › IEEE 802.1 Audio Video Bridging (AVB) Task Group (TG)
 - Started in 2005
 - Address professional audio, video market
 - Consumer electronics
 - Automotive infotainment
 - AVnu Alliance: associated group for compliance and marketing
- › IEEE 802.1 Time-Sensitive Networking (TSN) TG
 - AVB features become interesting for other use cases, e.g.
 - › Industrial
 - › Automotive
 - AVB was not an appropriate name to cover all use cases
 - AVB TG was renamed to TSN TG in 2012
 - Interworking TG and TSN TG were merged in 2015

AVB Standards

- › IEEE Std. 802.1AS-2011 – generalized Precision Time Protocol (gPTP)
 - A Layer 2 profile of the IEEE 1588 Precision Time Protocol (PTP)
- › IEEE Std. 802.1Qav – Forwarding and Queuing Enhancements for Time-Sensitive Streams (FQTSS):
 - Specifies Credit-Based Shaper (CBS)
- › IEEE Std. 802.1Qat – Stream Reservation Protocol (SRP)
 - Registration and reservation of time-sensitive streams
- › IEEE Std. 802.1BA – AVB Systems
 - Provides an overall AVB architecture and AVB profiles
- › CBS + SRP to provide delays under 250 μ s per bridge

TSN **Standards** and Projects

- › **802.1Qbu – Frame Preemption**
 - › **802.1Qbv – Enhancements for Scheduled Traffic**
 - › **802.1Qca – IS-IS Path Control and Reservation (PCR)**
 - › **802.1Qch – Cyclic Queuing and Forwarding**
 - › **802.1Qci – Per-Stream Filtering and Policing**
 - › **802.1CB – Frame Replication and Elimination for Reliability**
 - › P802.1Qcc – Stream Reservation Protocol (SRP) Enhancements & Performance Improvements and TSN configuration
 - › P802.1Qcr – Asynchronous Traffic Shaping (ATS)
 - › P802.1AS-Rev – Timing and Synchronization - Revision
 - › P802.1CM – Time-Sensitive Networking for Fronthaul
 - › P802.1CS – Link-local Registration Protocol (LRP)
- 

Further TSN Projects

- › P802.1Qcp – YANG Data Model
- › P802.1Qcw – YANG Data Models for Scheduled Traffic, Frame Preemption, and Per-Stream Filtering and Policing
- › P802.1ABcu – YANG Data Model for the Link Layer Discovery Protocol (LLDP)
- › *P802.1Qcj – Auto-attach to PBB services*
- › *P802.1Qcx – YANG Data Model for Connectivity Fault Management (CFM)*
- › *P802.1AX-Rev – Link Aggregation - Revision*

- › more coming: <http://www.ieee802.org/PARs.shtml>

Status & Industry Interest

Standard / Project	Subject	Status	D #	Industry			
				P	A	I	M
P802.1AS-Rev	Time synchronization	WG	6.0				
802.1Qbu	Frame Preemption	Published					
802.1Qbv	Scheduled Traffic	Published					
802.1Qca	IS-IS Path Control & Rsv	Published					
P802.1Qcc	SRP Enhancements	Sponsor	2.1				
802.1Qch	Cyclic Queuing	Published					
802.1Qci	Per-Stream Filtering	Published					
P802.1Qcj	Auto-attach to PBB	TG	0.2				
P802.1Qcp	YANG	Sponsor	2.1				
P802.1Qcr	Asynchronous Shaping	TG	0.3				
802.1CB	Frame Repl. & Elimin.	Published					
P802.1CM	TSN for Fronthaul	Sponsor	2.0				
P802.1CS	LRP (Registration)	TG	1.2				

P: pro AV
A: Automotive
I: Industrial
M: Mobile

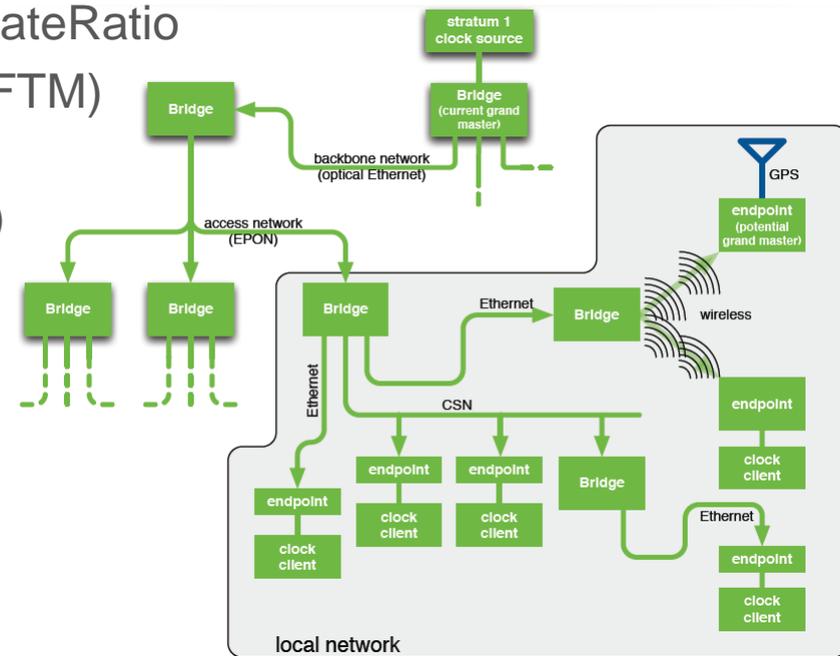
Status & Industry Interest

Standard / Project	Subject	Status	D #	Industry			
				P	A	I	M
802.1CB	Frame Repl. & Elimin.	Published		Red	Green	Blue	White
802.1Qbu	Frame Preemption	Published		Red	Green	Blue	Yellow
802.1Qbv	Scheduled Traffic	Published		White	Green	Blue	White
802.1Qca	IS-IS Path Control & Rsv	Published		White	White	Blue	White
802.1Qci	Per-Stream Filtering	Published		Red	Green	Blue	White
802.1Qch	Cyclic Queuing	Published		Red	Green	Blue	White
P802.1Qcc	SRP Enhancements	Sponsor	2.1	Red	White	Blue	White
P802.1Qcp	YANG	Sponsor	2.1	Red	White	Blue	White
P802.1Qcj	Auto-attach to PBB	TG	0.2	White	White	White	White
P802.1Qcr	Asynchronous Shaping	TG	0.3	White	Green	Blue	White
P802.1AS-Rev	Time synchronization	WG	6.0	Red	Green	Blue	White
P802.1CM	TSN for Fronthaul	Sponsor	2.0	White	White	White	Yellow
P802.1CS	LRP (Registration)	TG	1.2	Red	White	Blue	White

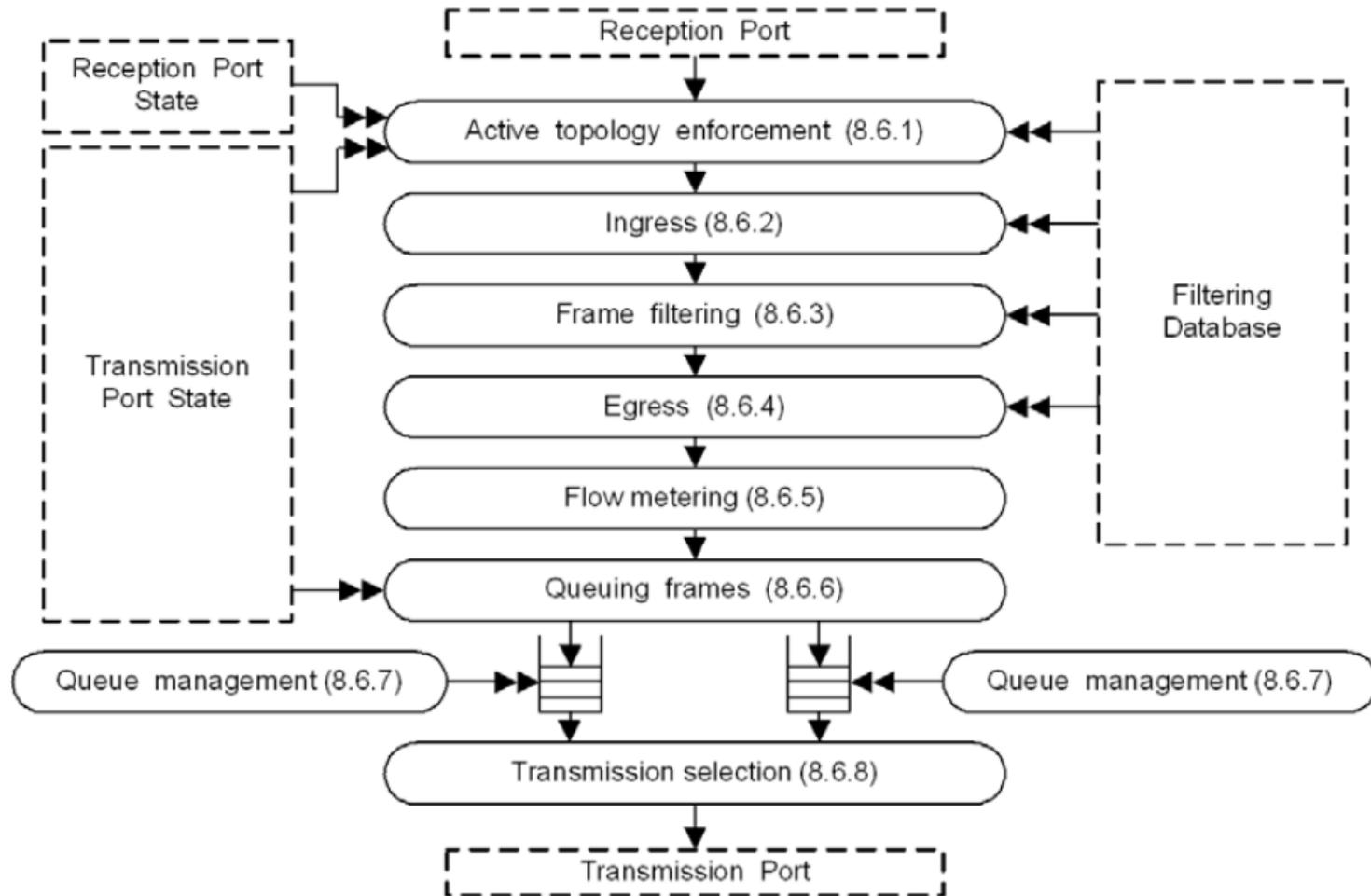
P: pro AV
A: Automotive
I: Industrial
M: Mobile

