IEEE 802.1 TSN – An Introduction

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Authors:

Name	Affiliations	Address	Phone	email
János Farkas	Ericsson		+3614377100	janos.farkas@ericsson.com

Abstract

This presentation gives an introduction to IEEE 802.1 Time-Sensitive Networking (TSN) for the joint session of 802.11 TGbe and 802.1 TSN TG held at the IEEE 802 Plenary, July 2019.

Outline

- **Deterministic service**
- **TSN standards and projects**
- **Basic concepts**
- **Example TSN tools**
  - Scheduled Traffic (802.1Qbv)
  - Asynchronous Traffic Shaping (P802.1Qcr)
  - Frame Replication and Elimination for Reliability (802.1CB)
  - TSN Configuration (802.1Qcc)
- **Summary**

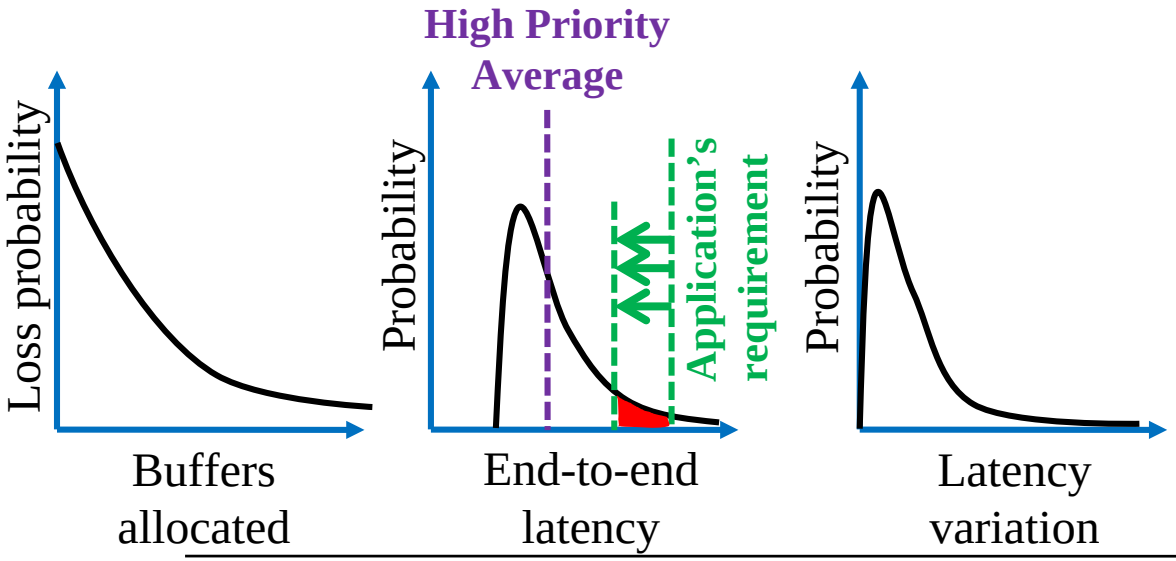
We Are Interested in Deterministic Service

Traditional Service

Curves have long tail

Average latency is good

Lowering the latency means
losing packets (or overprovisioning)

