

# Introduction to IEEE 802.1

## Focus on the Time-Sensitive Networking Task Group

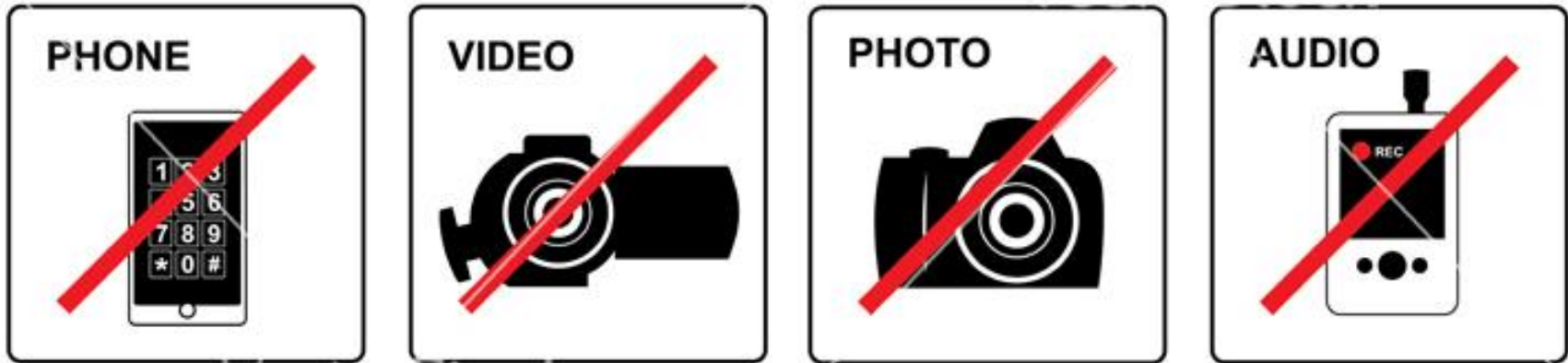
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May 15, 2017

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

› <http://standards.ieee.org/about/sasb/patcom/materials.html>

# 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

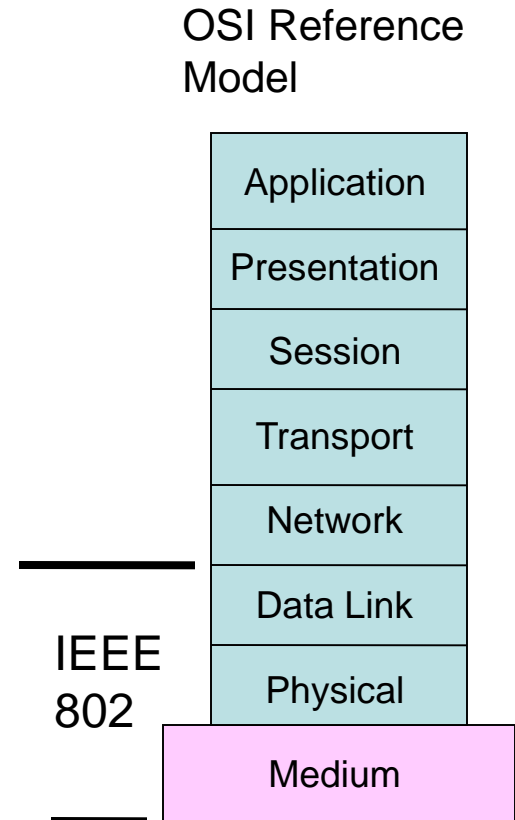
- › IEEE 802.1 Overview
- › IEEE 802.1 Time-Sensitive Networking (TSN)
  - Audio Video Bridging (AVB) and TSN
  - AVB standards
  - TSN standards
  - TSN projects
- › Background
  - Bridge architecture