P802.1AS-REV – Timing and Synchronization

- › A profile of 1588 for Layer 2 Ethernet
- › The Revision includes:
 - Common peer delay service for all domains, for measuring link delay and neighborRateRatio
 - Support of Fine Timing Measurement (FTM) for IEEE 802.11 transport
 - Support for Link Aggregation (802.1AX)
 - Improved scalability
 - One step processing
 - Improved support for long chains, rings
 - More responsive
 - Faster Grand Master change over
 - Reduce BMCA convergence time
 - Multiple domains with synchronization information
 - Redundancy: configure redundant paths and redundant GMs (further redundancy may be defined by a new project)

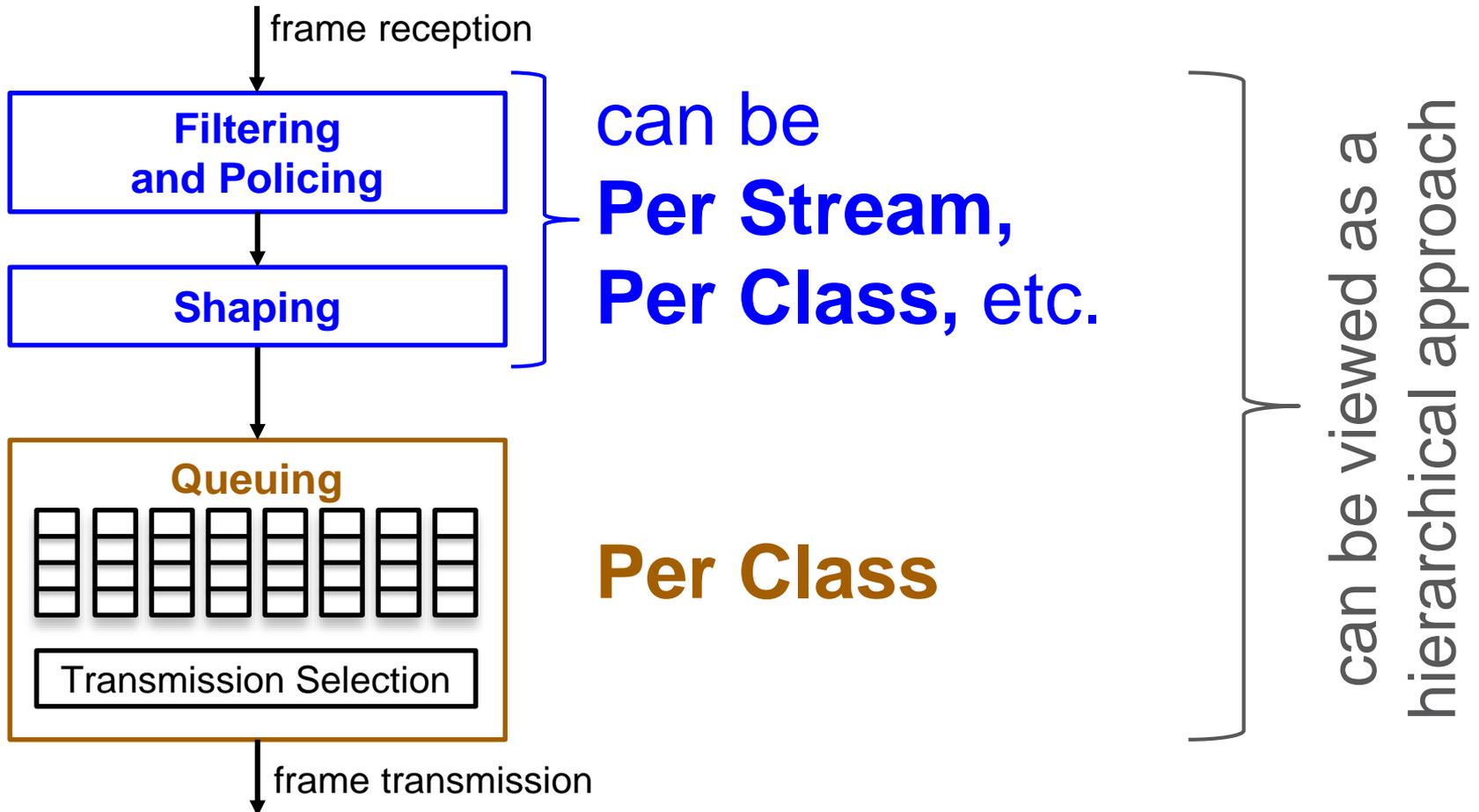


Lookout – Forwarding Process in 802.1Q



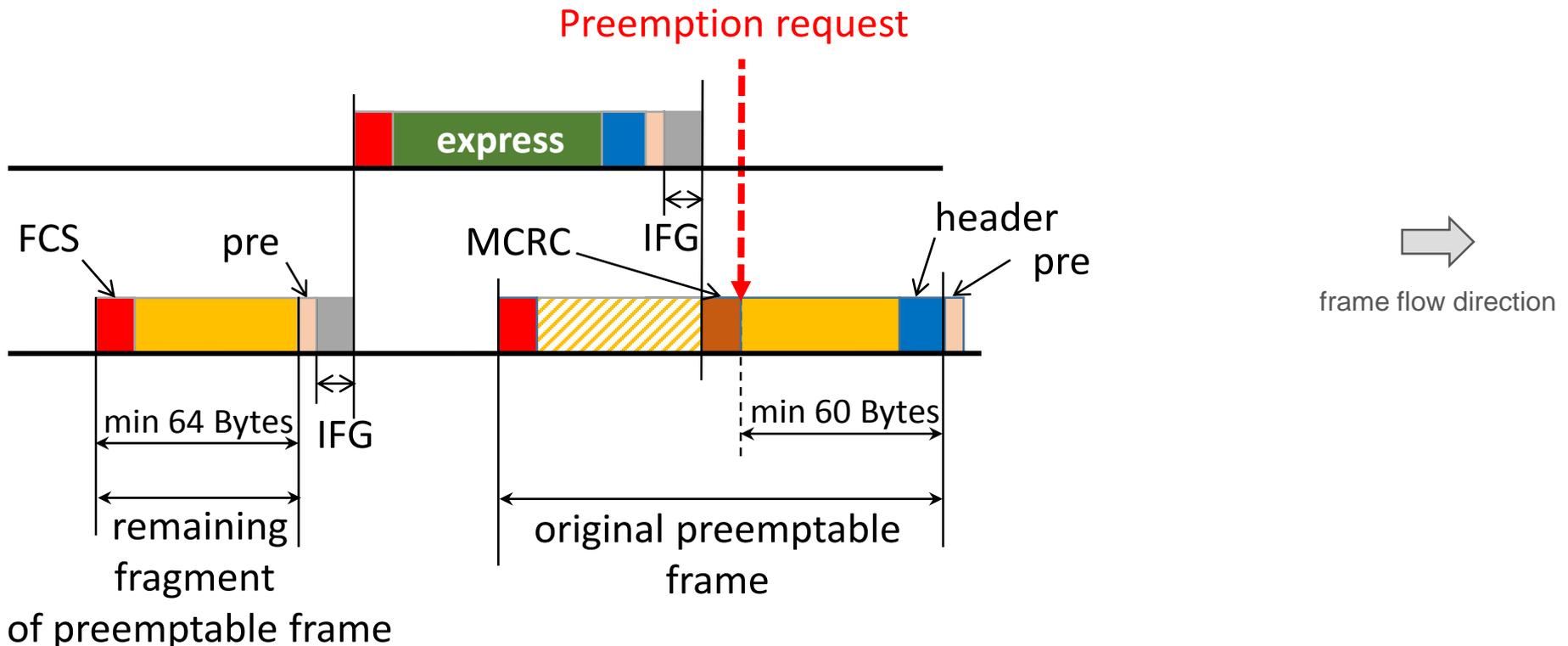
› We will refer to it very soon

Illustration of QoS Functions



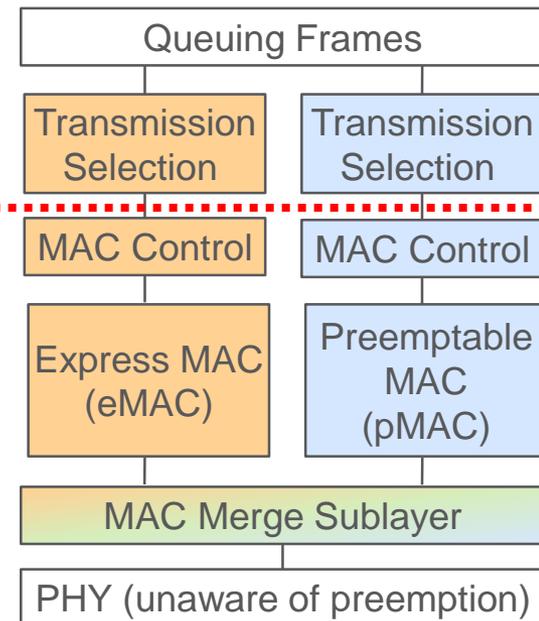
802.3br – Interspersing Express Traffic (Frame Preemption) – Illustration