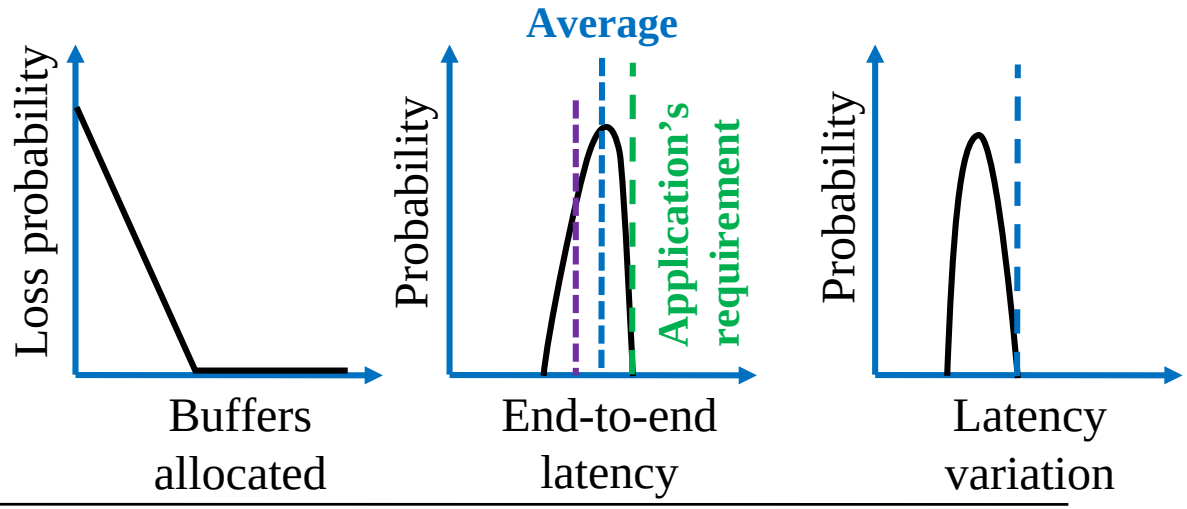


Deterministic Service

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

Bounded latency, no tails

The right packet at the right time

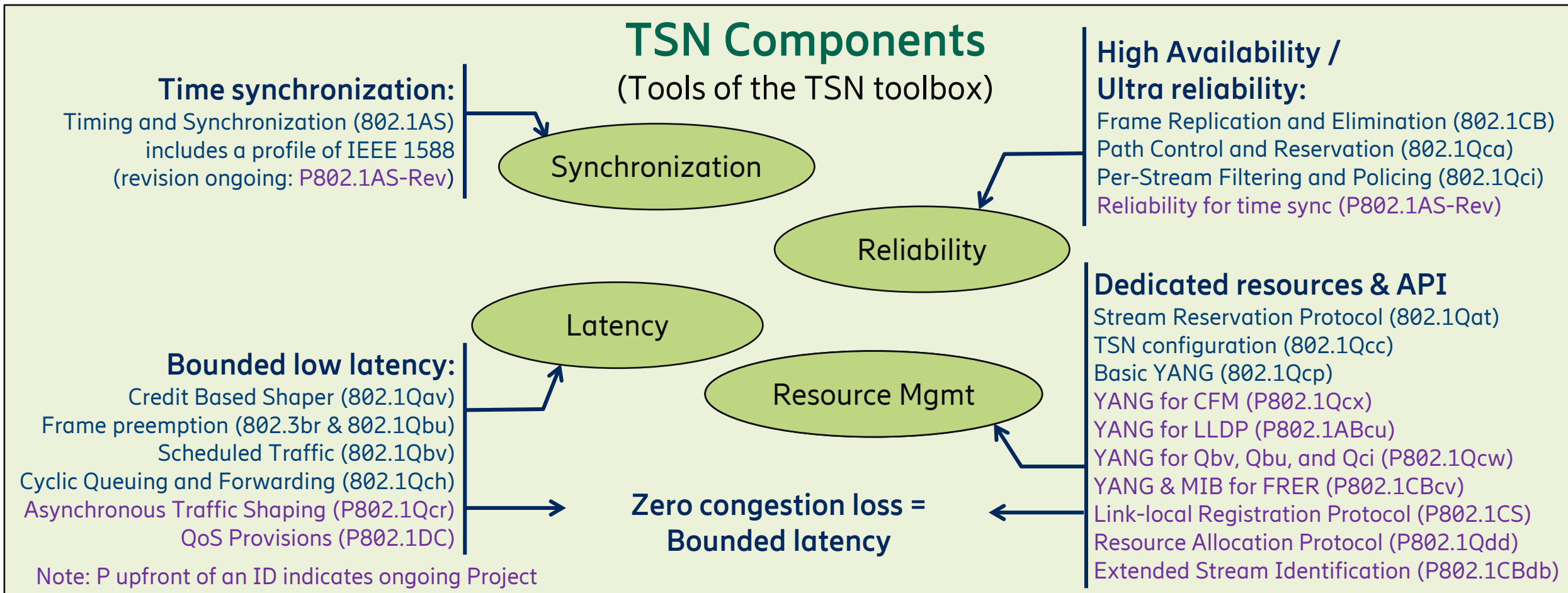


TSN Profiles (Selection and use of TSN tools)

Audio Video Bridging (802.1BA)	Fronthaul (802.1CM)	Industrial Automation (IEC/IEEE P60802)	Automotive In-Vehicle (P802.1DG)	Service Provider (P802.1DF)