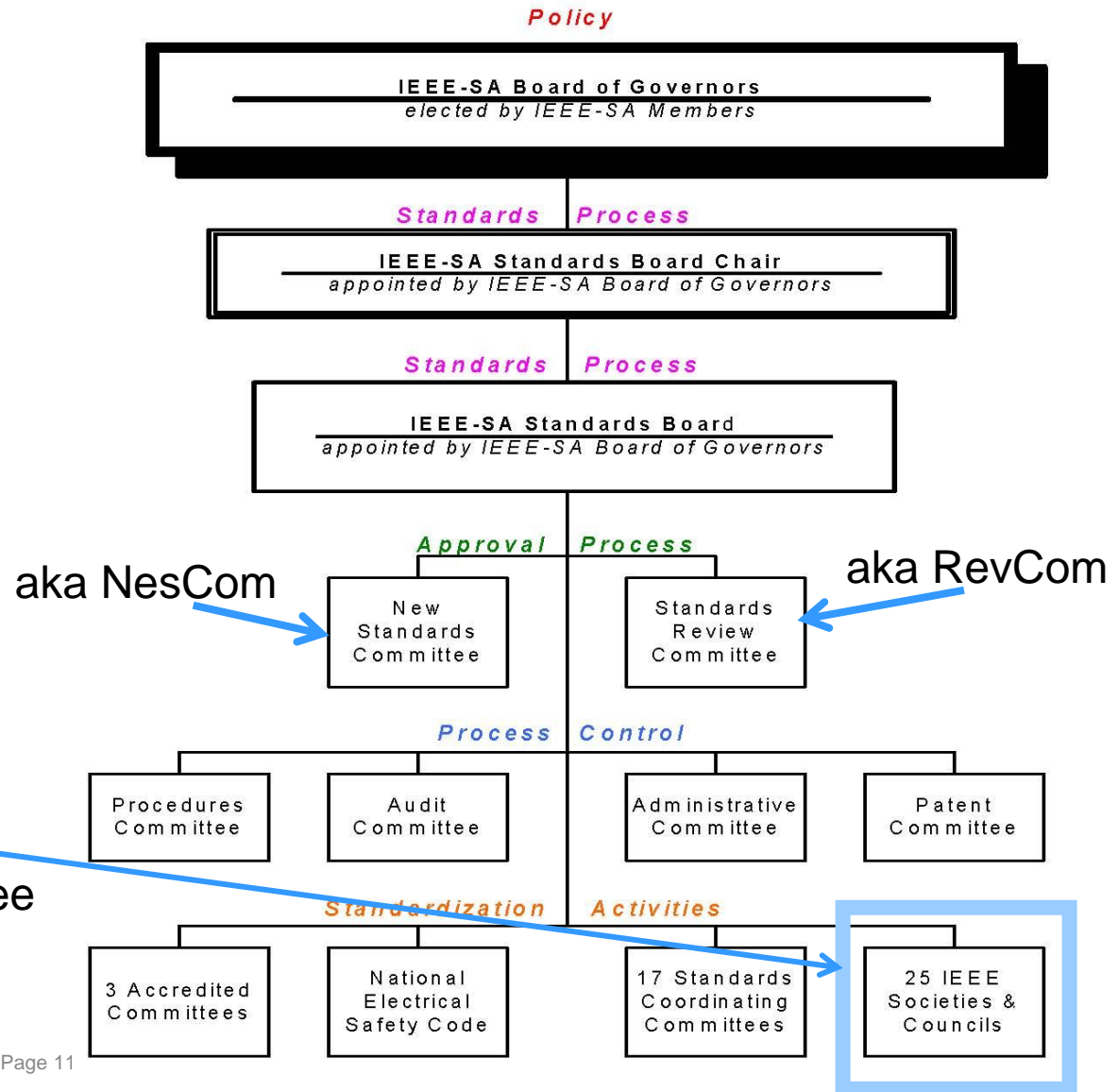
# IEEE 802.1 Overview

# 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



IEEE 802 is here:  
a standards committee  
formed by the  
Computer Society

# 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

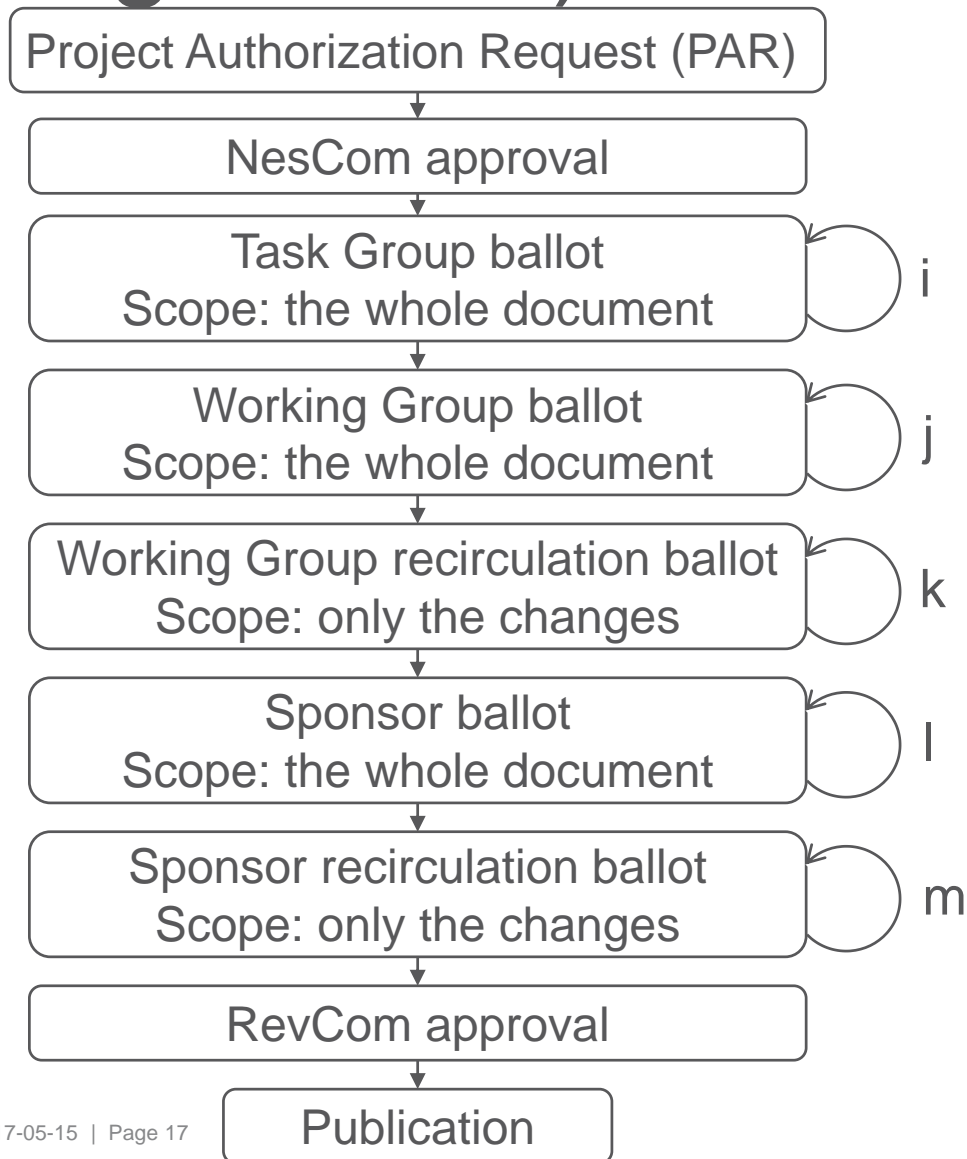
- › Chair: Glenn Parsons
- › Vice-chair: John Messenger
- › Addressing and Data Center Bridging (DCB) TG
  - Chair: Patricia Thaler
- › Maintenance TG
  - Chair: John Messenger
- › OmniRAN TG
  - Chair: Maximilian Riegel
- › Security TG
  - Chair: Michael Seaman
- › Time-Sensitive Networking (TSN) TG
  - 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: <http://www.ieee802.org/1/meetings>
- 802 agenda (meeting rooms): <http://802world.org/attendee>
- attendance: <https://imat.ieee.org>
- TSN agenda: <http://www.802tsn.org/agenda>
  - › agenda request: <http://www.802tsn.org/agenda-for-next-meeting>

## › Virtual

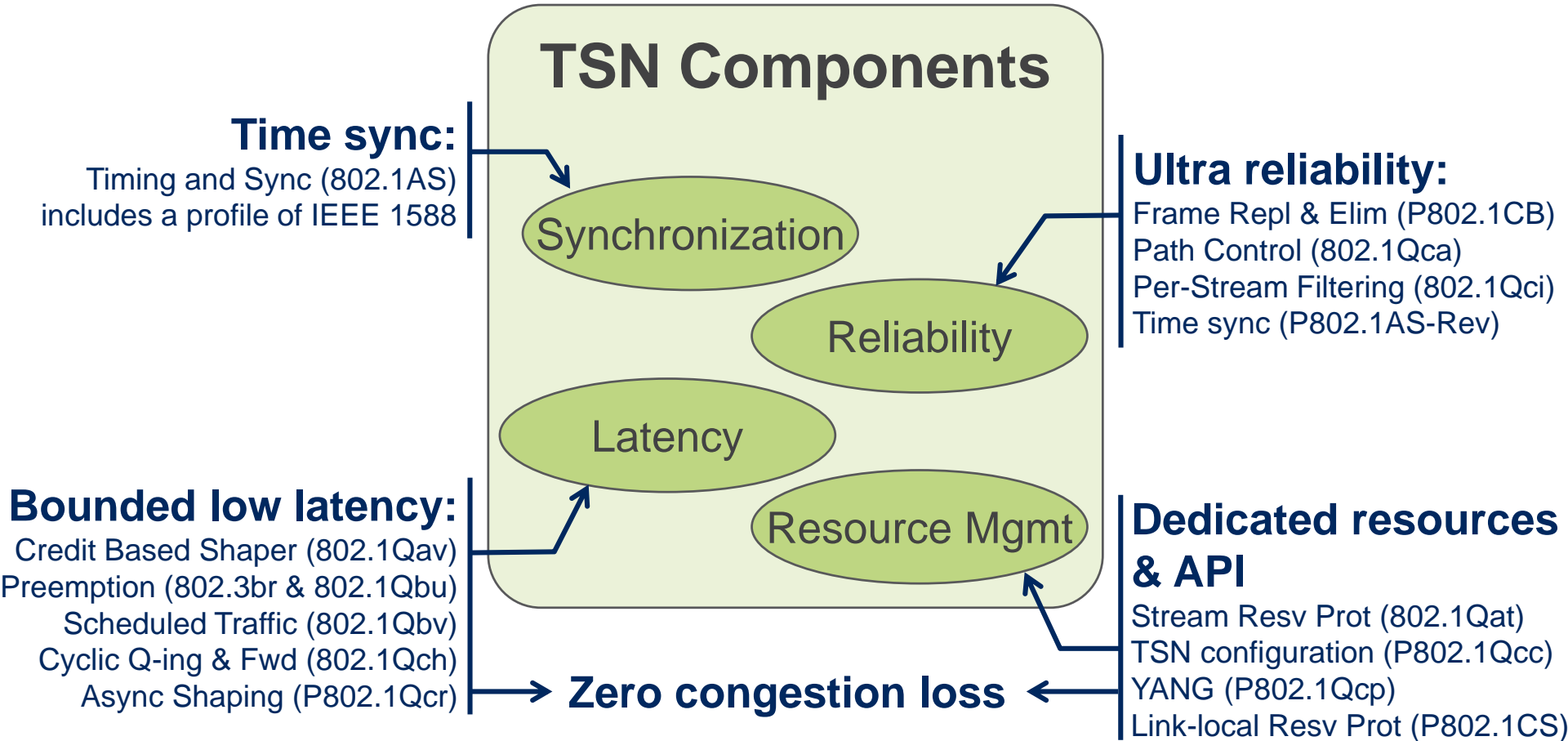
- TSN virtual meetings: <http://www.ieee802.org/1/pages/tsn.html>  
(<https://join.me/ieee802.1>)
  - › **Mondays: 8am PT: Generic TSN** – 9am PT: Synchronization
  - › agenda request by **Thursday**:  
<http://www.802tsn.org/weekly-call-agenda-requests>
- Virtual meetings of each Task Group are announced on the 802.1 email list
  - › TSN agenda items or cancellation on **Friday**

# Further Navigation

- › <http://www.ieee802.org/1> (projects, drafts, everything)
  - TSN: <http://www.ieee802.org/1/pages/tsn.html> (conference calls, etc.)
- › public folder: <http://www.ieee802.org/1/files/public>
- › file upload – at the bottom of <http://www.ieee802.org/1/filenaming.html>
  - Follow the file naming conventions please
- › email list: <http://www.ieee802.org/1/email-pages>
- › ongoing ballots: <http://www.ieee802.org/1/email-pages/ballots.html>
- › minutes & opening/closing plenary slides: <http://www.ieee802.org/1/pages/minutes.html>
- › IEEE 802 “Get” program: <https://standards.ieee.org/about/get/802/802.1.html>

# 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 of 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  $\mu$ 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**
- › P802.1Qcc – Stream Reservation Protocol (SRP) Enhancements & Performance Improvements and TSN configuration
- › *P802.1Qcj – Auto-attach to PBB services*
- › *P802.1Qcp – YANG Data Model*
- › P802.1Qcr – Asynchronous Traffic Shaping (ATS)
- › P802.1AS-Rev – Timing and Synchronization - Revision
- › 802.1CB – Frame Replication and Elimination for Reliability
- › P802.1CM – Time-Sensitive Networking for Fronthaul
- › P802.1CS – Link-local Registration Protocol (LRP)

} related  
} related

# Status & Industry Interest

Standard / Project	Subject	Status	D #	Industry			
				P	A	I	M
P802.1AS-Rev	Time synchronization	TG	4.5				
802.1Qbu	Frame Preemption	Published					
802.1Qbv	Scheduled Traffic	Published					
802.1Qca	IS-IS Path Control & Rsv	Published					
P802.1Qcc	SRP Enhancements	WG	1.4				
802.1Qch	Cyclic Queuing	Approved					
802.1Qci	Per-Stream Filtering	Published					
P802.1Qcj	Auto-attach to PBB	Editor	0.1				
P802.1Qcp	YANG	WG	1.1				
P802.1Qcr	Asynchronous Shaping	TG	0.1				
802.1CB	Frame Repl. & Elimin.	Approval	2.8				
P802.1CM	TSN for Fronthaul	TG	0.5				
P802.1CS	LRP (Registration)	Editor					