- Express frames can suspend the transmission of preemptable frames



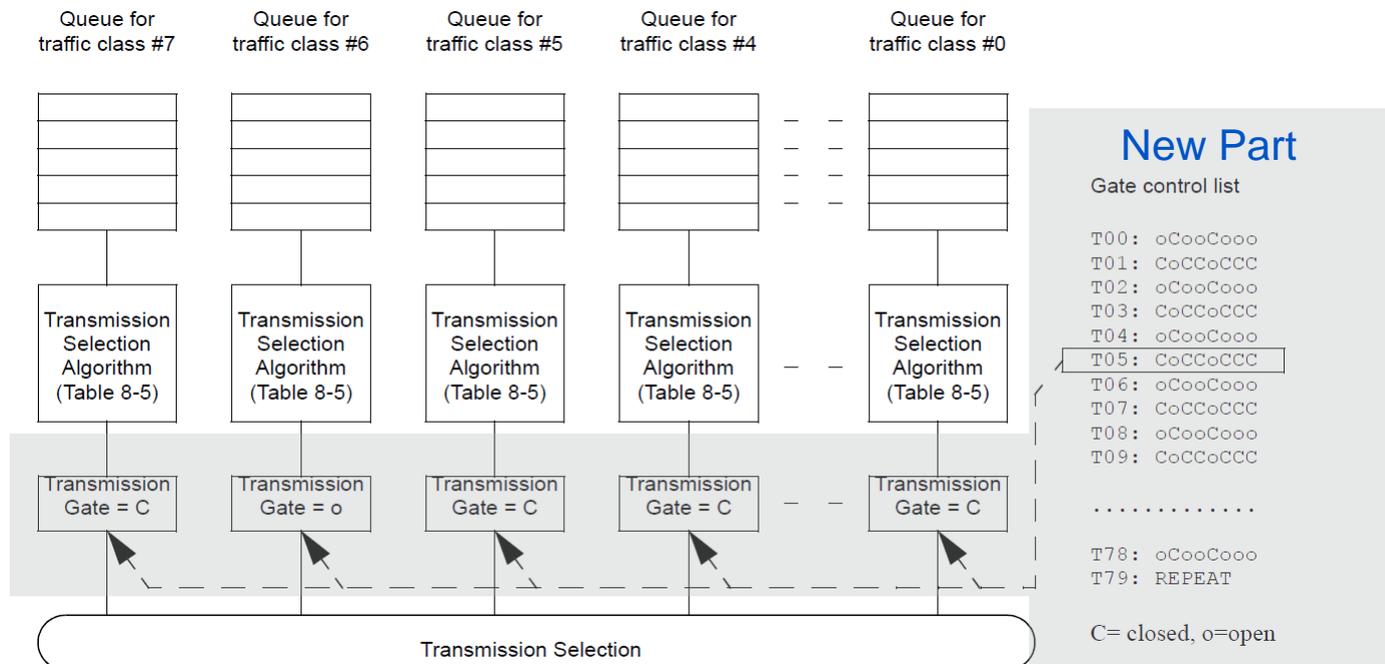
Frame Preemption / Interspersing Express Traffic

- › Time-critical frames can suspend the transmission of non-time-critical frames while one or more time-critical frames are transmitted
- › Specified by
 2. 802.1Qbu – Frame Preemption
 1. 802.3br – Interspersing Express Traffic (IET)
- › 802.1Qbu makes the adjustments needed in 802.1Q in order to support 802.3br, e.g.
 - each traffic class queue supported by the Port is assigned a value of frame preemption status
 - the possible values of frame preemption status are **express** or **preemptable**
- › Minimum fragment size is 64 bytes including CRC



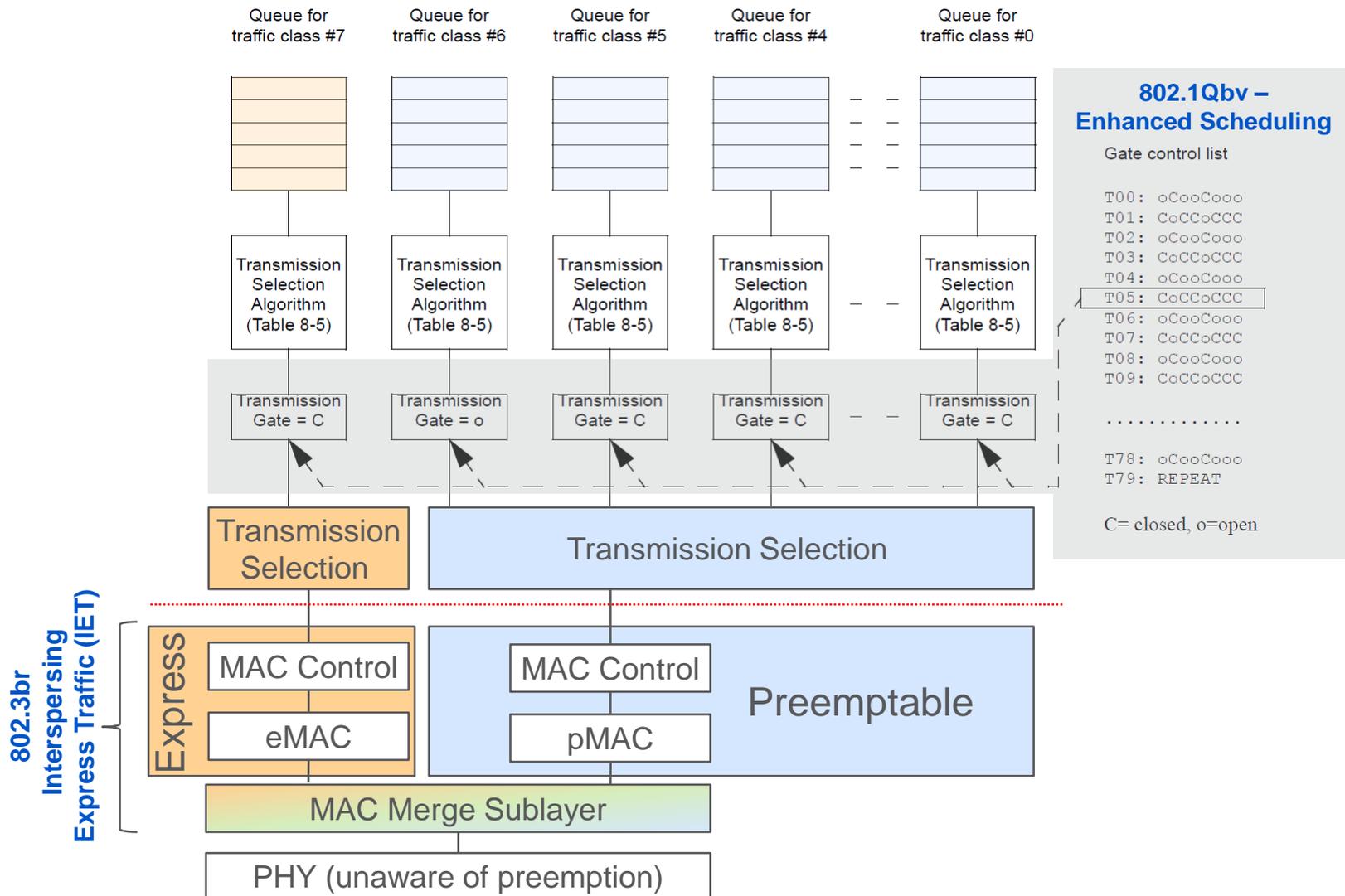
802.1Qbv – Enhancements for Scheduled Traffic

- › Transmission from each queue to be scheduled relative to a known timescale
- › A transmission gate is associated with each queue
 - the state of the gate determines whether or not queued frames can be selected for transmission
 - **open (o)**: queued frames are selected for transmission, (according to the transmission selection algorithm associated with the queue)
 - **Closed (C)**: queued frames are not selected for transmission