TSN Components

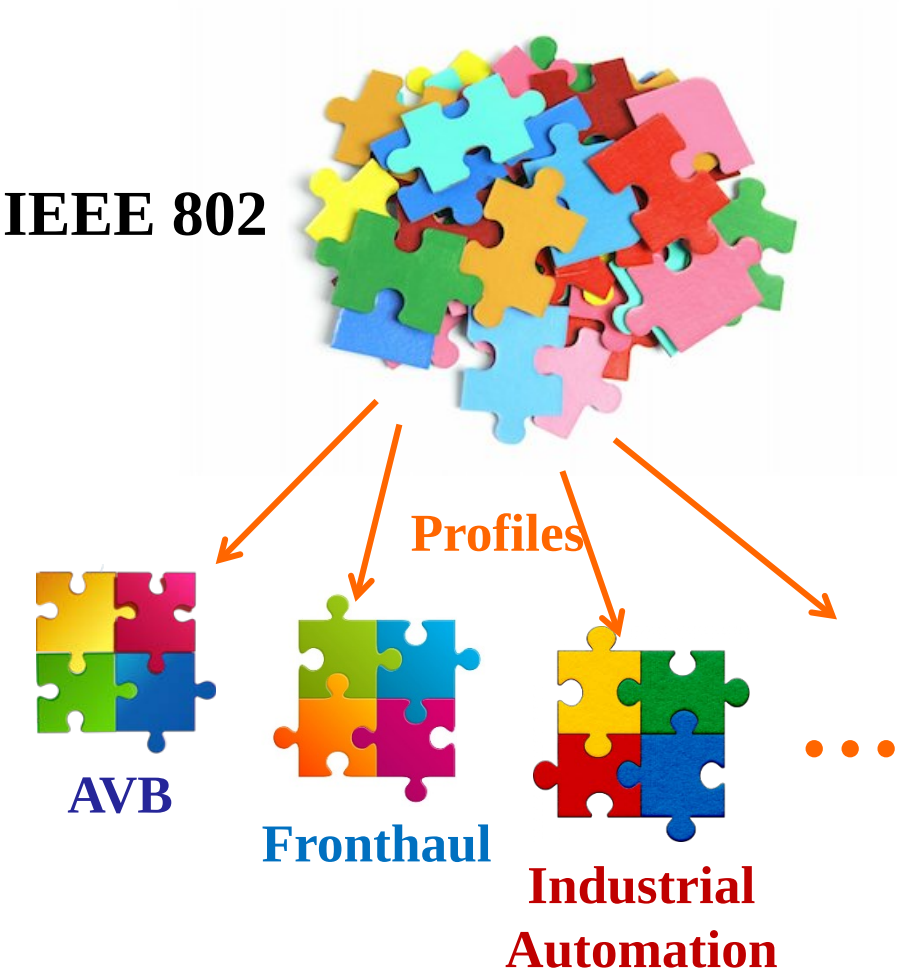
(Tools of the TSN toolbox)