M: Mobile

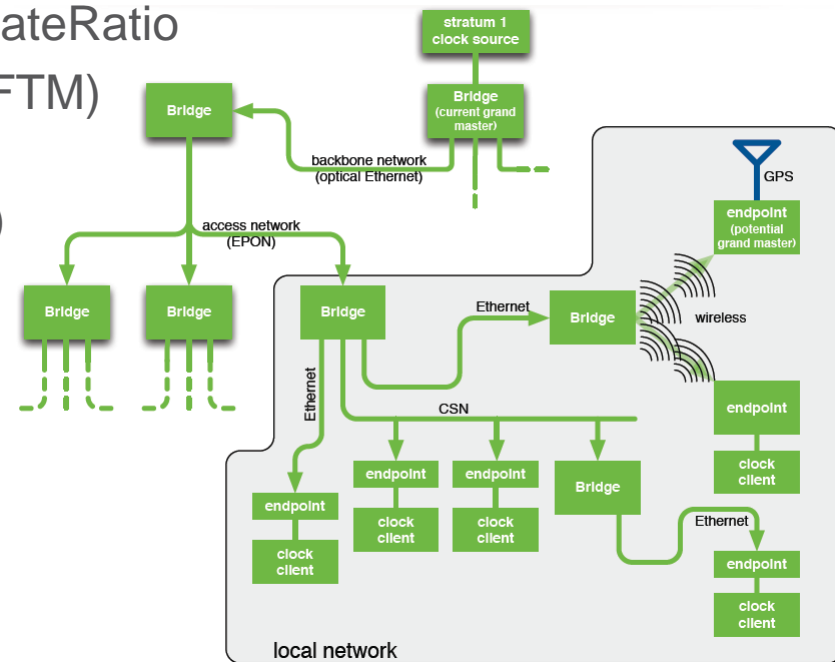
I: Industrial

A: Automotive

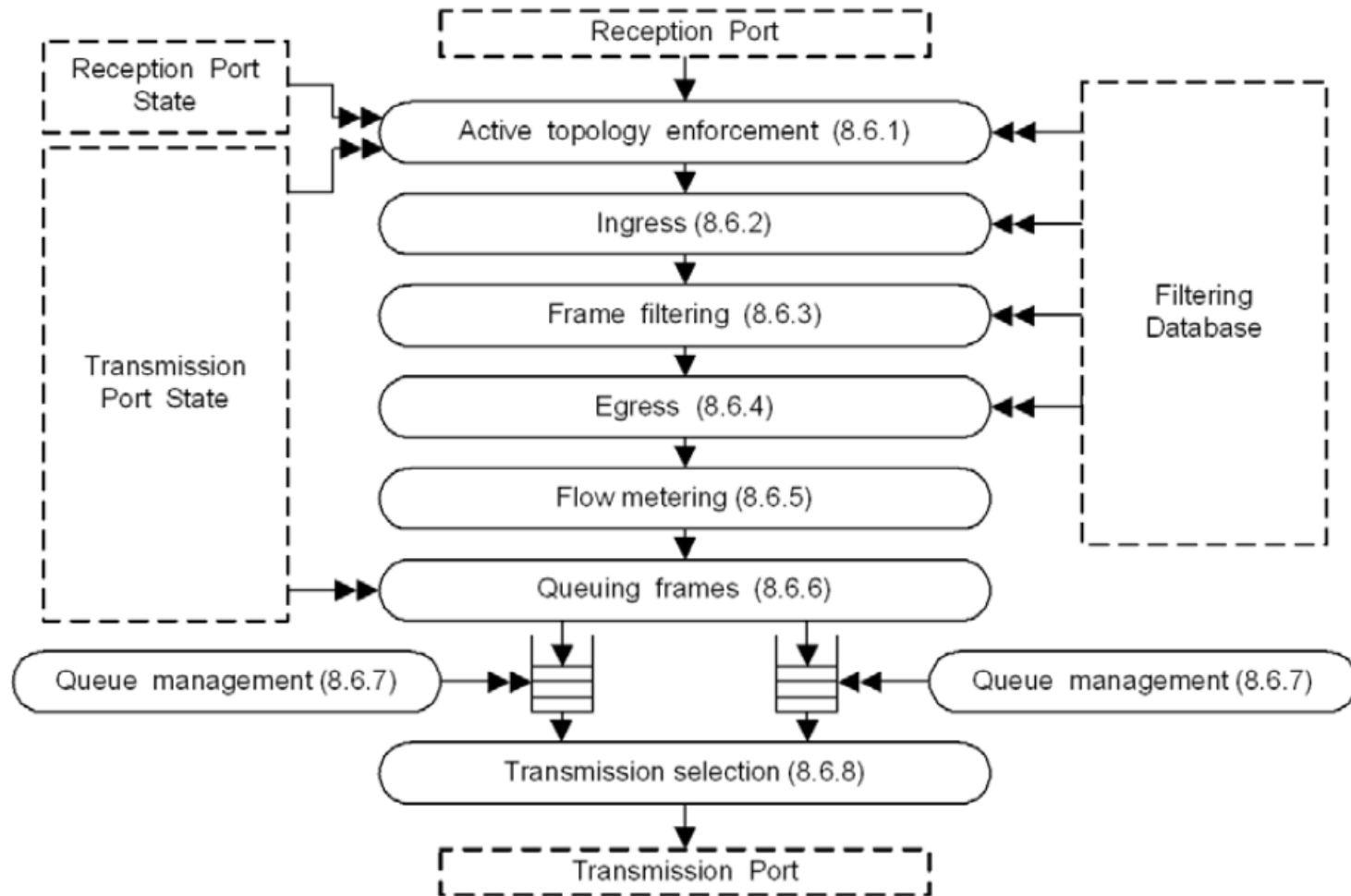
P: pro AV

# 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)



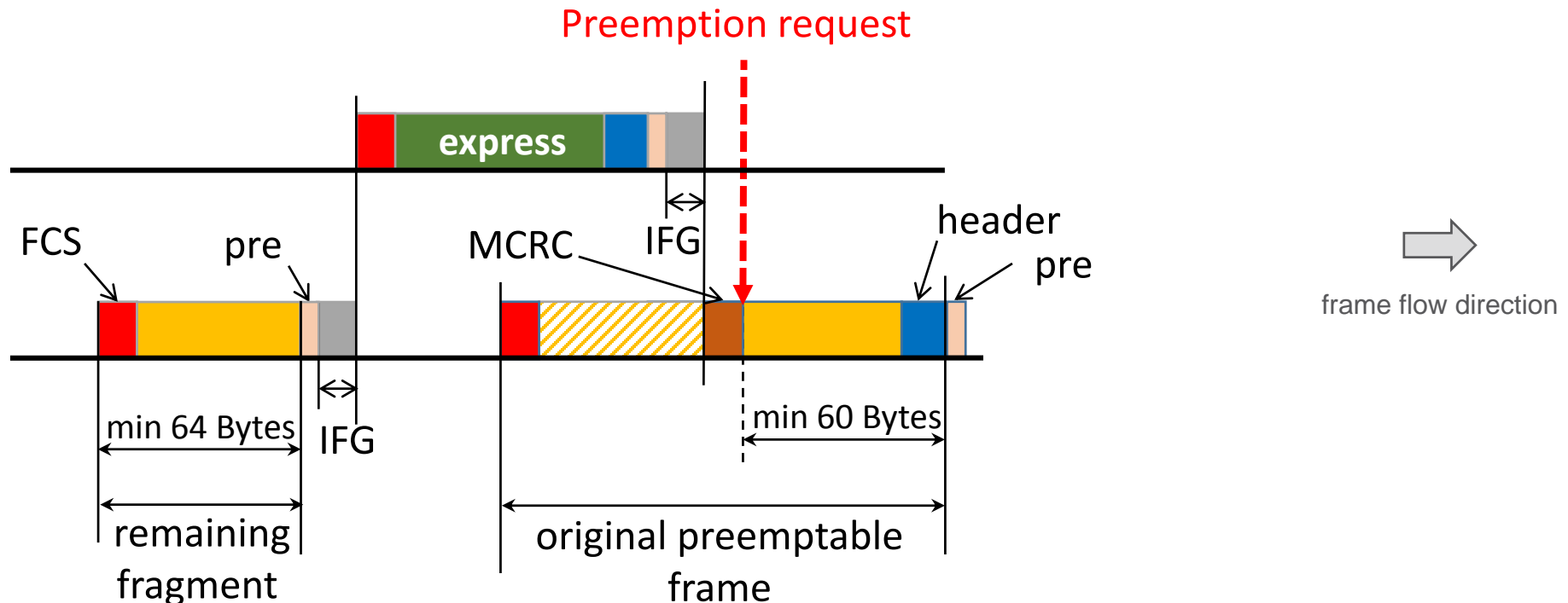
# Lookout – Forwarding Process in 802.1Q