Preemption and Enhanced Scheduling

Overview

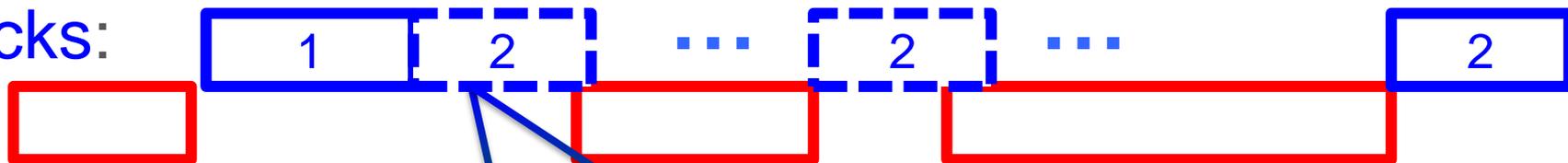


Frame Preemption Added to Scheduled Traffic

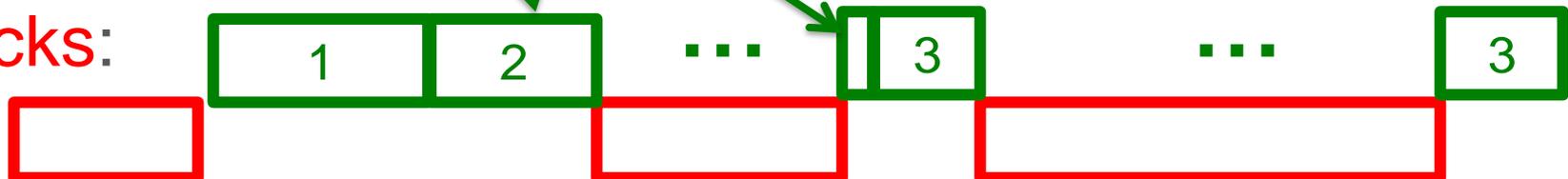
- › **Express** frames suspend the transmission of **preemptable** frames
- › Scheduled **rocks of critical packets** in each cycle:



- › Conflict excessively with **non-guaranteed packet** rocks:

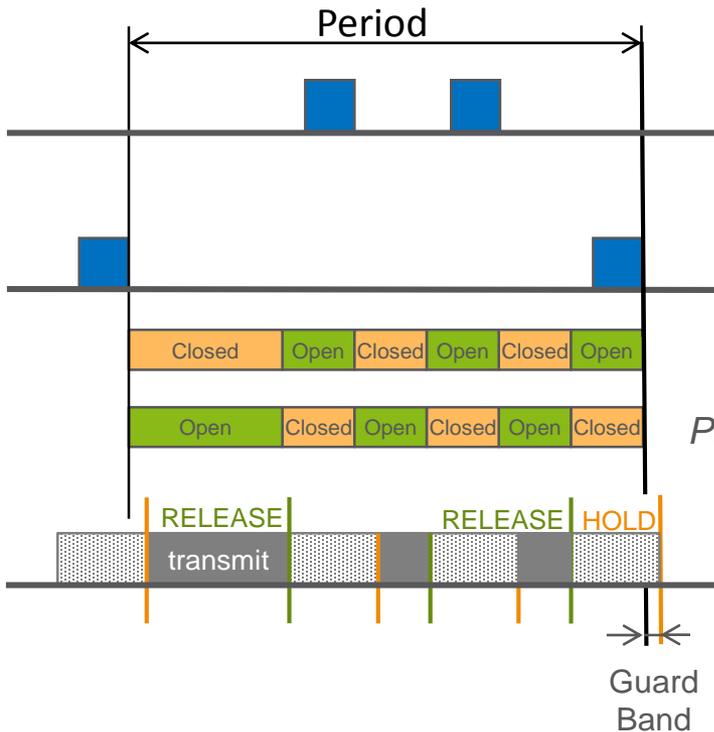


- › Problem solved by preemptive **sand** between the **rocks**:



Frame Preemption and Enhancements for Scheduled Traffic with Guard Band

Example 1



Legend

Express From Port 1

Express From Port 2

Express Gate at egress port

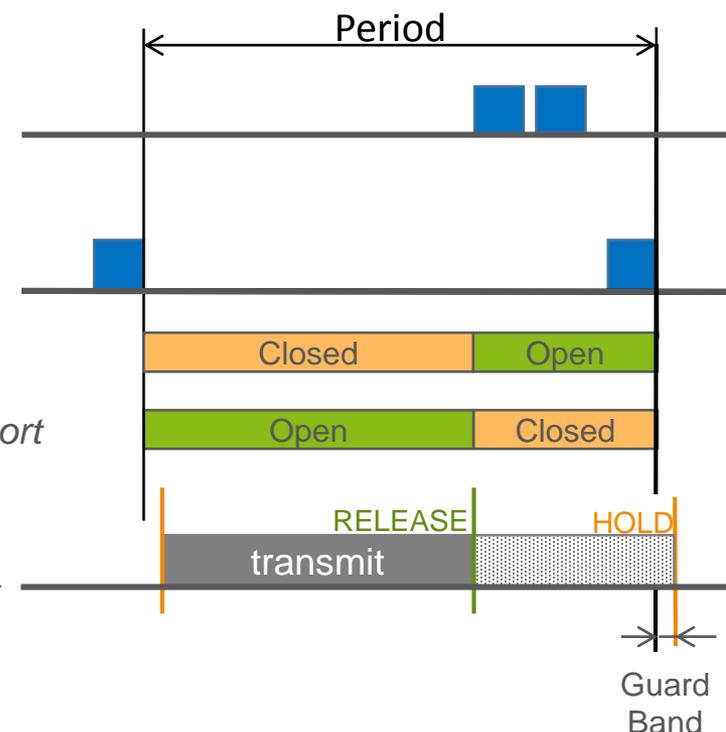
Preemptable Gate at egress port

Preemptable transmission possibilities at egress port



frame flow direction

Example 2



- › Guard band can protect the express traffic completely from interference from preemptable traffic
- › Guard band can be used without preemption too

802.1Qci – Per Stream Filtering and Policing

› Per-Stream Filtering and Policing (PSFP) allows filtering and policing decisions to be made on a per-stream basis

› Stream filter

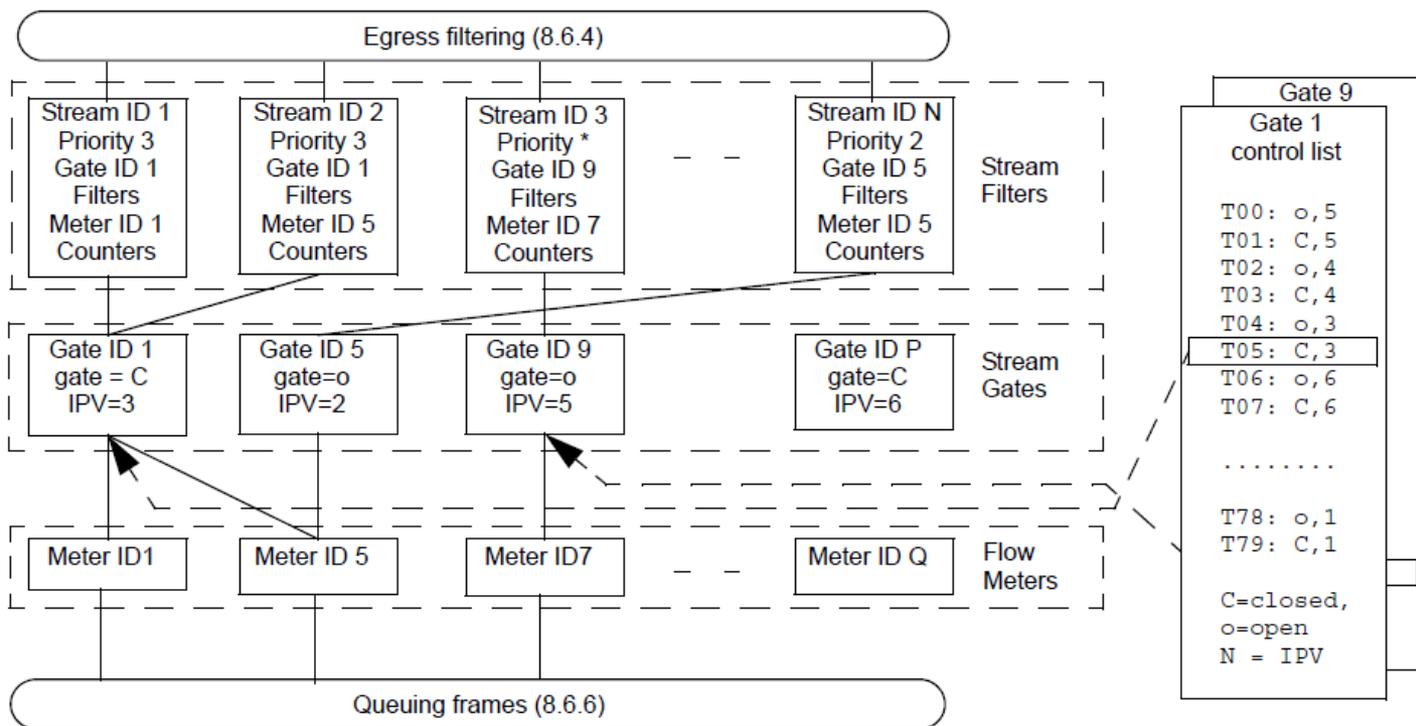
- Stream ID
- Priority
- Filters
- Meter ID
- Counters

› Stream gate

- open (o)
- Closed (C)

