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STANDARDS ASSOCIATION

FOUNDATIONAL TECHNOLOGIES

TSN Time Sensitive Networking Powered by IEEE 802

DRIVING DIGITAL TRANSFORMATION THROUGH IEEE 802.1 TSN TECHNOLOGY

IEEE TIME-SENSITIVE NETWORKING AN INTRODUCTION TO IEEE 802.1

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IEEE

SPEAKER – GLENN PARSONS

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Glenn Parsons leads standards strategy and policy for Ericsson, including network architecture for 5G radio transport networks.
Glenn is an internationally known expert in networking, including mobile transport and Ethernet. Over the past number of years, he has held several technical management and editor positions in various standards activities including MEF, IETF, IEEE SA, and ITU-T. He has also held elected and appointed leadership roles in standardization governance in IEEE SA and ITU-T. He is currently involved with 5G transport standardization in IEEE SA and ITU-T and is the chair of IEEE 802.1 working group. In addition to being the founding Editor-in-chief for IEEE Communications Standards Magazine, he was previously a Senior Technical Editor for IEEE Communications Magazine.

He graduated in 1992 with a B.Eng. degree in electrical engineering from Memorial University of Newfoundland, Canada.

BEFORE WE START – DISCLAIMER

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OUTLINE

IEEE 802.1 working group

802.1 Architecture

802.1 Interworking

802.1 Time-Sensitive Networking (TSN)

802.1 TSN Components

Summary

IEEE SA STANDARDS ASSOCIATION

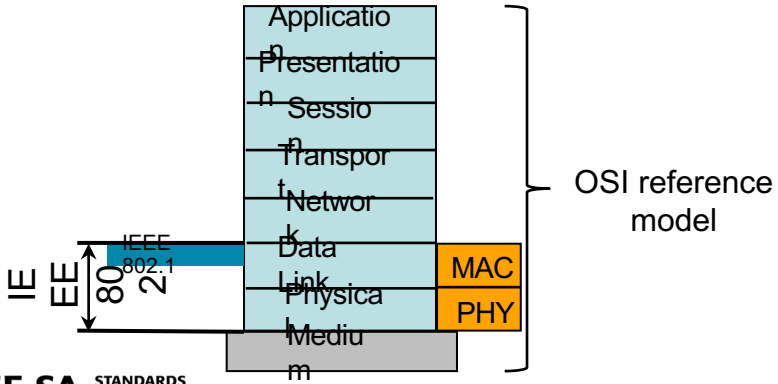
IEEE 802.1 WORKING GROUP

Architecture and Bridging

- Traditionally, the Higher Layer Interface

Part of the LAN / MAN Standards Committee

- Along with 802.3, 802.11, 802.15, …
- Wired and wireless standards for data link and physical layers
- In operation since March 1980