› We will refer to it very soon

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

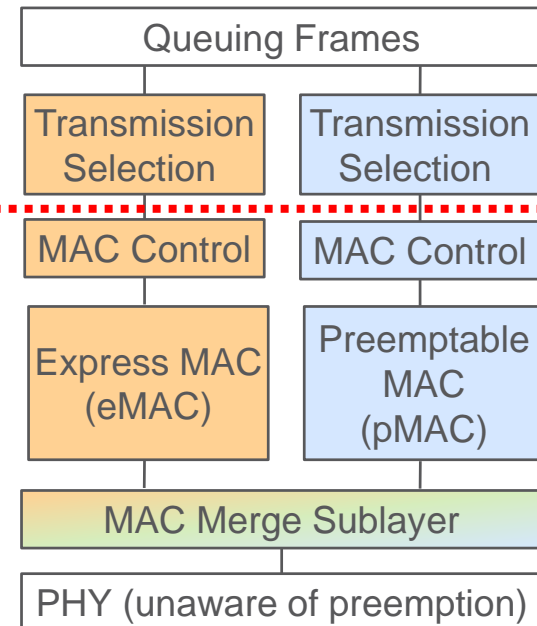
- › Express frames can suspend the transmission of preemptable frames



of preemptable frame

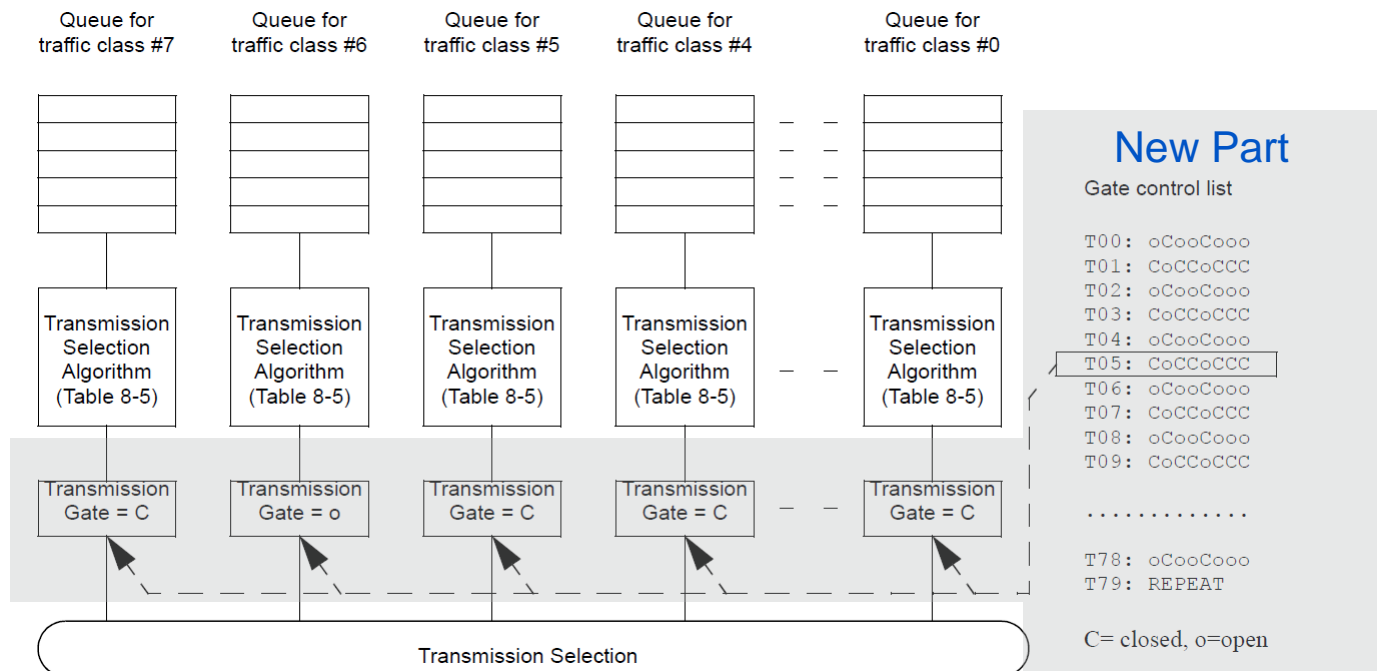
# Frame Preemption / Interspersing Express Traffic

- › 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



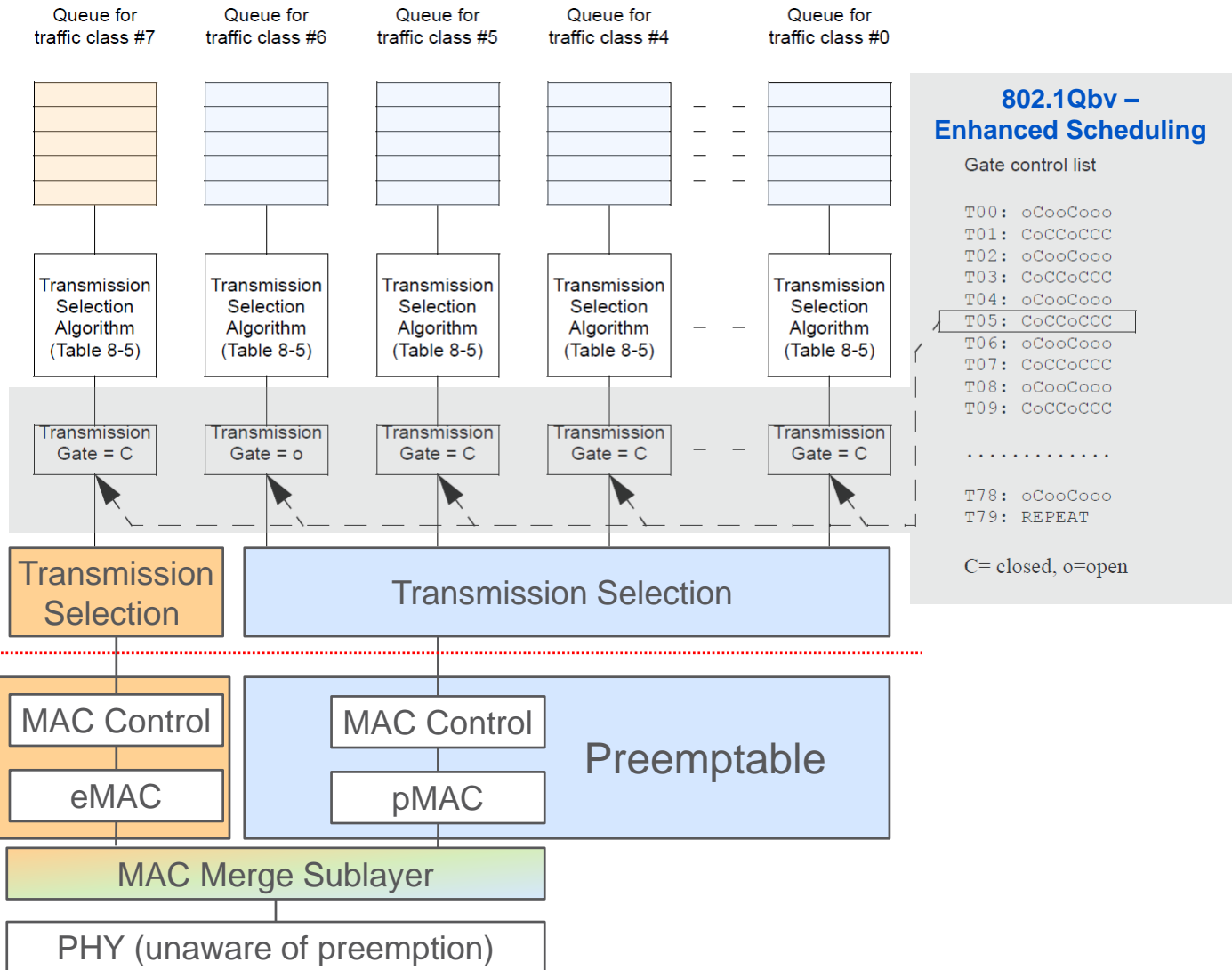
# 802.1Qbv – Enhancements for Scheduled Traffic

- › 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

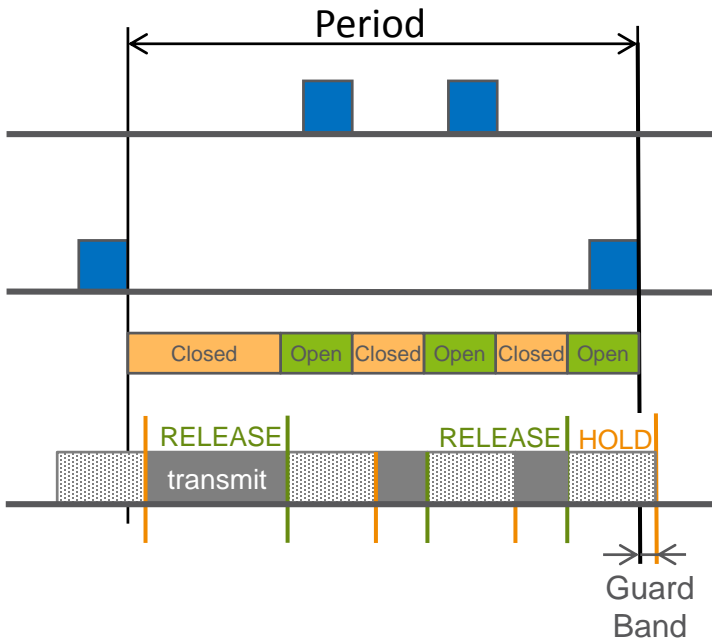
802.3br  
Interspersing  
Express Traffic (IET)





# Frame Preemption and Enhancements for Scheduled Traffic with Guard Band

Example 1



Legend

*Express From Port 1*

*Express From Port 2*

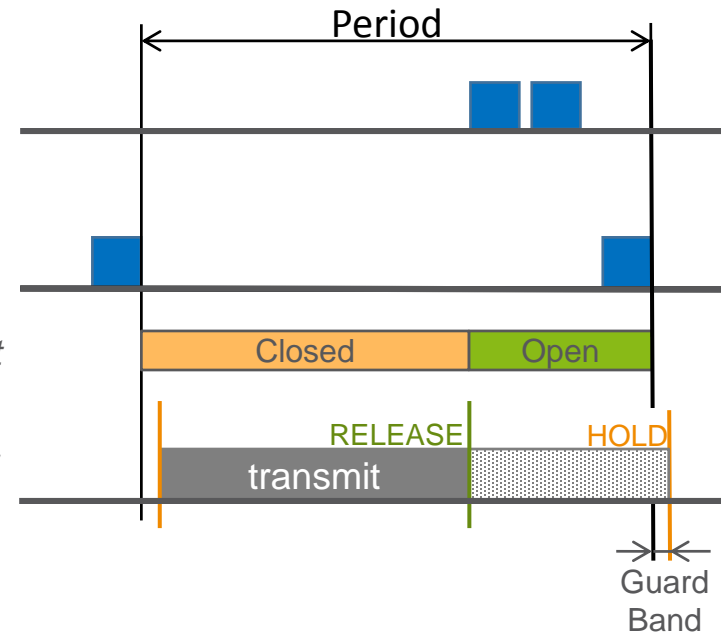
*Express Gate at egress port*

*Preemptible at egress port*



*frame flow direction*

Example 2



- › Guard band can protect the express traffic completely from interference from preemptible traffic