› Flow meter

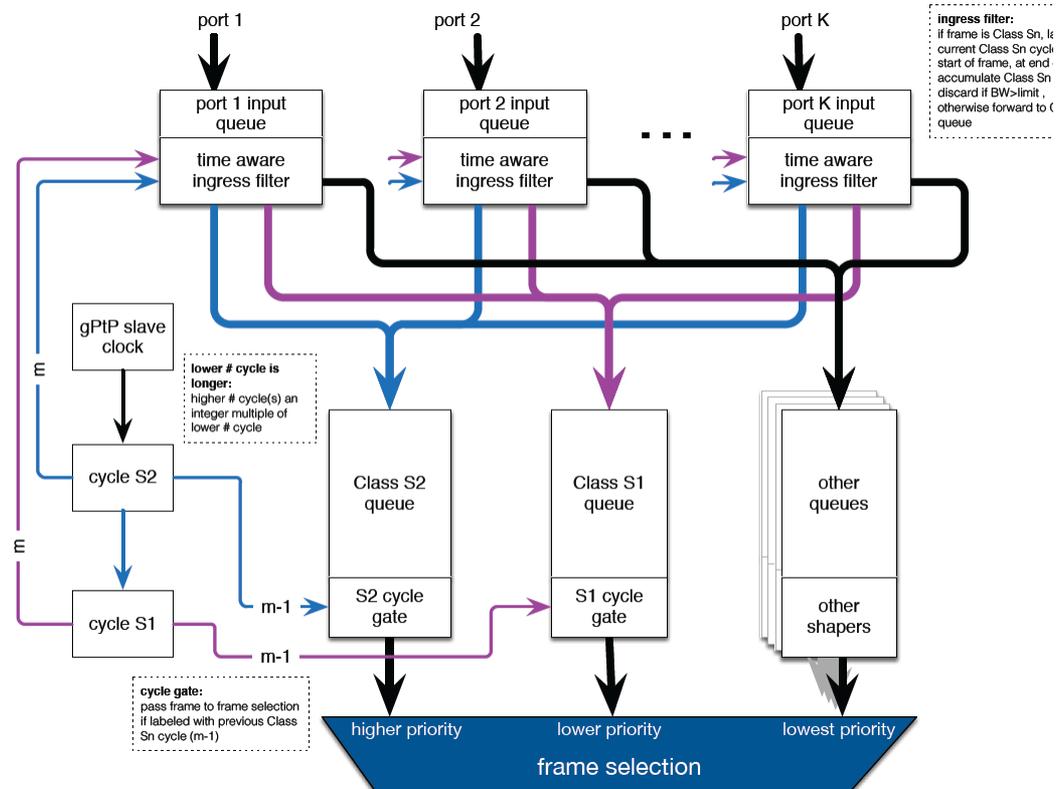
- Parameters as specified in Bandwidth Profile Parameters and Algorithm in MEF 10.3, plus some additional parameters



802.1Qch – Cyclic Queueing and Forwarding (CQF)

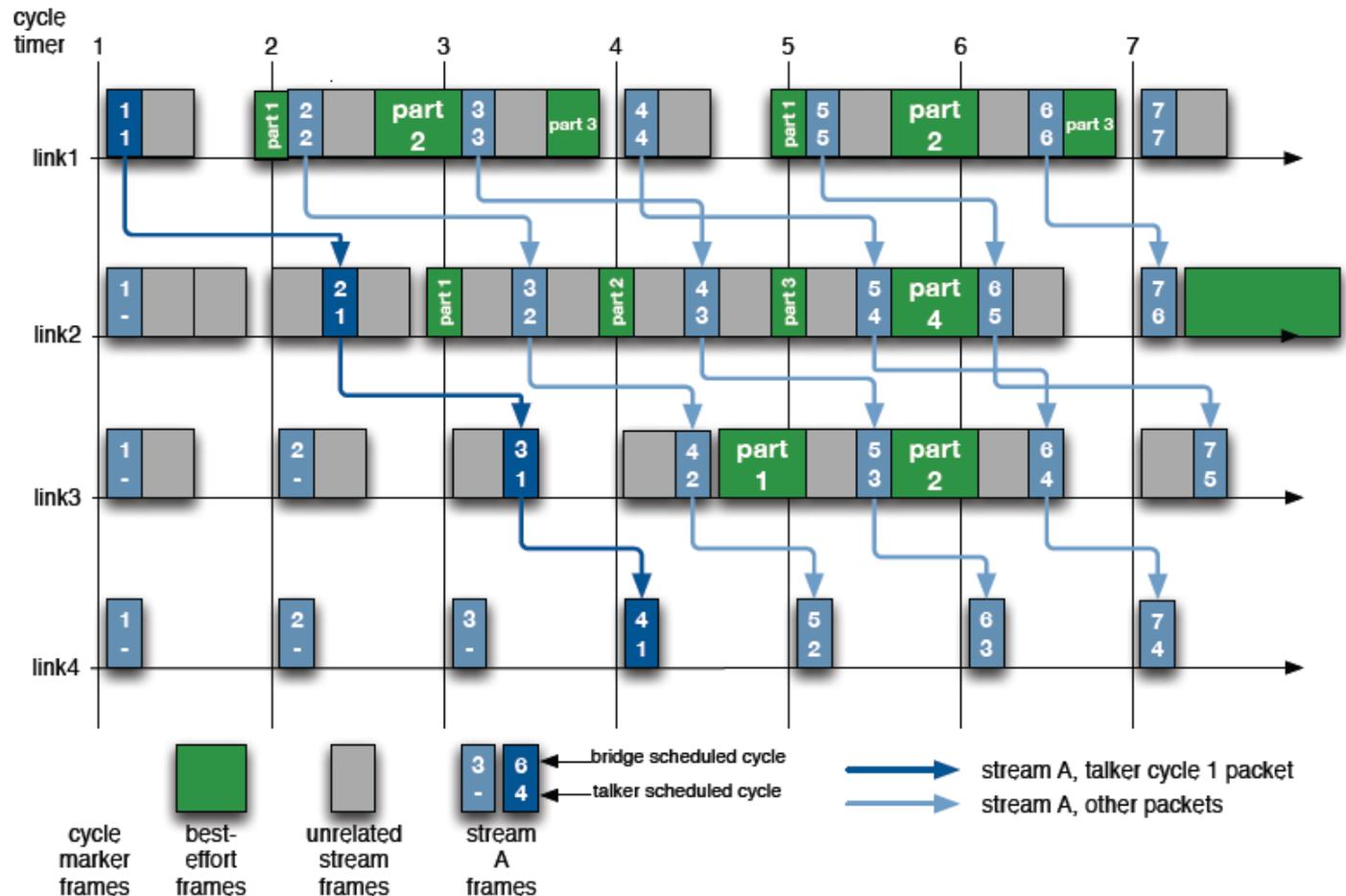
- › Synchronized cyclic enqueueing and queue draining achieve zero congestion loss and deterministic latency
- › Two buffers served alternated, e.g., that of S1 and S2
- › To be combined with frame preemption, see next slide

Example bridge with two delay classes, S1 and S2



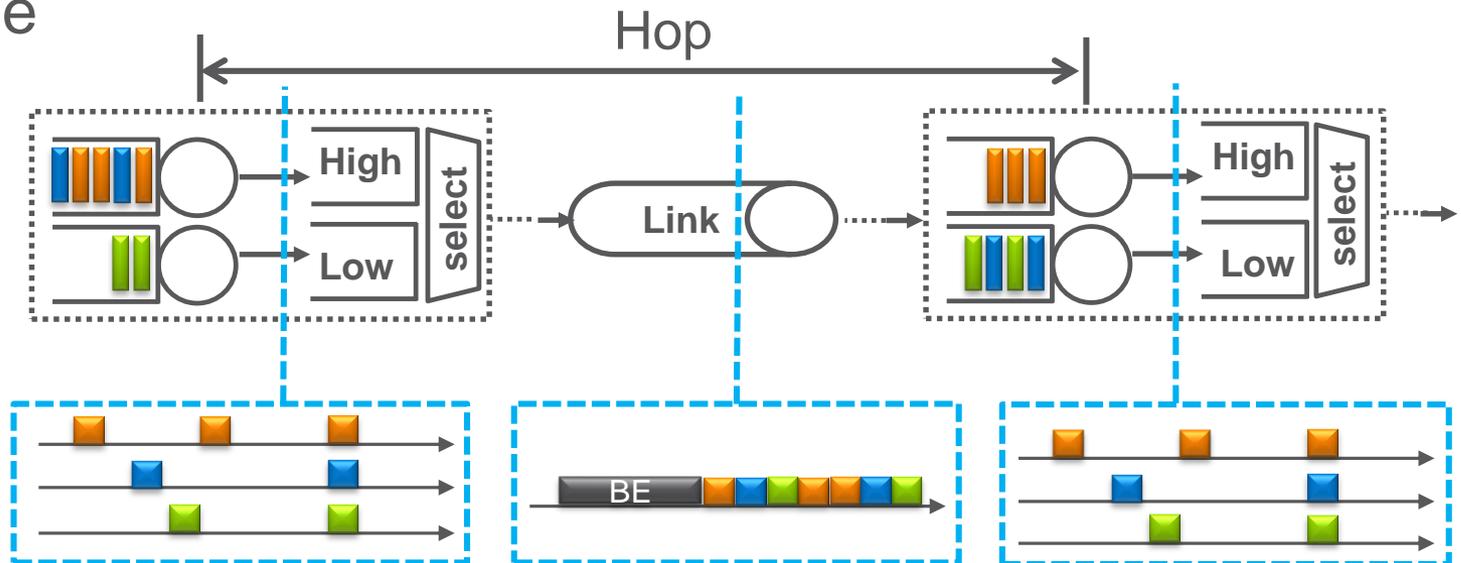
802.1Qch – Cyclic Queueing and Forwarding with Frame Preemption