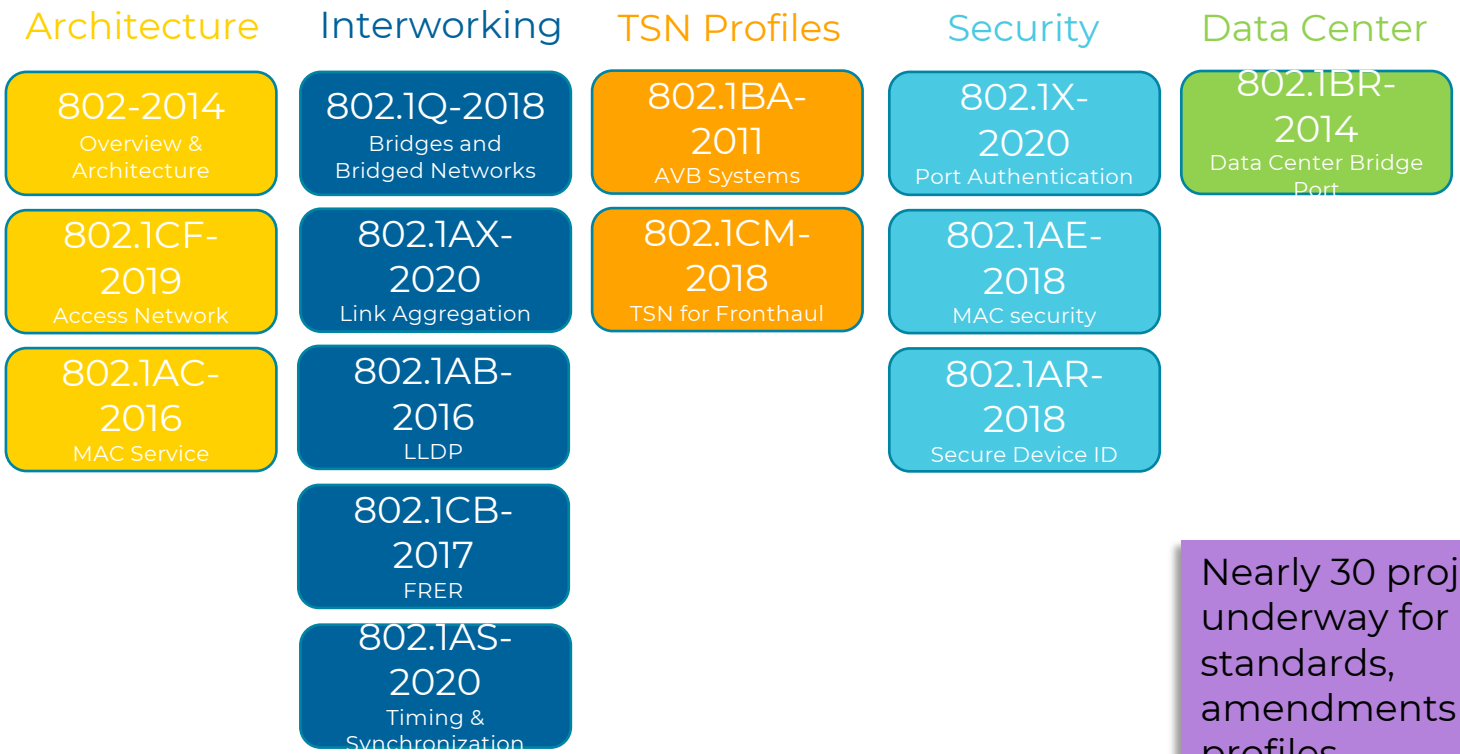


Group

Chair: Glenn Parsons
Vice-chair: Jessy Rouyer

- TSN Task Group — *Chair: János Farkas*
- Security Task Group — *Chair: Mick Seaman*
- Maintenance Task Group — *Chair: Paul Congdon*
- YANGsters — *Chair: Scott Mansfield*
- NENDica — *Chair: Roger Marks*

APPROVED IEEE 802.1 BASE STANDARDS



Nearly 30 projects are underway for new standards, amendments and profiles

802.1 ARCHITECTURE

802 REFERENCE MODEL

MSAP MAC service access point
LSAP link service access point

PSAP PHY service access point

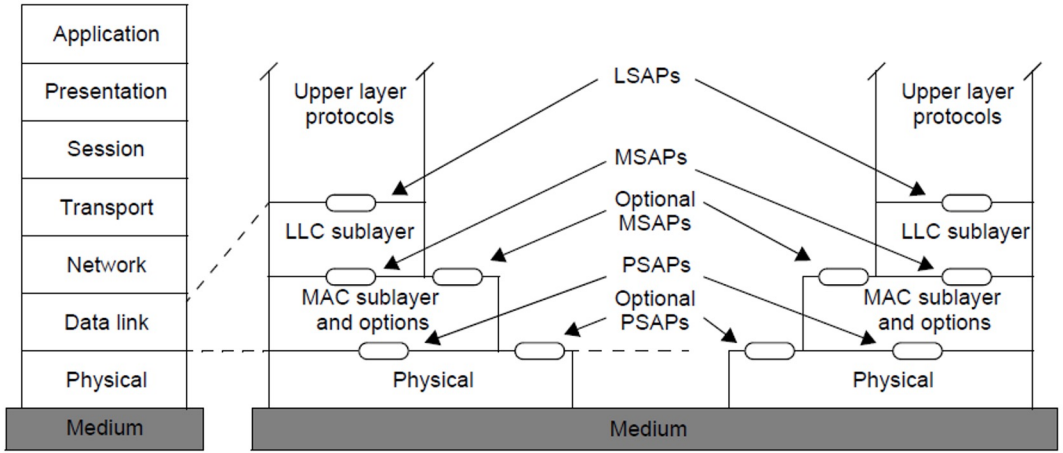


Figure 3 - IEEE Std 802

Current IEEE 802 family of working groups

802.1 Bridging and Architecture
802.3 Ethernet
802.11 Wireless LAN (WLAN)
802.15 Wireless Personal Area Network (WPAN)
802.16 Broadband Wireless Access (BWA)
802.21 Media Independent Handover
802.22 Wireless Regional Area Networks (WRAN)

BRIDGING TIES IT TOGETHER

IEEE Std 802.1AC specifies the MAC Service provided by all IEEE 802 LANs

IEEE Std 802.1Q specifies interworking among IEEE 802 LANs by bridging at the MAC sublayer

- Interworking can be heterogeneous (across different 802 technologies).
- MAC frames are forwarded (or filtered) based on address and Virtual LAN information in the MAC frame.
- Relaying and filtering belong entirely within the MAC sublayer.