# 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

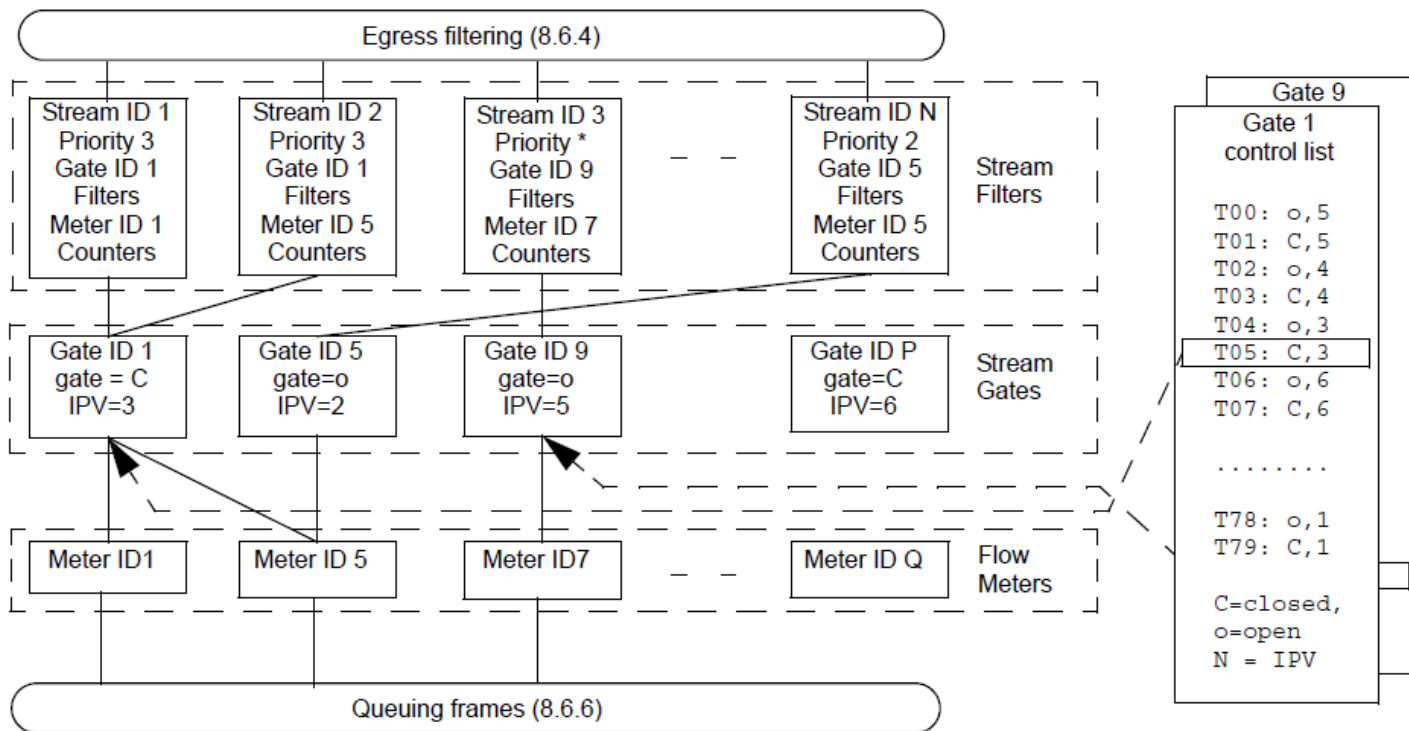
- Stream ID
- Priority
- Filters
- Meter ID
- Counters

› Stream gate

- open (o)
- Closed (C)

› Flow meter

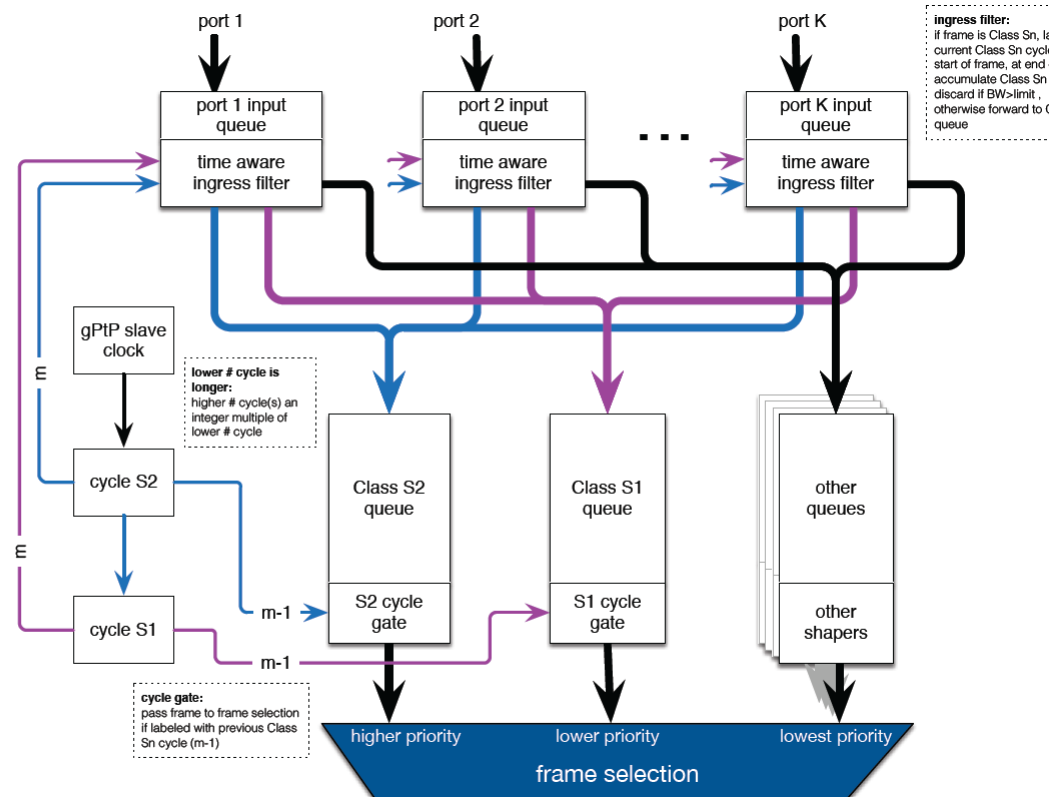
- Parameters as specified in Bandwidth Profile Parameters and Algorithm in MEF 10.3, plus some additional parameters



# 802.1Qch – Cyclic Queueing and Forwarding (CQF)

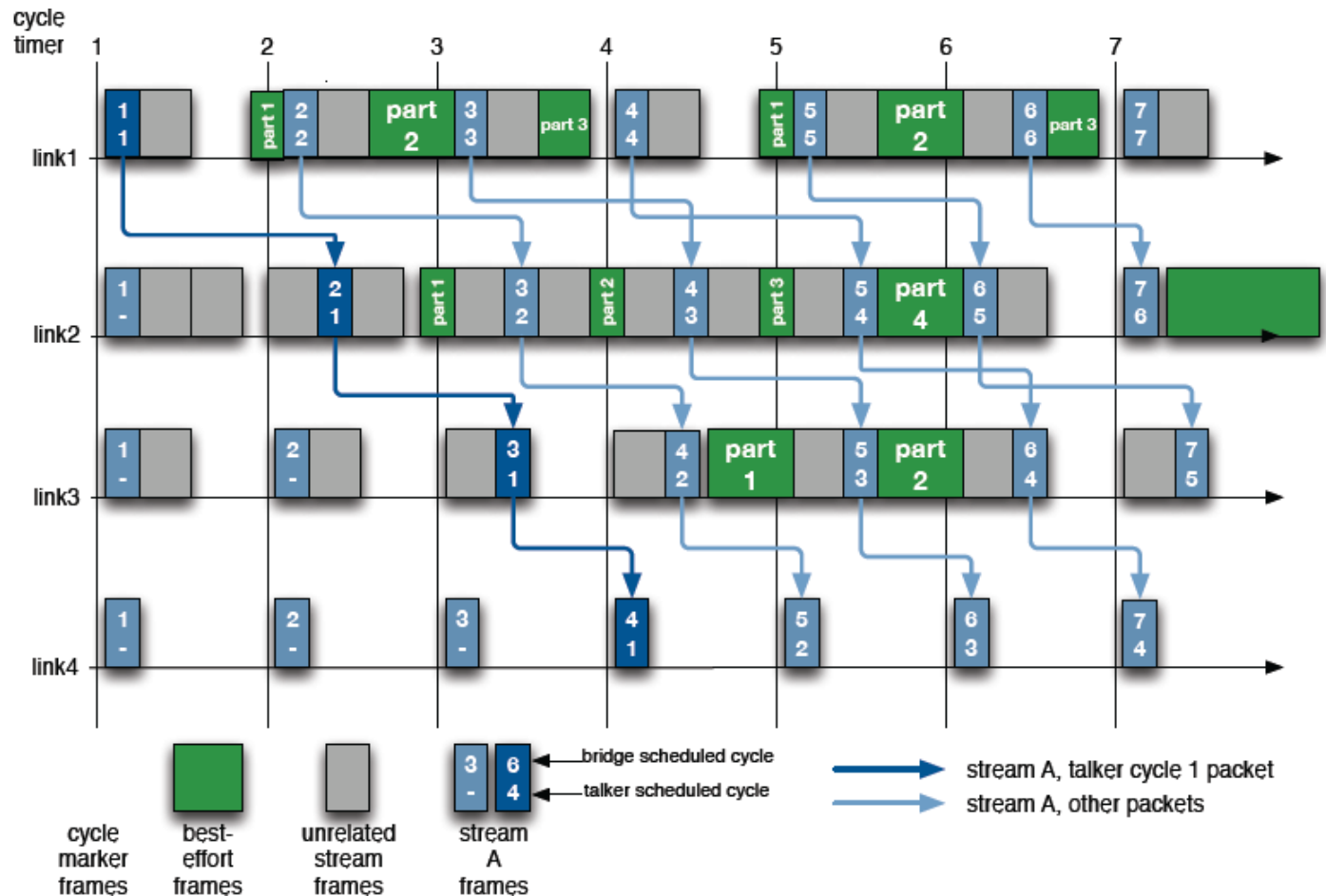
- › Synchronized cyclic enqueueing and queue draining achieve zero congestion loss and deterministic latency
- › Two buffers served alternated, e.g., that of S1 and S2
- › To be combined with frame preemption, see next slide