- › Each frame of a Stream stays one cycle at each hop



P802.1Qcr – Asynchronous Traffic Shaping (ATS)*

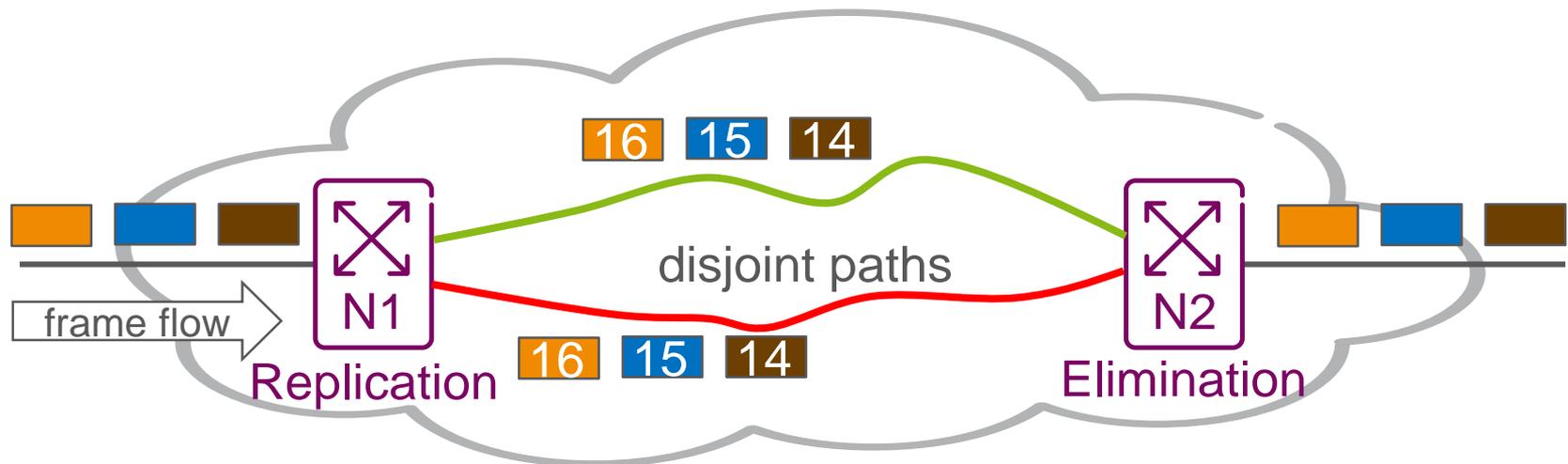
- › Zero congestion loss without time sync
- › Basic idea
 1. Smoothen traffic patterns by re-shaping per hop
 2. Prioritize urgent traffic over relaxed traffic
- › Example



* formerly referred to as Urgency Based Scheduler (UBS)

802.1CB – Frame Replication and Elimination for Reliability (FRER)

- › Avoid frame loss due to equipment failure
- › It is a per-frame 1+1 (or 1+n) redundancy
 - NO failure detection / switchover
- › Send frames on 2 (or more) maximally disjoint paths, then combine and delete extras

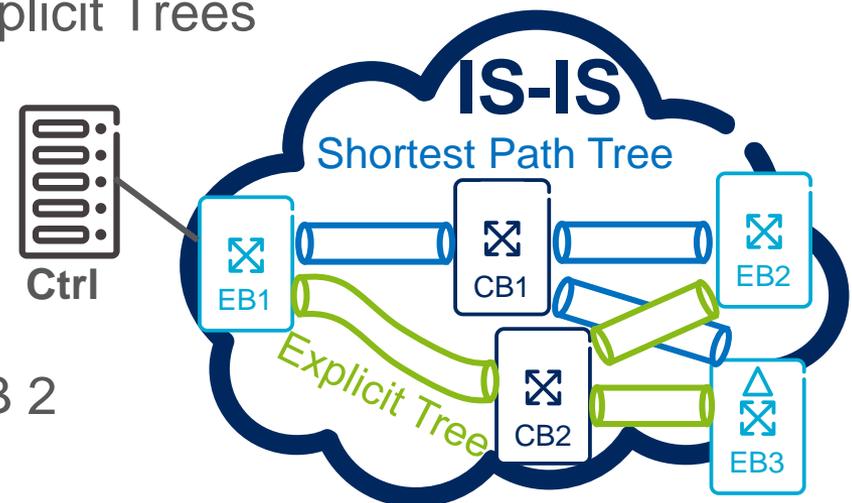


802.1Qca – IS-IS Path Control & Reservation

- › Provide IS-IS control beyond Shortest Path Trees (SPTs)
 - Augmenting IS-IS with non-shortest path capabilities
- › No protocol changes, only a couple of new sub-TLVs and reuse of existing ones as much as possible
- › A hybrid Software Defined Networking (SDN) approach
 - IS-IS provides basic functions, e.g., topology discovery, default paths
 - One or more controllers control Explicit Trees

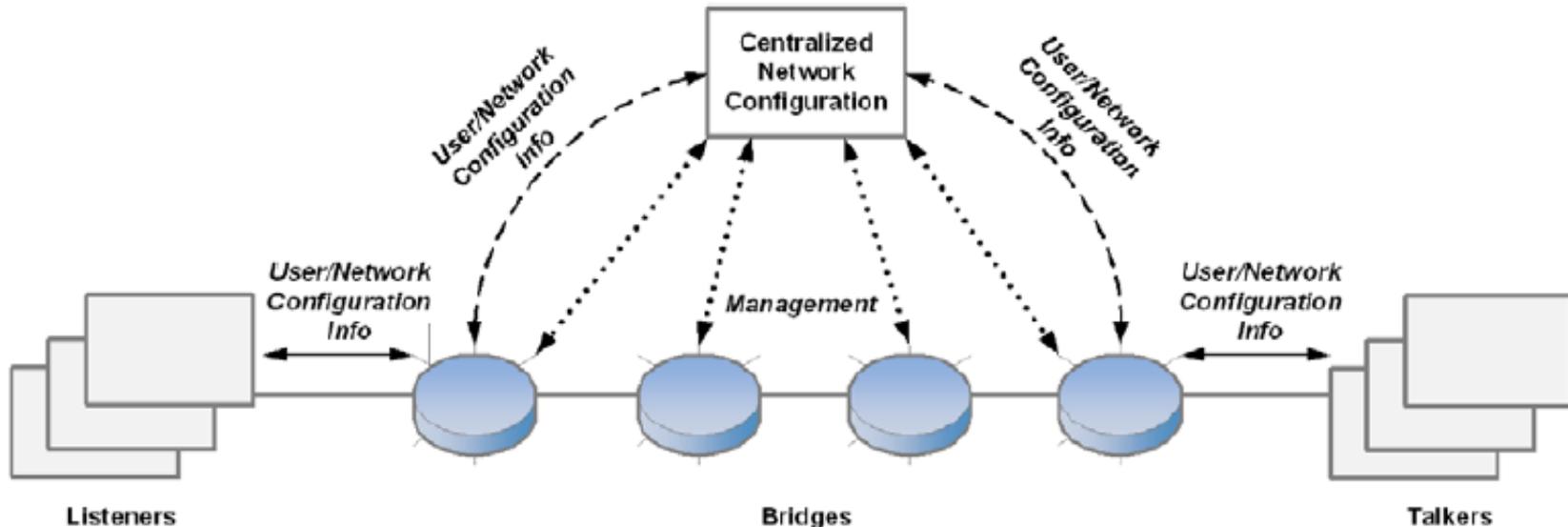
› Example

- Exception traffic steering
- SPT of Edge Bridge (EB) 1 is via Core Bridge (CB) 1
- Explicit Tree (ET) of EB 1 is via CB 2



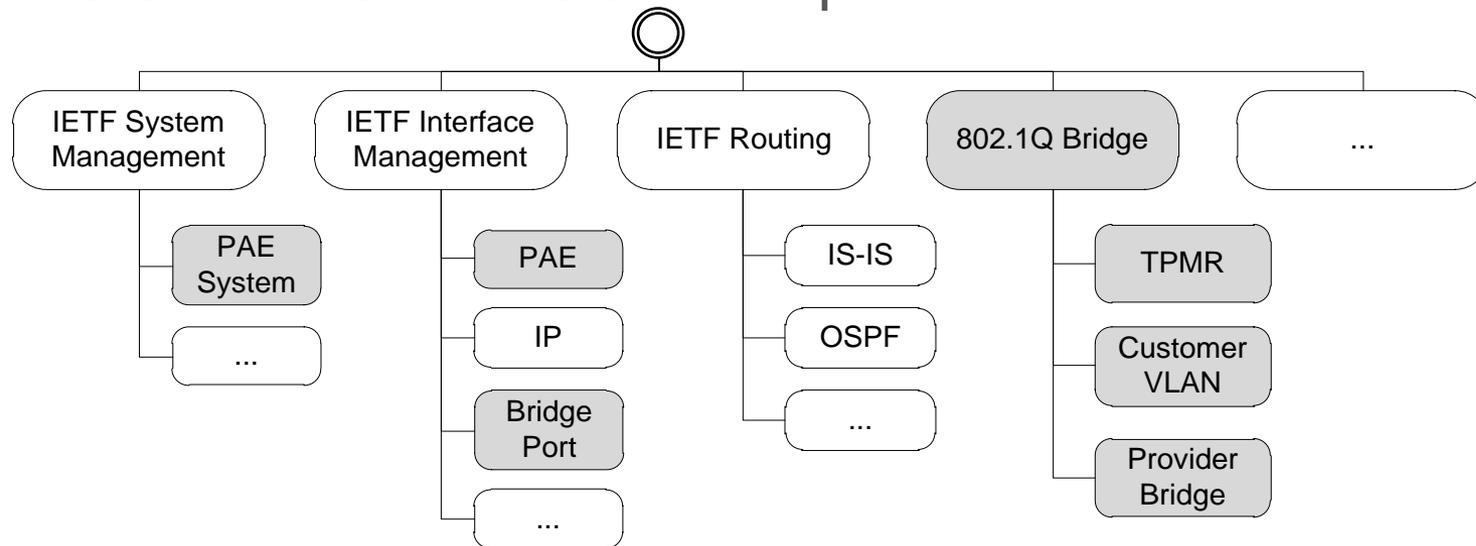
P802.1Qcc – Stream Reservation Protocol (SRP) Enhancements