Note: P upfront of an ID indicates ongoing Project

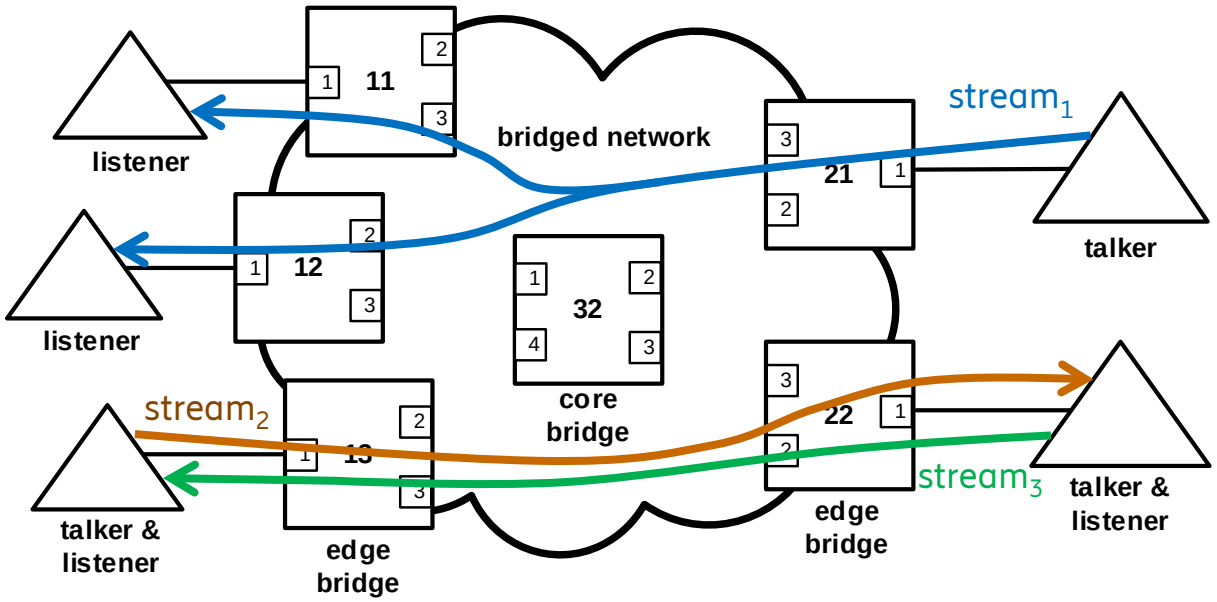
TSN Profiles

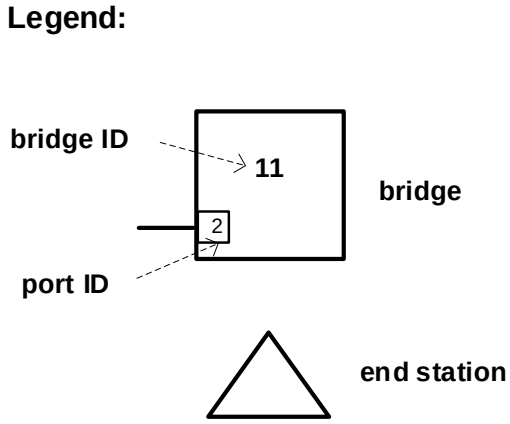
- **Wide breadth of choices in IEEE 802 standards**
- **A TSN Profile**
  - Narrows the focus → ease interoperability and deployment
  - Selects features, options, defaults, protocols, and procedures
  - Describes how to build a network for a particular use
  - Provides configuration guideline if needed
- **TSN Profiles so far**
  - Published TSN Profiles:
    - IEEE Std 802.1BA for Audio-Video Bridging (AVB) networks
    - IEEE Std 802.1CM TSN for Fronthaul (for cellular networks)
  - Ongoing:
    - IEC/IEEE 60802 TSN Profile for Industrial Automation
    - P802.1DF TSN Profile for Service Provider Networks
    - P802.1DG TSN Profile for Automotive In-Vehicle Ethernet Communications



Basic Components

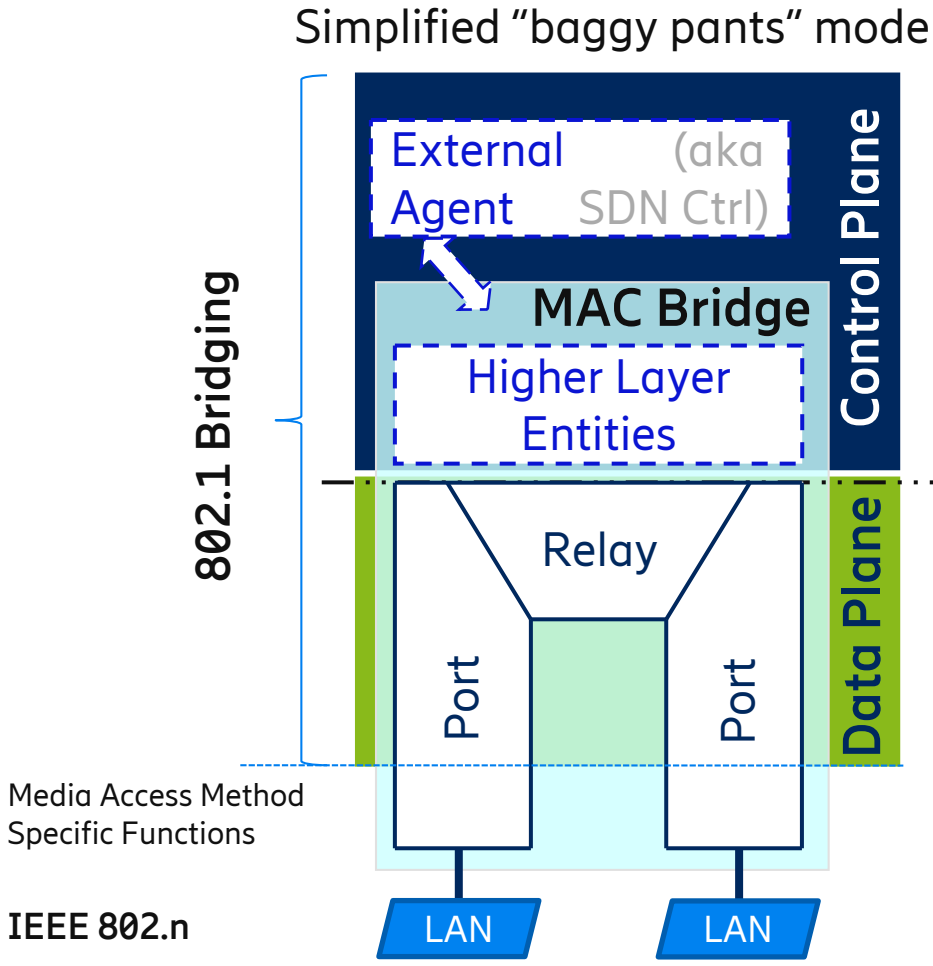
- From IEEE 802.1 perspective, the world is divided into two types of devices: bridges and end stations
- Talker: The end station that is the source or producer of a stream
- Listener: The end station that is the destination, receiver, or consumer of a stream
- Stream: A unidirectional flow of data from a Talker to one or more Listeners
- Bridge: see next slides