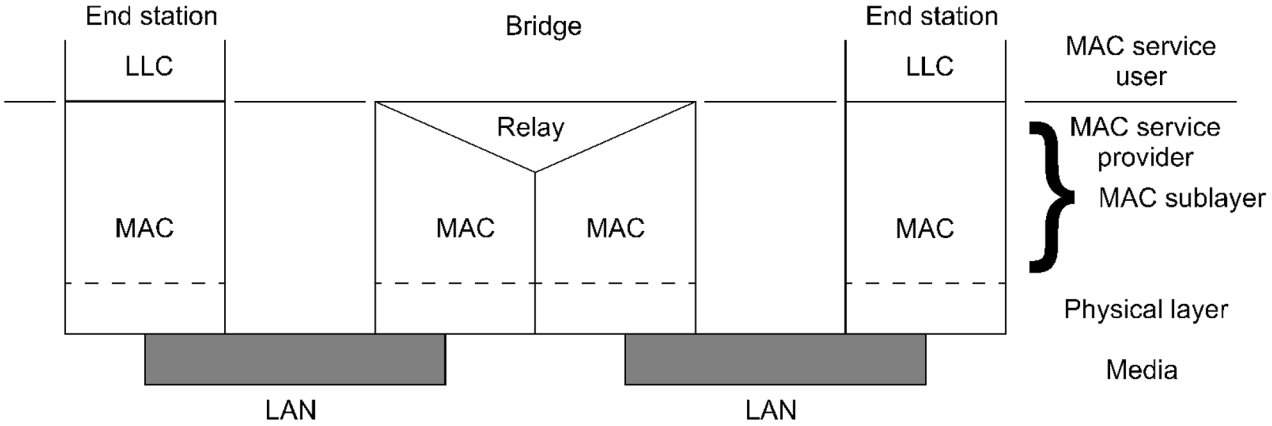


Figure 7 - IEEE Std 802

802.1 INTERWORKING

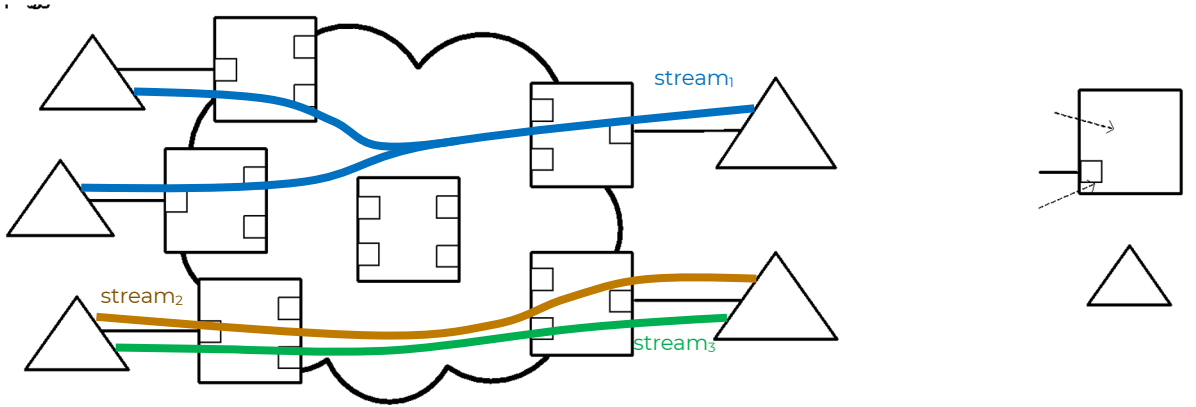
FUNDAMENTAL COMPONENTS

From the IEEE Std 802.1Q perspective, the world is divided into two types of devices: bridges and end stations

Talker: The end station that is the source or producer of a stream

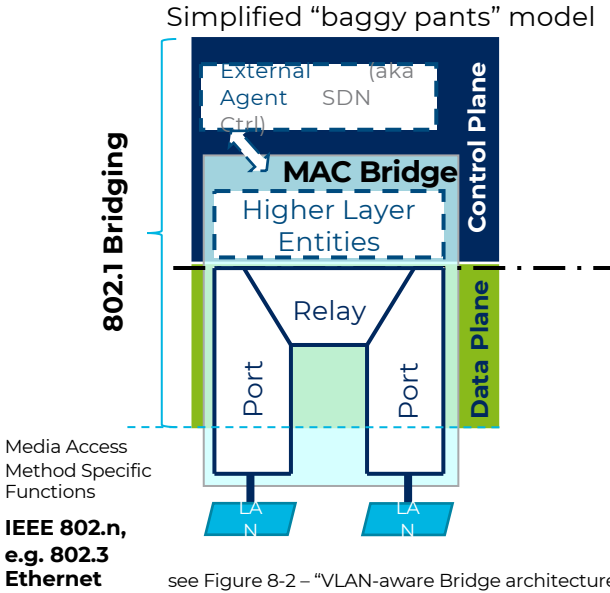
Listener: The end station that is the destination, receiver, or consumer of a stream

Stream: A unidirectional flow of data from a Talker to one or more Listeners



BRIDGE ARCHITECTURE

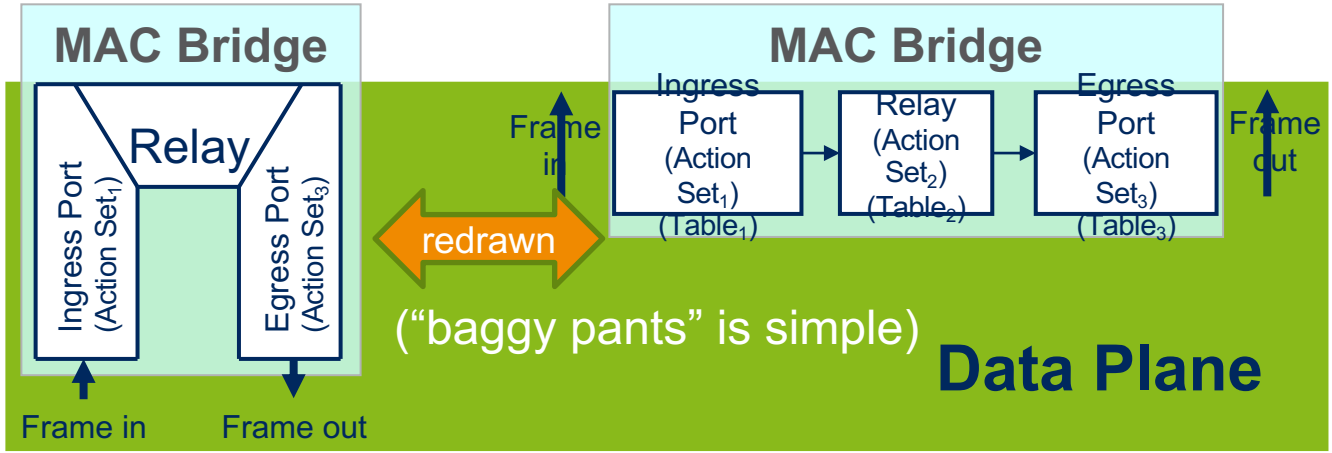
Control Plane Separated from Data Plane



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

- Control protocols are implemented as Higher Layer Entities
- External Agent (SDN Controller) may provide control instead of the distributed protocols
- The data plane is comprised of
  - A MAC Relay and
  - At least two ports

BRIDGE DATA PLANE ACTIONS



Ingress Port (Action Set$_1$)