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

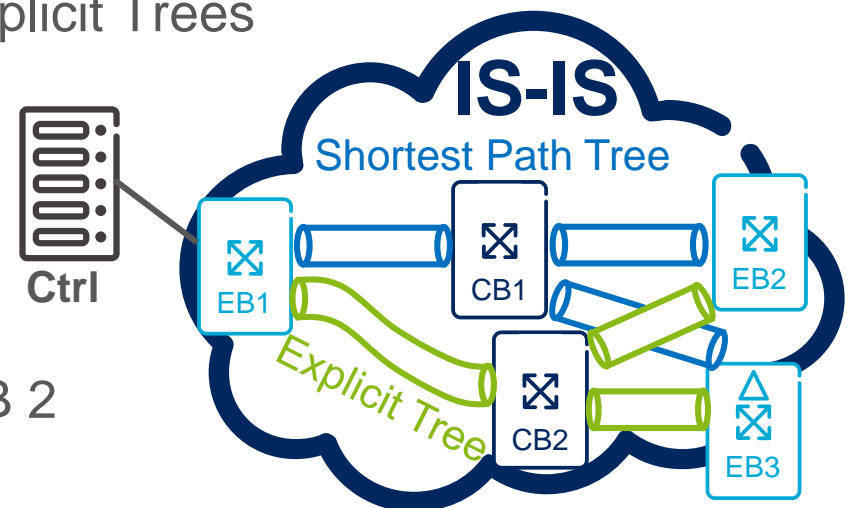


# 802.1Qca – IS-IS Path Control & Reservation

- › 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

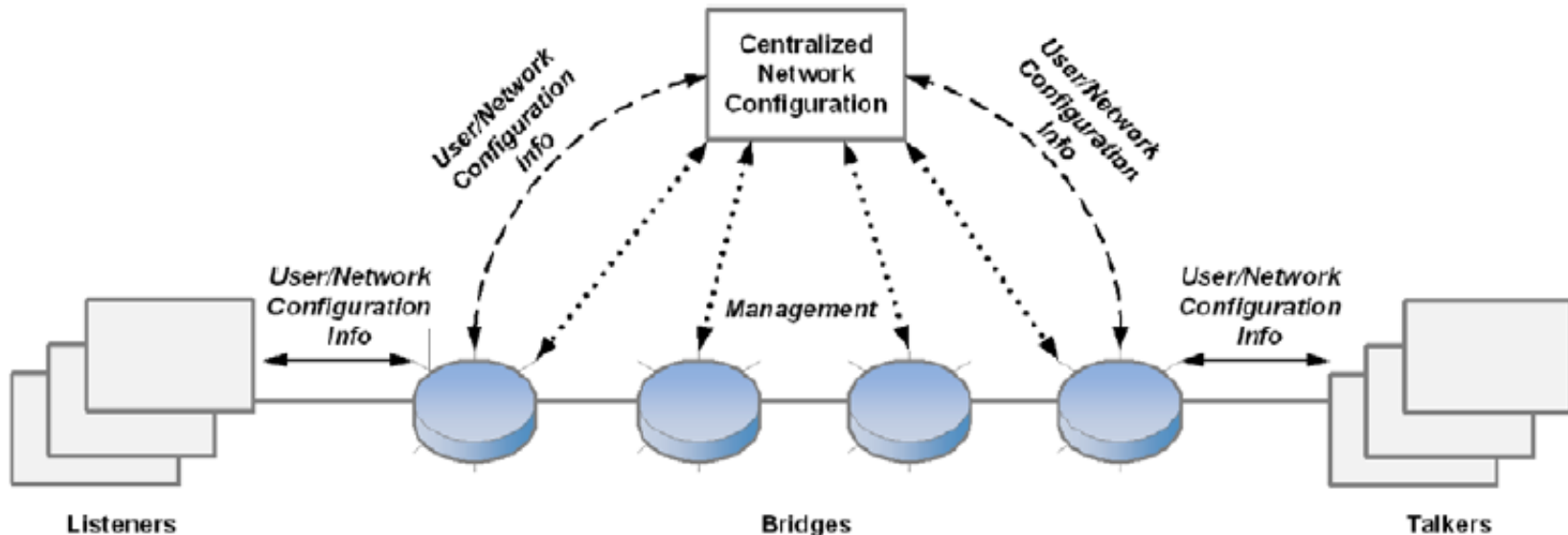
## › Example

- 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



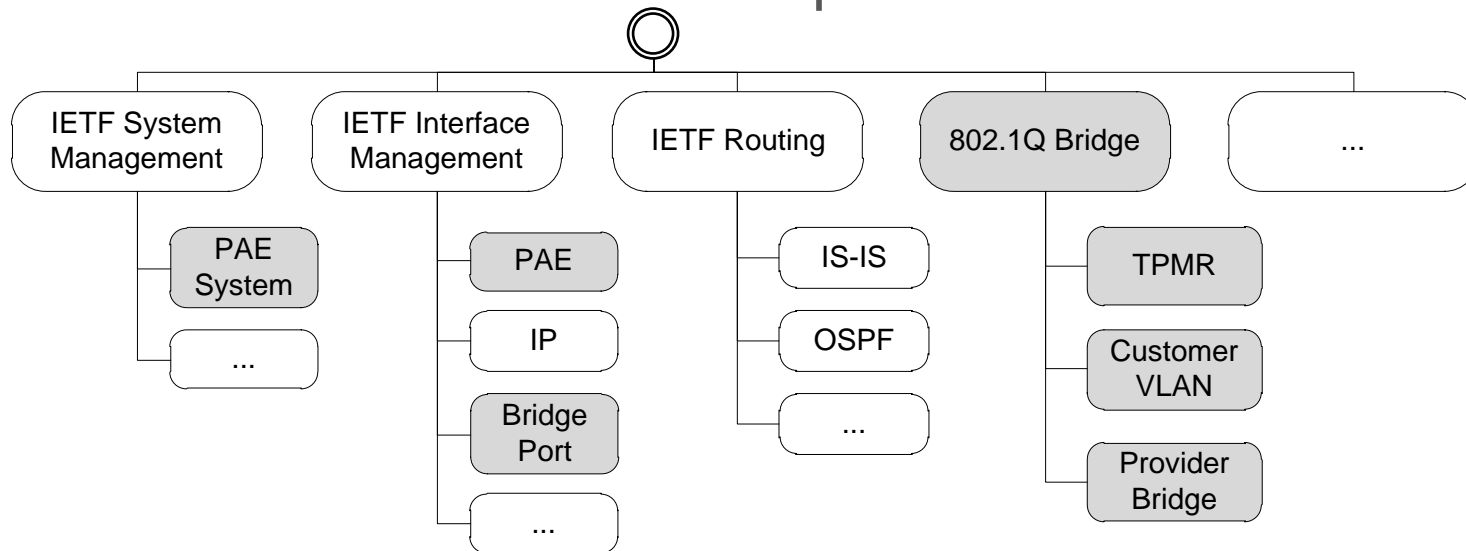
# P802.1Qcc – Stream Reservation Protocol (SRP) Enhancements