Bridge Architecture

Control Plane Separated from Data Plane



- **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

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

Bridge Forwarding Process Functions

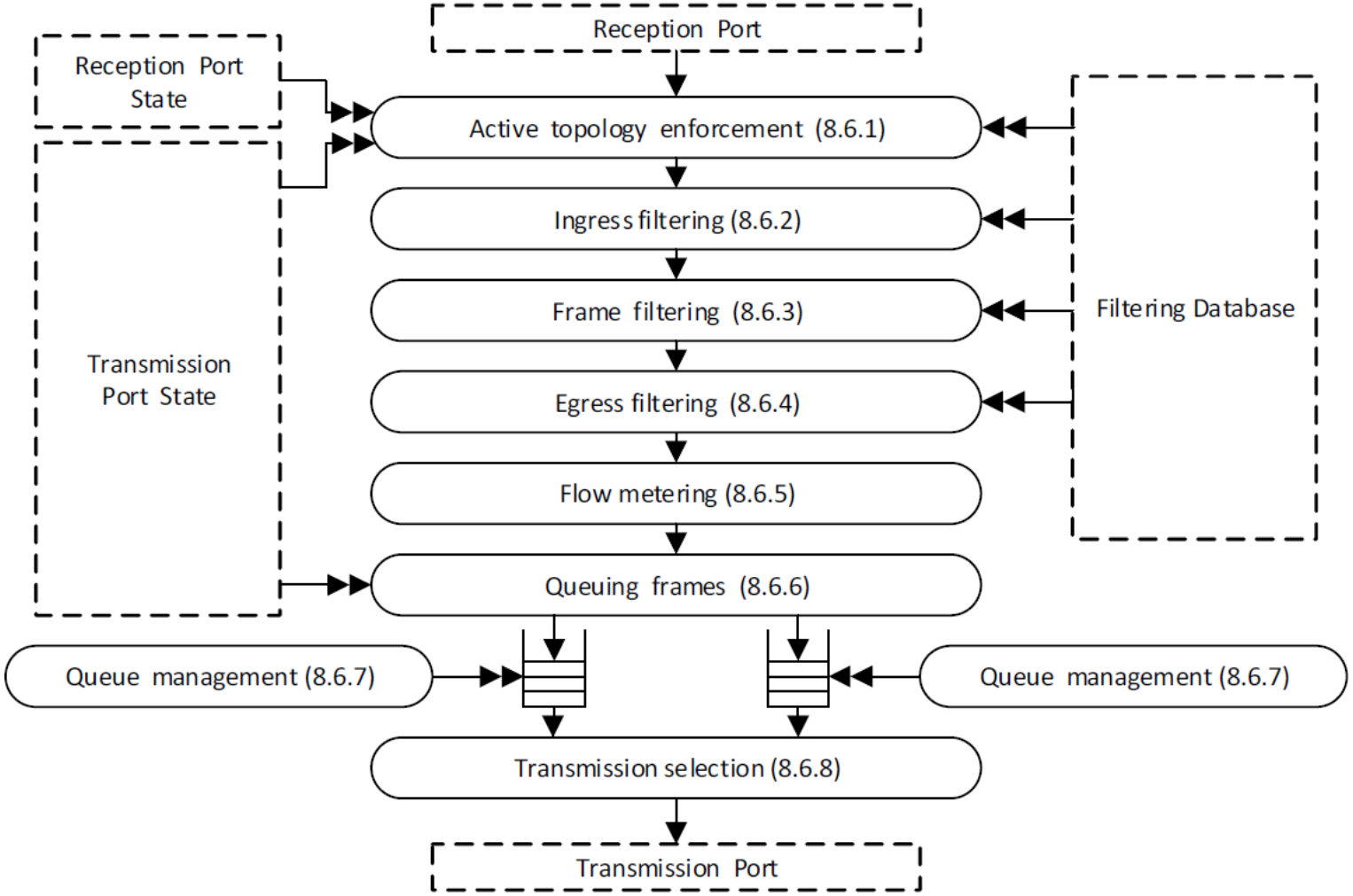
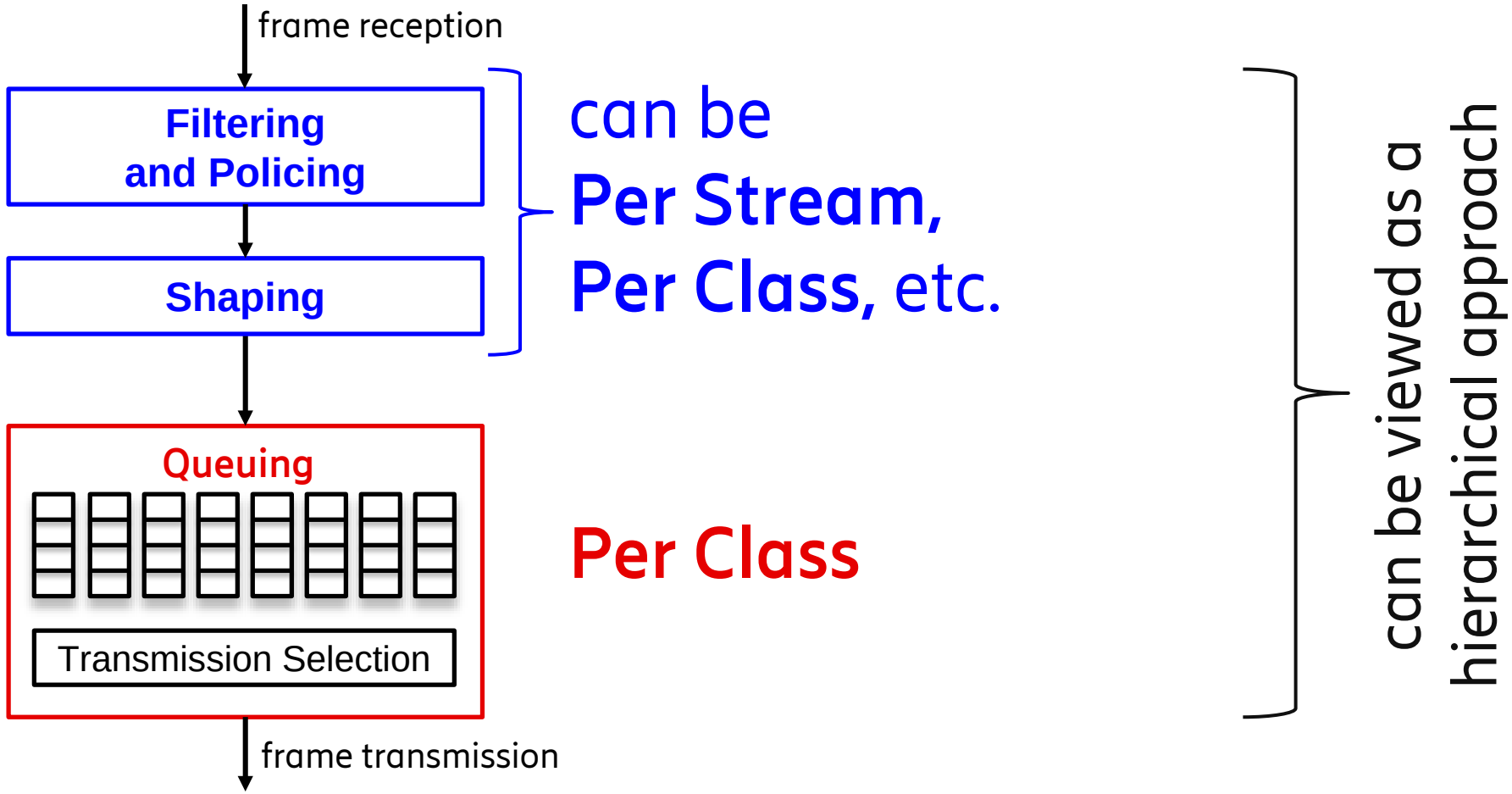
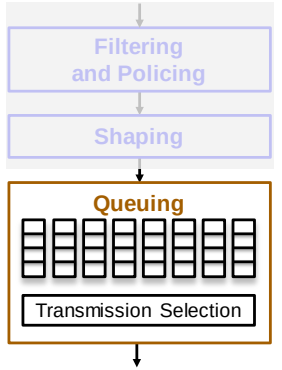