Filtering (drop), (un)tagging, VID translation, de/en-capsulation

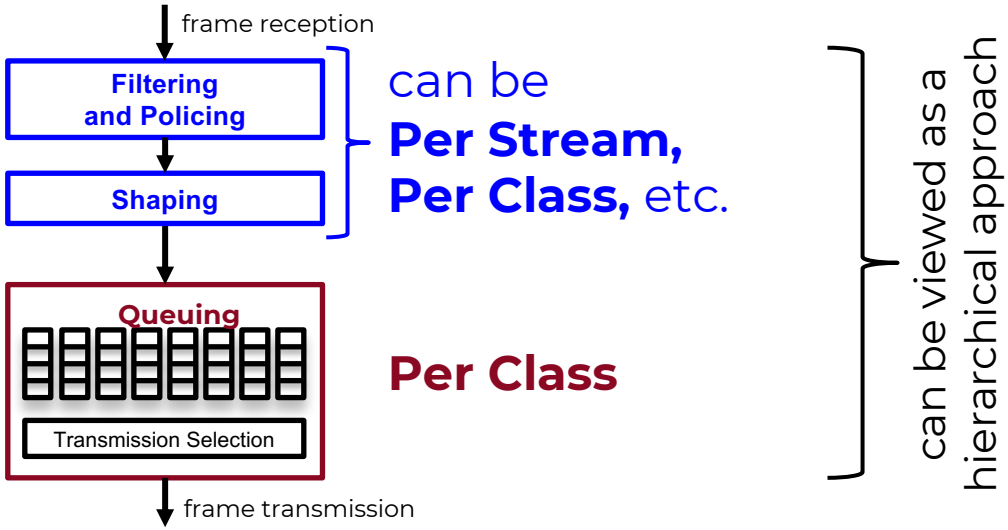
Relay (Action Set$_2$)

Forwarding, filtering

Egress Port (Action Set$_3$)

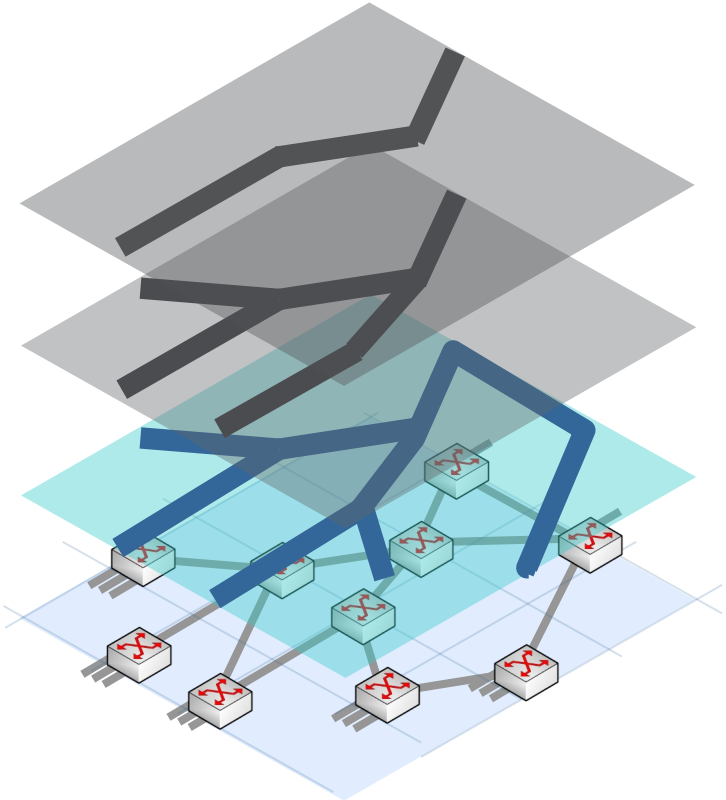
Filtering, (un)tagging, VID translation, de/en-capsulation, metering, queuing, transmission selection

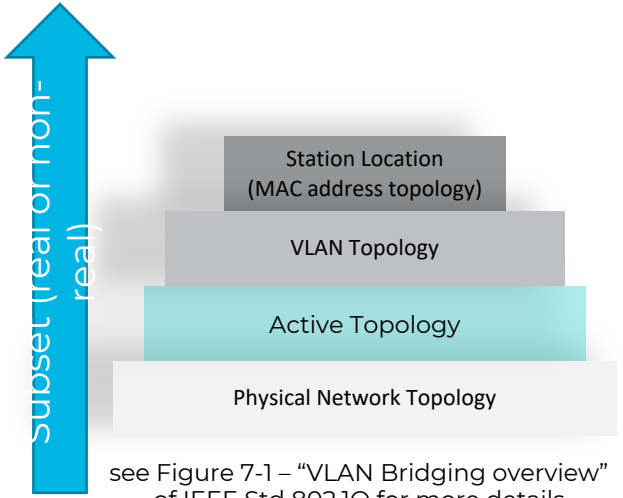
ILLUSTRATION OF QOS FUNCTIONS



note: other functions are not shown in this figure, e.g., relay, reliability

TOPOLOGY LAYERS (CONTEXTS)