- › SRP enhancements
 - New version: MSRPv1, which translates to MSRPv0
 - New AttributeTypes that provide enhanced capabilities
- › TSN configuration
 - Fully Distributed Model
 - Fully Centralized Model
 - Centralized Network / Distributed User Model



P802.1Qcp – YANG Data Model

- › Scope: subset of 802.1Q features
- › Model representation via UML
- › YANG structure and relationships

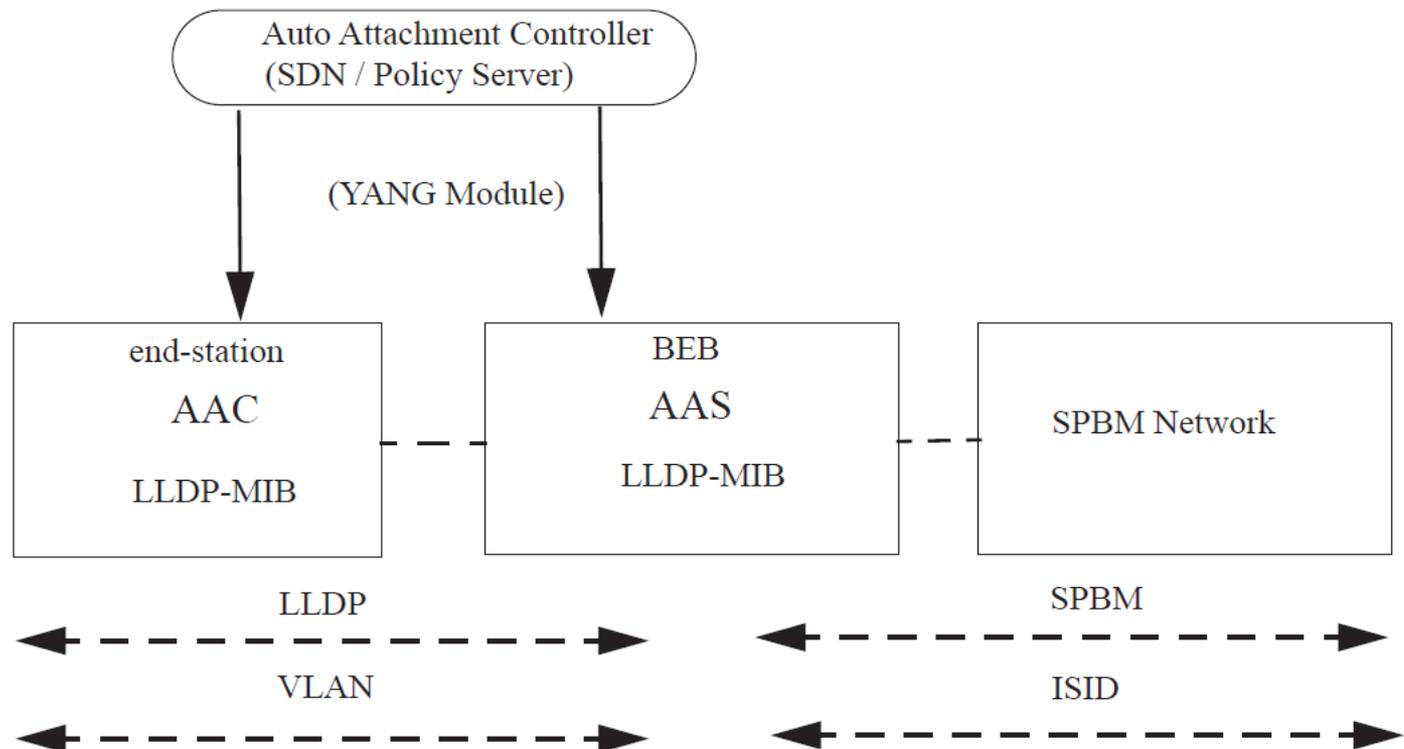


- › GitHub as a repository: <https://github.com/YangModels/yang/tree/master/standard/ieee>
<http://www.ieee802.org/1/files/public/docs2016/cp-mholness-Bridge-Port-YANG-0816-v053.pdf>

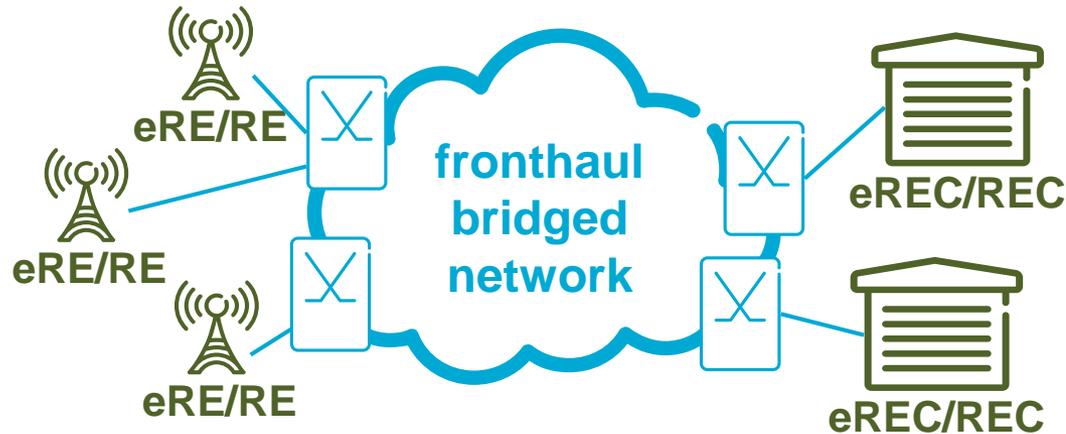
P802.1Qcj – Auto-attach to PBB services

› Auto Attach Model

- Auto Attach Clients (AAC): non-Provider Backbone Bridging (PBB) device
- Auto-Attach Server (AAS): PBB device, e.g., Backbone Edge Bridge (BEB)



P802.1CM – TSN for Fronthaul



- › Develop standard TSN Profiles for Fronthaul in order to enable the transport of Fronthaul streams in a bridged network
- › Profiles for
 - [CPRI 7.0](#) Radio Base Station (RBS) split such that the different fronthaul flows (IQ, C&M, and Sync) are supported **separate**
 - [eCPRI](#)
- › Joint effort with CPRI Cooperation

P802.1CM – TSN for Fronthaul – Cont'd

- › A Profile is a set of feature and option selections that specifies aspects of bridge and end station operation, and states the conformance requirements for support of a specific class of user applications
- › The 802.1CM specification
 - collects requirements for Fronthaul networks
 - provide guidance for meeting Fronthaul requirements, which includes
 - › selecting 802.1 TSN features in order to build networks capable of transmitting Fronthaul streams like decomposed CPRI
 - › describing how the selected TSN features and components can be combined, configured and used in order to meet Fronthaul requirements