- › 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

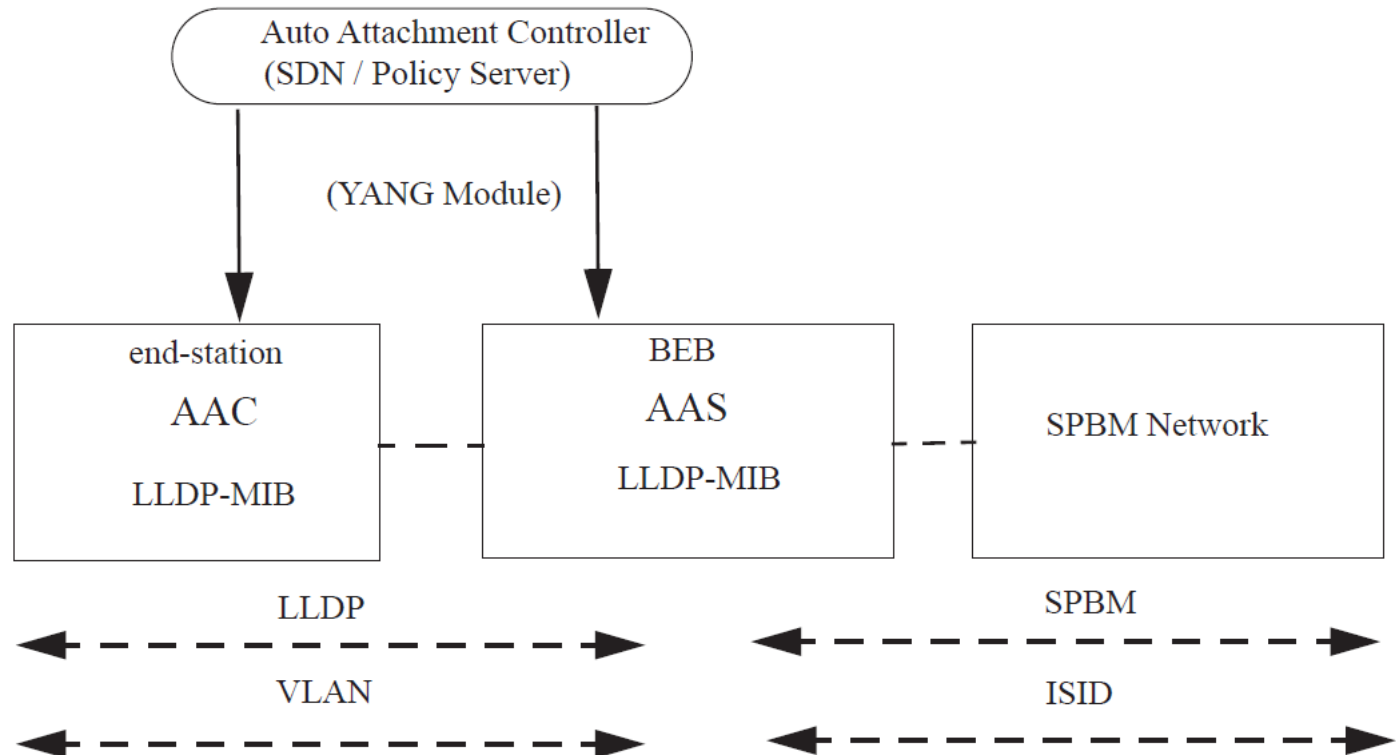


- › GitHub as a repository: <https://github.com/YangModels/yang/tree/master/standard/ieee>  
<http://www.ieee802.org/1/files/public/docs2016/cp-mholness-Bridge-Port-YANG-0816-v053.pdf>

# P802.1Qcj – Auto-attach to PBB services

## › Auto Attach Model

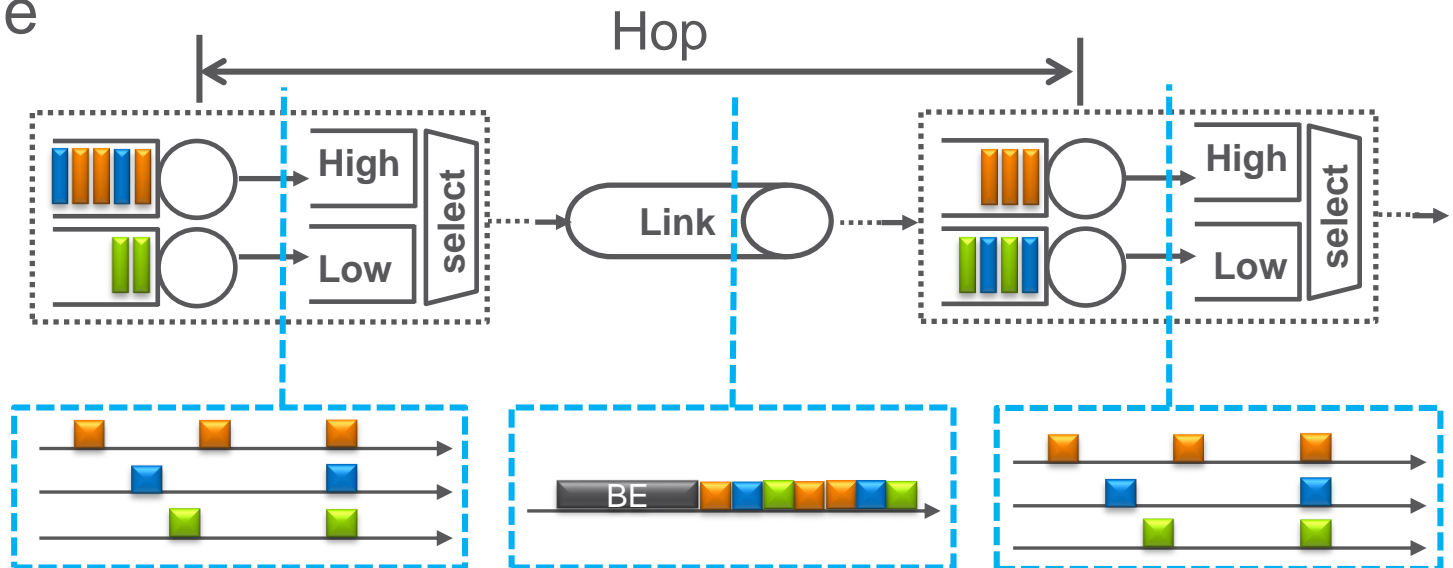
- Auto Attach Clients (AAC): non-Provider Backbone Bridging (PBB) device
- Auto-Attach Server (AAS): PBB device, e.g., Backbone Edge Bridge (BEB)





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

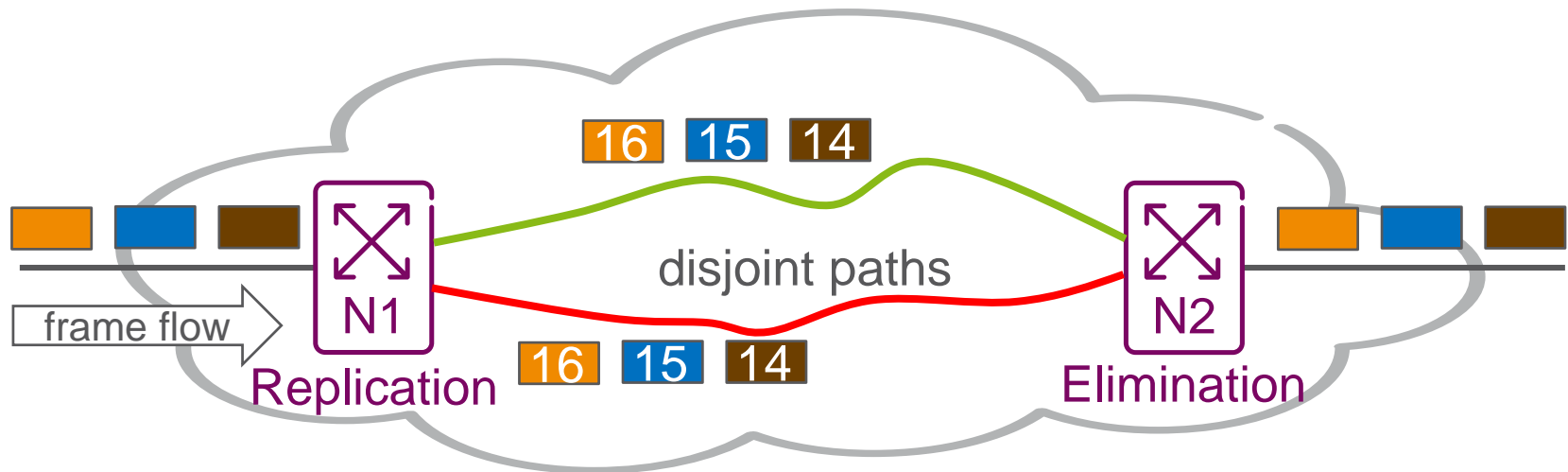
- › Asynchronous: no time synchronization needed
- › Basic idea
  1. Smoothen traffic patterns by re-shaping per hop
  2. Prioritize urgent traffic over relaxed traffic
- › Example



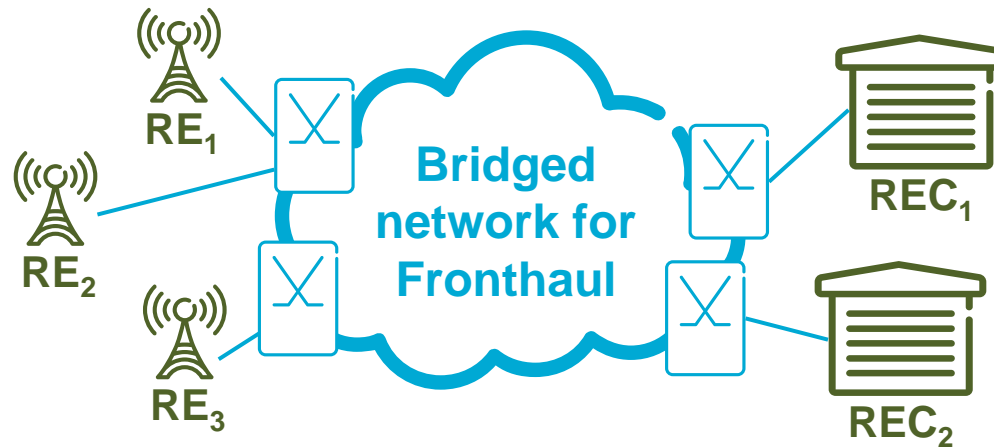
\* formerly referred to as Urgency Based Scheduler (UBS)