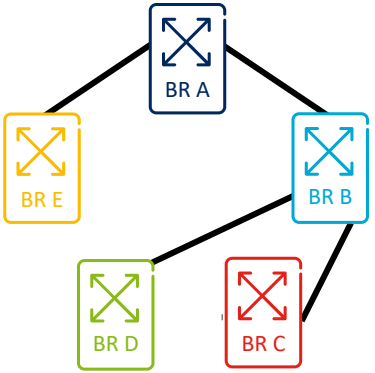




see Figure 7-1 – “VLAN Bridging overview” of IEEE Std 802.1Q for more details

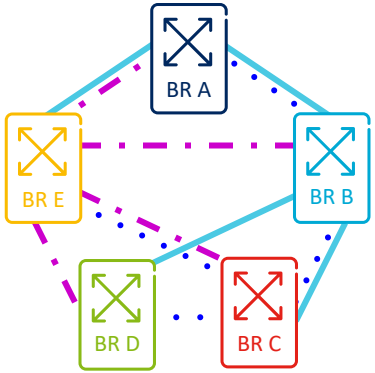
THE ACTIVE TOPOLOGY

Distributed Protocols for the Control Plane



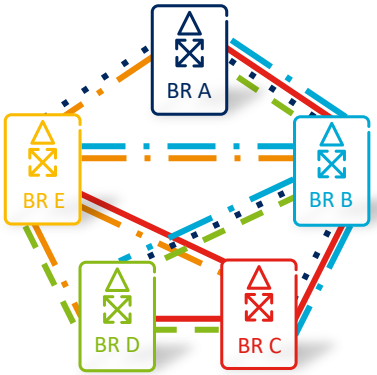
RSTP

Rapid Spanning Tree Protocol



MSTP

Multiple Spanning Tree Protocol



SPB

Shortest Path Bridging

- RSTP: a single spanning tree shared by all traffic
- MSTP: different VLANs may share different spanning trees
- SPB: each node has its own **Shortest Path Tree (SPT)**

Note: the Spanning Tree Protocol (STP) is historical, it has been replaced by RSTP

802.1 TIME-SENSITIVE NETWORKING

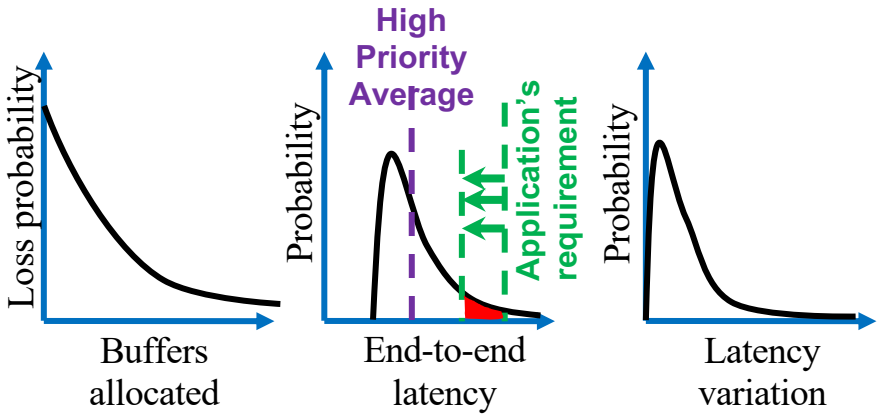
WE ARE INTERESTED IN DETERMINISTIC SERVICE

Traditional Service

Curves have long tail

Average latency is good

Lowering the latency means
losing packets (or overprovisioning)

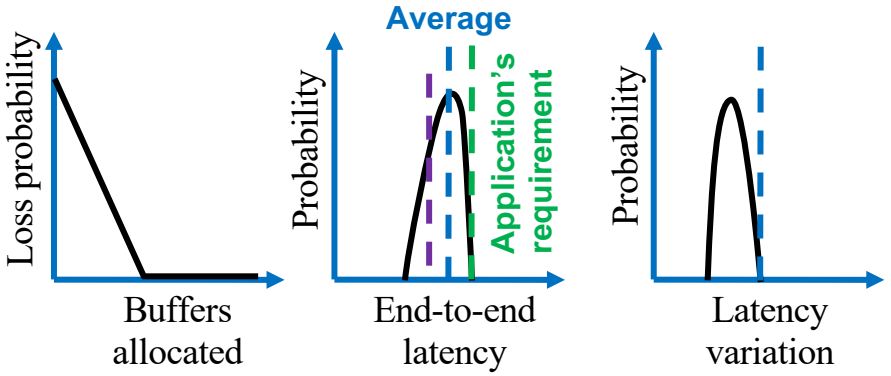


Deterministic Service

Packet loss is at most due to equipment failure (zero congestion loss)

Bounded latency, no tails

The right packet at the right time

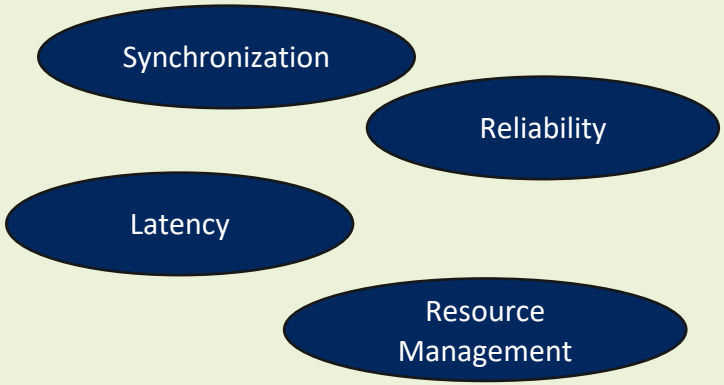


Time-Sensitive Networking (TSN) Profiles (Selection and Use of TSN tools)

Audio Video Bridging [802.1BA/Revision]	Fronthaul [802.1CM/de]	Industrial Automation [IEC/IEEE 60802]	Automotive In-Vehicle [P802.1DG]	Service Provider [P802.1DF]	Aerospace Onboard [IEEE P802.1DP / SAE AS6675]

TSN Components

(Tools of the TSN toolset)



Time synchronization:
Timing and Synchronization [802.1AS-2020]
(a profile of IEEE 1588)
Hot Standby [P802.1ASdm]
YANG [P802.1ASdn]
Inclusive Terminology [P802.1ASdr]
Support for Half-duplex [P802.1ASds]