Further Reading

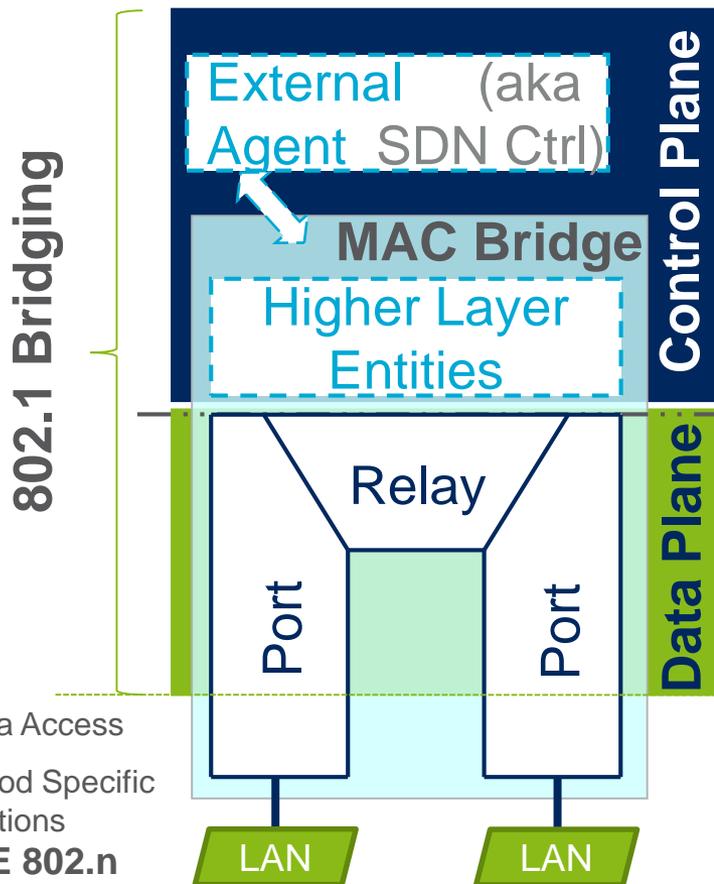
- › <https://1.ieee802.org> (<http://www.ieee802.org/1>)
- › Tutorial on TSN at IETF 99
<https://datatracker.ietf.org/meeting/99/materials/slides-99-edu-sessf-time-sensitive-networking-tutorial-english-language-janos-farkas-norman-finn-patricia-thaler>
- › Tutorial on IEEE 802 Ethernet Networks for Automotive
http://www.ieee802.org/802_tutorials/2017-07/tutorial-Automotive-Ethernet-0717-v02.pdf
- › IEEE 802.1 TSN for Automotive Networks – flyer
http://standards.ieee.org/downloads/TSN_for_Automotive_Networks.pdf
- › IEEE 802.1 TSN for Industrial Networks – flyer
http://standards.ieee.org/downloads/TSN_for_Industrial_Networks.pdf
- › “A Time-Sensitive Networking Primer: Putting It All Together”
https://drive.google.com/file/d/0B6Xurc4m_PVsZ1lzWWoxS0pTNVE/view?usp=sharing
- › “Heterogeneous Networks for Audio and Video: Using IEEE 802.1 Audio Video Bridging” <http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6595589>
- › Tutorial on IEEE 802 Ethernet Networks for Automotive <http://www.ieee802.org/Tutorials.shtml>
- › Tutorial on IEEE 802.3br Interspersing Express Traffic (IET) and IEEE 802.1 Time-Sensitive Networking http://www.ieee802.org/802_tutorials/2015-03/8023-IET-TF-1501-Winkel-Tutorial-20150115_r06.pptx
- › Tutorial on Deterministic Ethernet http://www.ieee802.org/802_tutorials/2012-11/8021-tutorial-final-v4.pdf
- › Tutorial on IEEE 802.1Q at IETF 86 <https://www.ietf.org/meeting/86/tutorials/86-IEEE-8021-Thaler.pdf>

Bridge Architecture

Control Plane Separated from Data Plane

(Basic SDN Characteristics)

Simplified “baggy pants” model



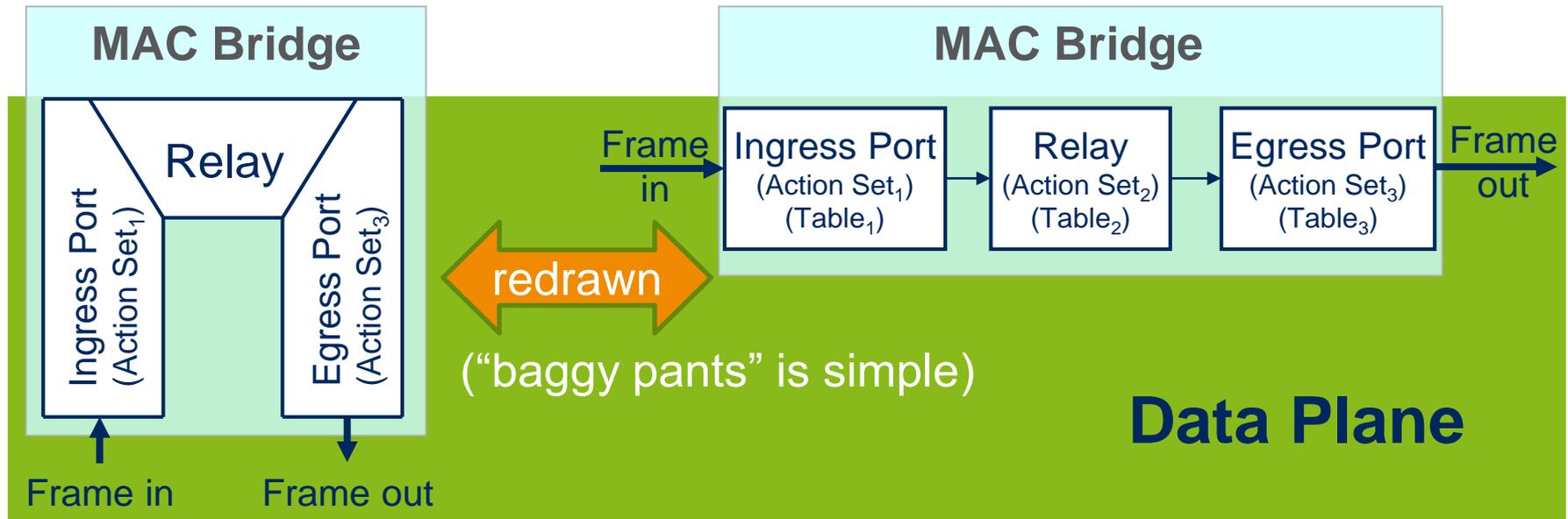
- › Control protocols are implemented as Higher Layer Entities
- › External Agent may provide control instead of the distributed protocols

- › The data plane is comprised of
 - A MAC Relay and
 - At least two ports

e.g. 802.3
Ethernet

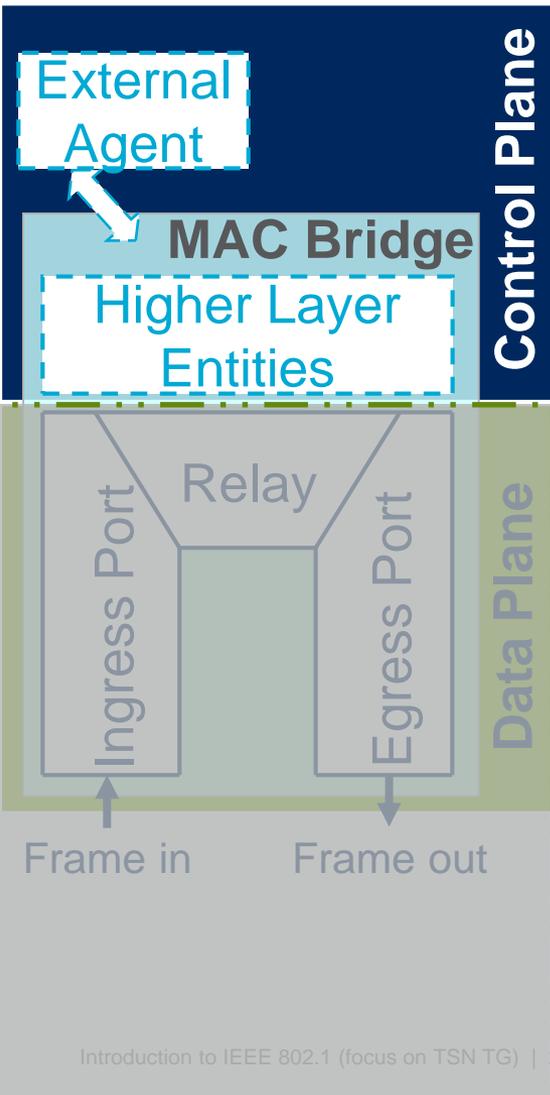
see Figure 8-2 – “VLAN-aware Bridge architecture” of 802.1Q for more details

Data Plane Actions (IEEE 802.1Q-2014)



- › Ingress Port (Action Set1)
 - Filtering (drop), (un)tagging, VID translation, de/en-capsulation
- › Relay (Action Set2)
 - Forwarding, filtering
- › Egress Port (Action Set3)
 - Filtering, (un)tagging, VID translation, de/en-capsulation, metering, queuing, transmission selection

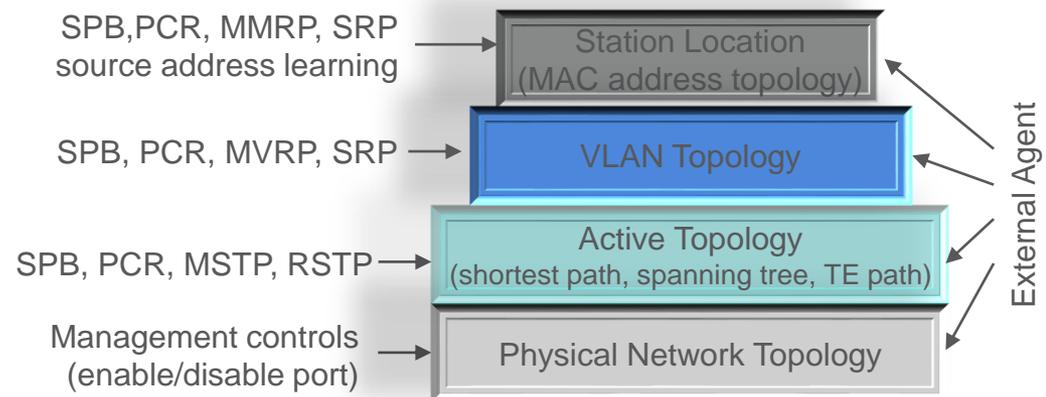
Control Plane Overview



- › A VLAN is assigned to a control mode
 - Multiple control modes may co-exist in the same network
 - Hybrid control by distributed protocols and an External Agent, e.g., an SDN controller
 - External control can be a non-802.1 protocol: PCE, GMPLS

VLAN space:	spanning tree VLANs	shortest path VLANs	software defined VLANs
Control:	Multiple Spanning Tree Protocol	IS-IS	External Agent

› Summary of control options



See You!