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

- › It is a per-frame 1+1 (or 1+n) redundancy
- › Serialize frames, send on 2 (or more) maximally disjoint paths, then combine and delete extras



# P802.1CM – TSN for Fronthaul



- › Develop standard TSN Profiles for Fronthaul in order to enable the transport of Fronthaul streams in a bridged network
- › Current focus: Profile(s) for current ([CPRI 7.0](#)) Radio Base Station (RBS) split such that the different Fronthaul flows (IQ, C&M, and Sync) are supported **separately** from each other
- › Next step is eCPRI: <http://www.cpri.info/press.html>
- › 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

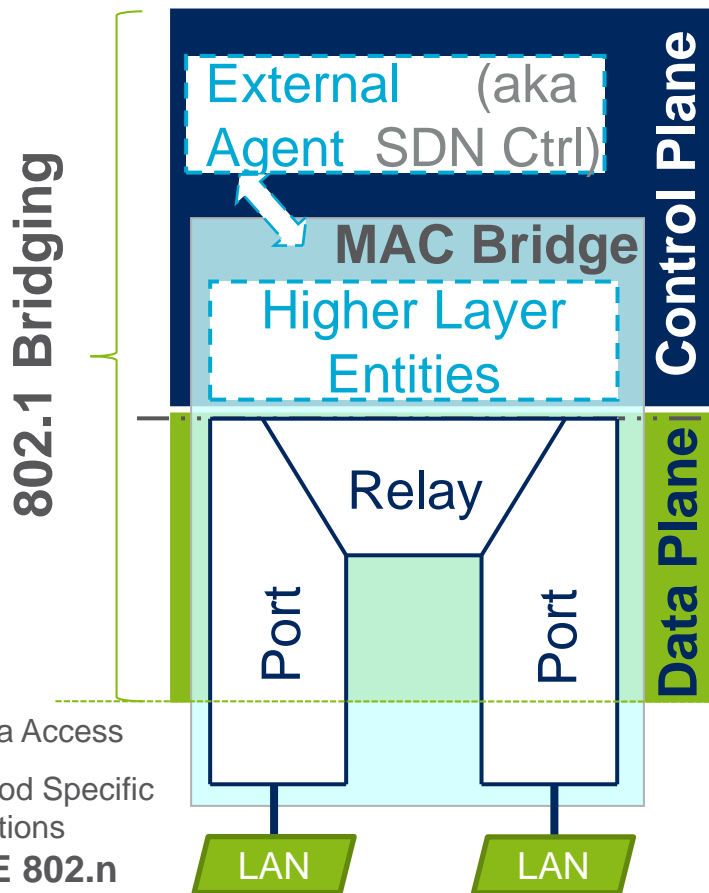
- › <http://www.ieee802.org/1>
- › <http://www.802tsn.org>
- › “A Time-Sensitive Networking Primer: Putting It All Together”  
[https://drive.google.com/file/d/0B6Xurc4m\\_PVsZ1lzWWoxS0pTNVE/view?usp=sharing](https://drive.google.com/file/d/0B6Xurc4m_PVsZ1lzWWoxS0pTNVE/view?usp=sharing)
- › “Heterogeneous Networks for Audio and Video: Using IEEE 802.1 Audio Video Bridging” <http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6595589>
- › Tutorial on IEEE 802.3br 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](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](http://www.ieee802.org/802_tutorials/2012-11/8021-tutorial-final-v4.pdf)
- › Tutorial on IEEE 802.1Q [http://www.ieee802.org/802\\_tutorials/2013-03/8021-IETF-tutorial-final.pdf](http://www.ieee802.org/802_tutorials/2013-03/8021-IETF-tutorial-final.pdf)
- › SDN by 802.1Q: <https://arxiv.org/abs/1405.6953>  
<http://www.ieee802.org/1/files/public/docs2014/Q-farkas-SDN-support-0314-v01.pdf>
- › [https://en.wikipedia.org/wiki/Audio\\_Video\\_Bridging](https://en.wikipedia.org/wiki/Audio_Video_Bridging)

# Bridge Architecture

# Control Plane Separated from Data Plane

## (Basic SDN Characteristics)

Simplified “baggy pants” model



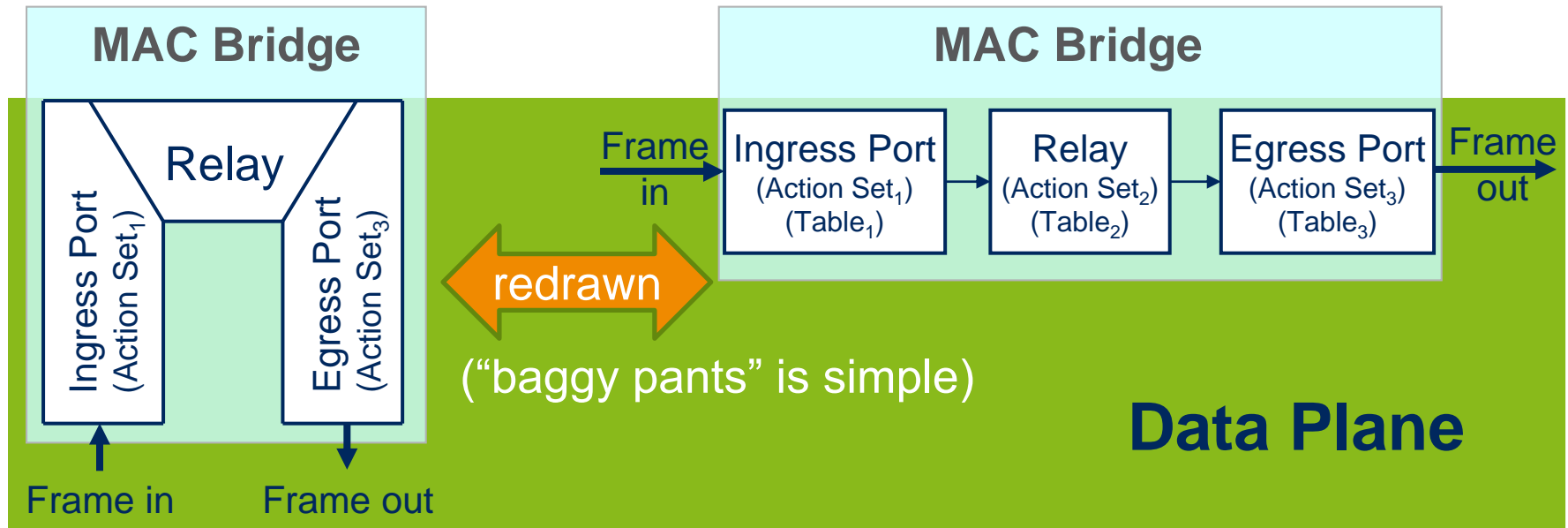
- › Control protocols are implemented as Higher Layer Entities
- › External Agent may provide control instead of the distributed protocols

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

Media Access  
Method Specific  
Functions  
IEEE 802.n  
  
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

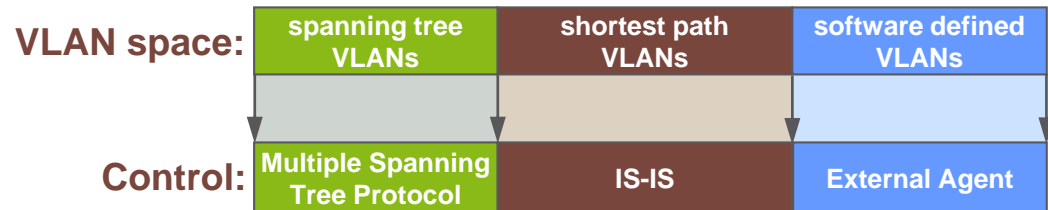


# Control Plane Overview

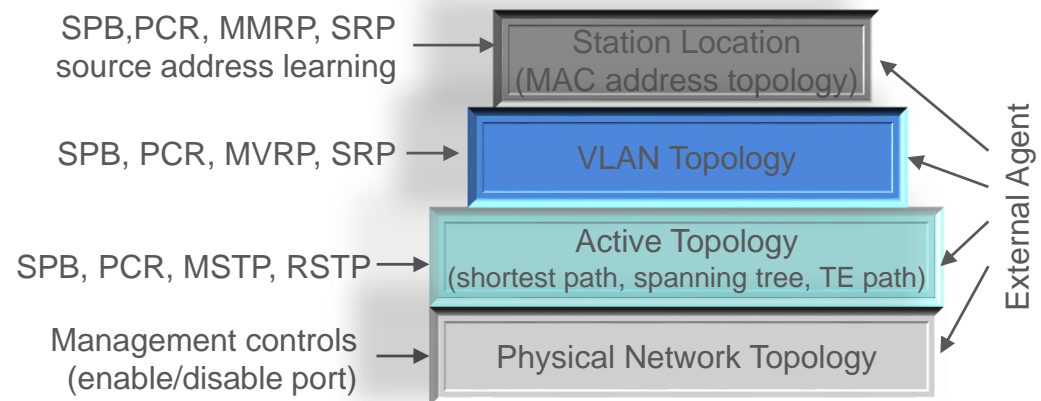


## > A VLAN is assigned to a control mode

- 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



## > Summary of control options



See You!