High availability / Ultra reliability:
Frame Replication and Elimination [802.1CB]
Path Control and Reservation [802.1Qca]
Per-Stream Filtering and Policing [802.1Qci]
Reliability for Time Sync [802.1AS-2020]
Hot Standby [P802.1ASdm]

Bounded low latency:
Credit Based Shaper [802.1Qav]
Frame Preemption [802.1Qbu & 802.3br]
Scheduled Traffic [802.1Qbv]
Cyclic Queuing and Forwarding [802.1Qch]
Asynchronous Traffic Shaping [802.1Qcr]
Shaper Parameter Settings [P802.1Qdq]
Enhanced CQF [P802.1Qdv]
QoS Provisions [P802.1DC]

Dedicated resources & API:
Stream Reservation Protocol [802.1Qat]
Link-local Registration Protocol [802.1CS]
TSN Configuration [802.1Qcc]
Foundational Bridge YANG [802.1Qcp]
YANG for CFM [802.1Qcx]
YANG for LLDP [P802.1ABcu]
YANG for 802.1Qbv/Qbu/Qci [P802.1Qcw]
YANG & MIB for FRER [P802.1CBcv]
Extended Stream Identification [P802.1CBdb]
Resource Allocation Protocol [P802.1Qdd]
TSN Configuration Enhancements [P802.1Qdj]
LLDPv2 for Multiframe Data Units [P802.1ABdh]
Multicast and Local Address Assignment [P802.1CQ]

Zero congestion loss = Bounded latency

Note: A 'P' in front of '802.1' indicates an ongoing Project.

TSN PROFILES

An IEEE 802.1 TSN Profile specification

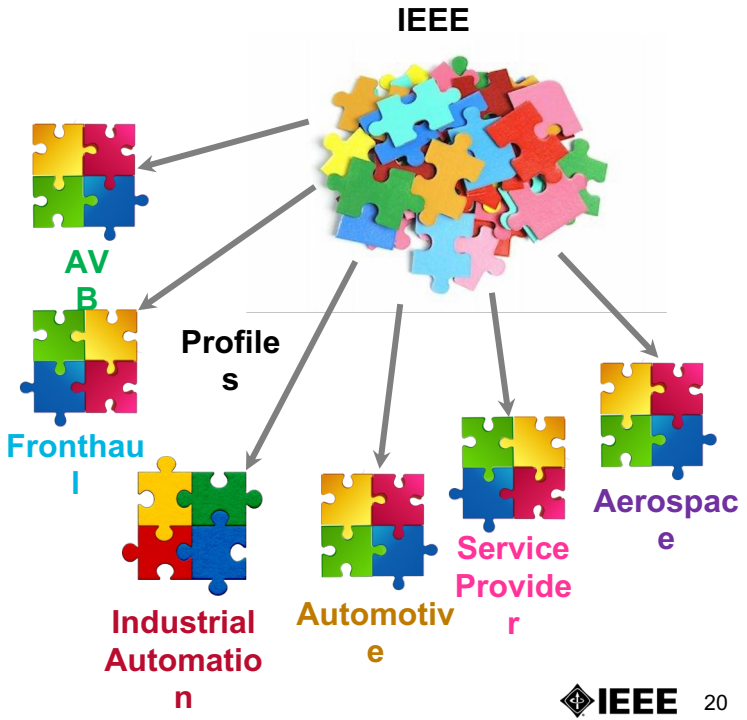
- Selects features, options, defaults, protocols, and procedures

Published IEEE 802.1 TSN profile standards:

- IEEE Std 802.1BA for Audio-Video Bridging (AVB) networks
- IEEE Std 802.1CM TSN for Fronthaul
- IEEE Std 802.1CMde Amendment on enhancements

Ongoing IEEE 802.1 TSN profile projects:

- IEC/IEEE 60802 TSN Profile for Industrial Automation
- P802.1DG TSN Profile for Automotive In-Vehicle Ethernet Communications
- P802.1DF TSN Profile for Service Provider Networks
- P802.1DP / AS6675 TSN Profile for Aerospace onboard Ethernet



TSN COMPONENTS

SYNCHRONIZATION

TIMING AND SYNCHRONIZATION [802.1AS]

IEEE Std 802.1AS

- specifies the generalized Precision Time Protocol (gPTP)
- is a proper profile of the IEEE Std 1588 Precision Time Protocol (PTP)
- includes protocol features additional to PTP
- includes performance requirements
- provides transport of time synchronization
- specifies the Best Master Clock Algorithm

The 2020 revision [802.1AS-2020] adds

- multiple gPTP domains
- external port configuration
- basic redundancy
- and more …

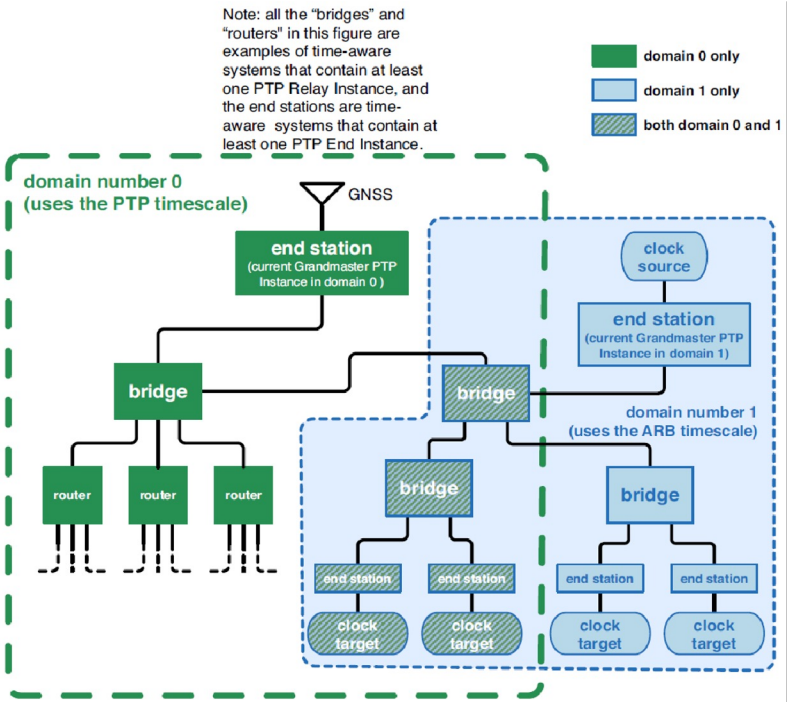


Figure 7-3—Time-aware network example for multiple gPTP domains

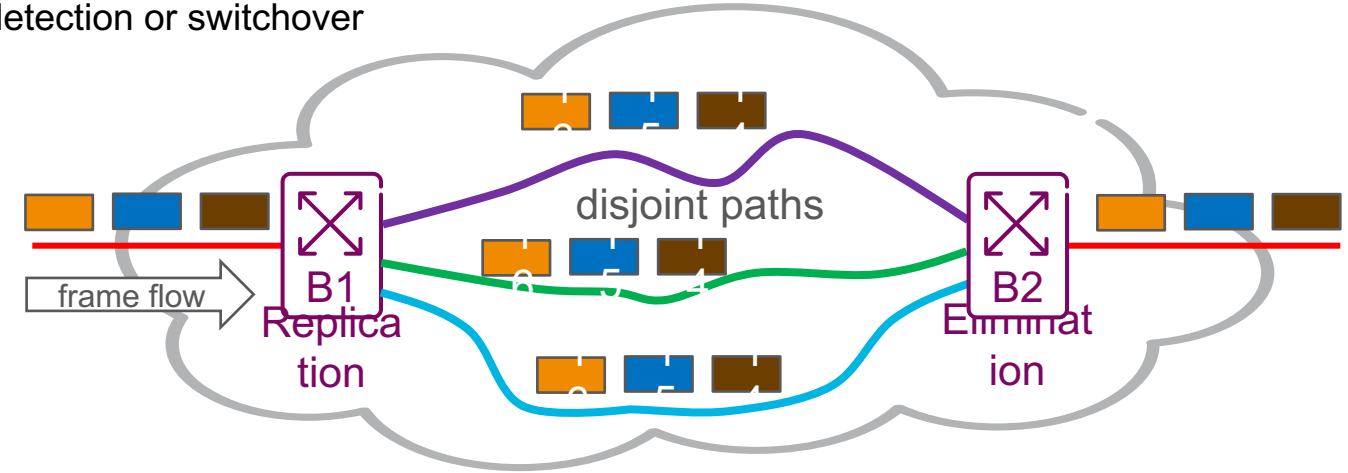
TSN COMPONENTS

RELIABILITY

FRAME REPLICATION AND ELIMINATION FOR RELIABILITY [802.1CB]

Avoids frame loss due to equipment failure

- Send frames on multiple maximally disjoint paths, then combine and delete extras
- A per-frame 1+n redundancy
- NO failure detection or switchover



TSN COMPONENTS

LATENCY

SCHEDULED TRAFFIC [802.1QBV]

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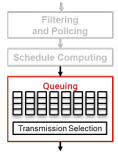
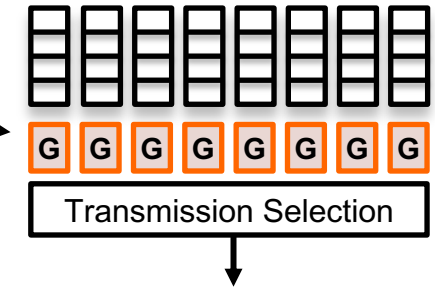


Reduces latency variation for frames with known timing

- Time-based control and programming of the bridge queues
- Time-Gated queues
- Transmission Gate (G): open or Closed
- Periodically repeated time schedule (gate control list)
- Time synchronization is needed
- 802.1Qbv is part of 802.1Q-2018



Gate control list

```
T00: oCooCooo
T01: CoCooCCo
T02: oCooCooo
T03: ooCooCCo
T04: oCooCooo
.............
T78: oCooCooo
T79: CoCooCCC
```

frame transmitted: gate(s) for critical / non-critical traffic

Note: gate of non-critical data can be closed in advance to protect critical data

ASYNCHRONOUS TRAFFIC SHAPING (ATS) [802.1QCR]

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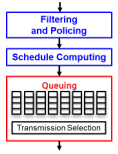
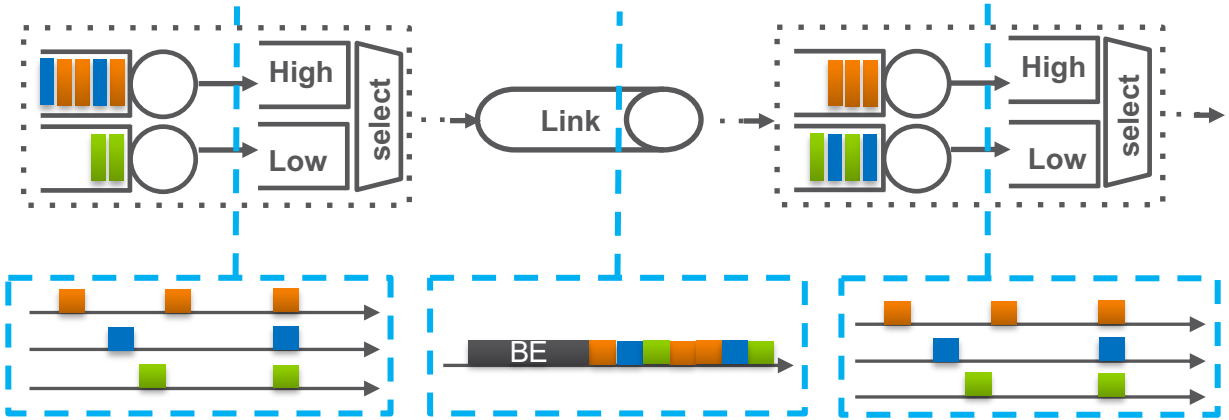
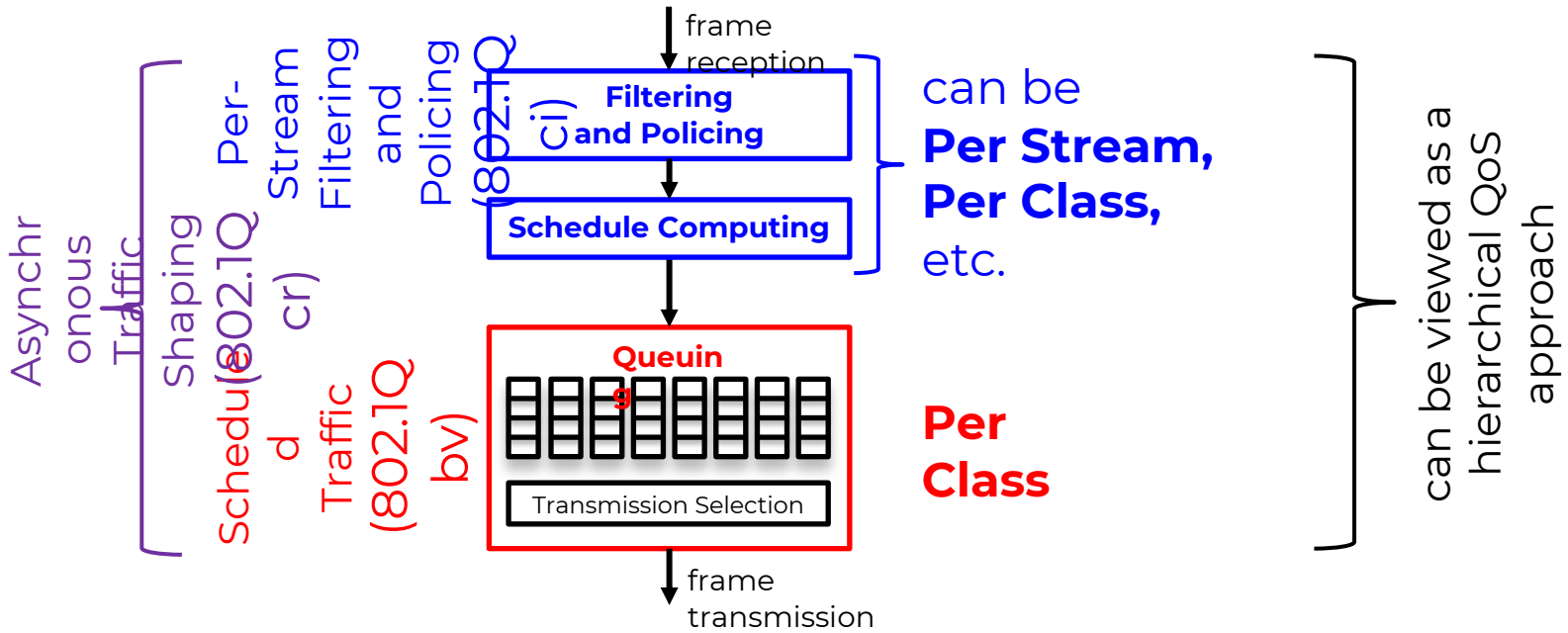


Zero congestion loss without time synchronization

- Similar to per-flow IntServ shaping, except that:
  - All streams from one input port to the same output port share the same queue
- A shaper state machine for a set of streams of the queue
- Smoothen traffic patterns by re-shaping per hop
- Prioritize urgent traffic over relaxed traffic
- 802.Qcr is part of to 802.1Q-2022



SUMMARY OF QOS FUNCTIONS



note: other functions are not shown in this figure, e.g., MAC relay, reliability

802.1 WORKING GROUP

SUMMARY

IEEE 802.1 is an individual-based working group open to all

- **Tieing together 802 LANs for over 40 years with a rich set of standards**
- Bridging, aggregation, discovery, security, management, …

- **The evolution of bridging is time-sensitive networking**
- Profiles of common functionality for a series of applications spaces:
  - AV, fronthaul, industrial automation, automotive, aerospace, …

- **The volunteer experts continue to excel and innovate**
- Recognized with 2020 IEEE Emerging Technology Award

ADDITIONAL INFORMATION

802.1 Working Group website - http://ieee802.org/1

IEEE-SA process

https://standards.ieee.org/about/policies/index.html

http://www.ieee802.org/1/files/public/docs2020/admin-parsons-SA+802-process-overview-0720.pdf

802 process

http://www.ieee802.org/devdocs.shtml

802 orientation

http://www.ieee802.org/orientation.shtml

WG process

https://1.ieee802.org/rules/

https://www.ieee802.org/1/files/public/docs2021/admin-parsons-WG-logistics-orientation-0721.pdf

WG technical orientations

http://www.ieee802.org/1/files/public/docs2018/tsn-farkas-intro-0318-v01.pdf

http://www.ieee802.org/1/files/public/docs2018/detnet-tsn-farkas-tsn-overview-1118-v01.pdf

http://www.ieee802.org/1/files/public/docs2018/detnet-tsn-farkas-tsn-basic-concepts-1118-v01.pdf

IEEE 802.1

THANK YOU

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