Illustration of QoS Functions

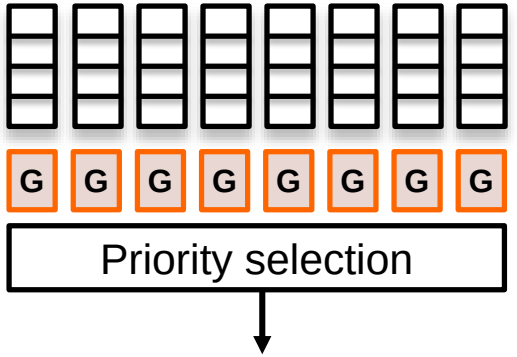


note: other functions are not shown in this figure, e.g., relay, reliability

Scheduled Traffic [802.1Qbv]

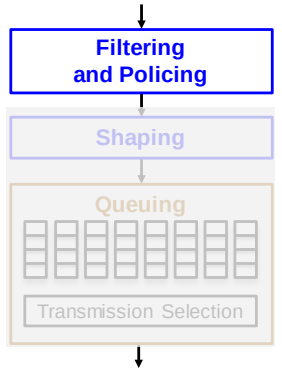


- Reduces latency variation for frames with known timing
- Time-based control and programming of the bridge queues
- Time-Gated queues
- Transmission Gate (G): Open or Closed
- Periodically repeated time schedule
- Time synchronization is needed

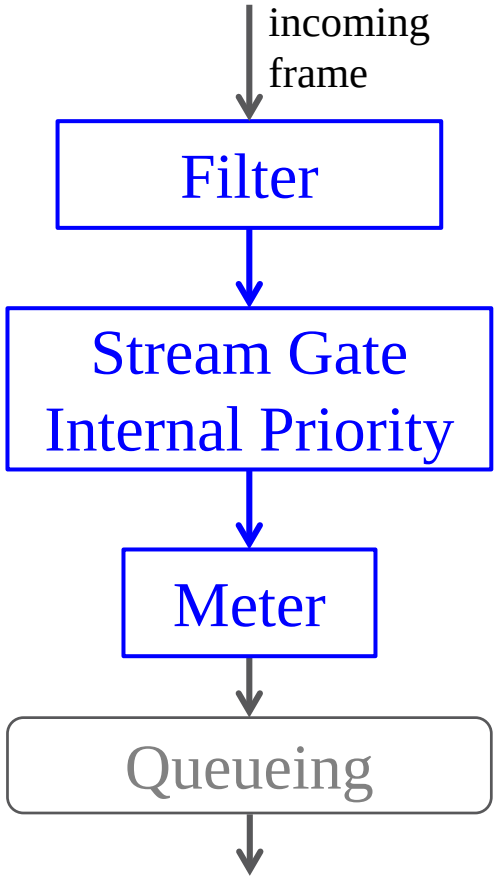


Note: gate of non-critical data can be closed in advance to protect critical data

Per-Stream Filtering and Policing (PSFP) [802.1Qci]

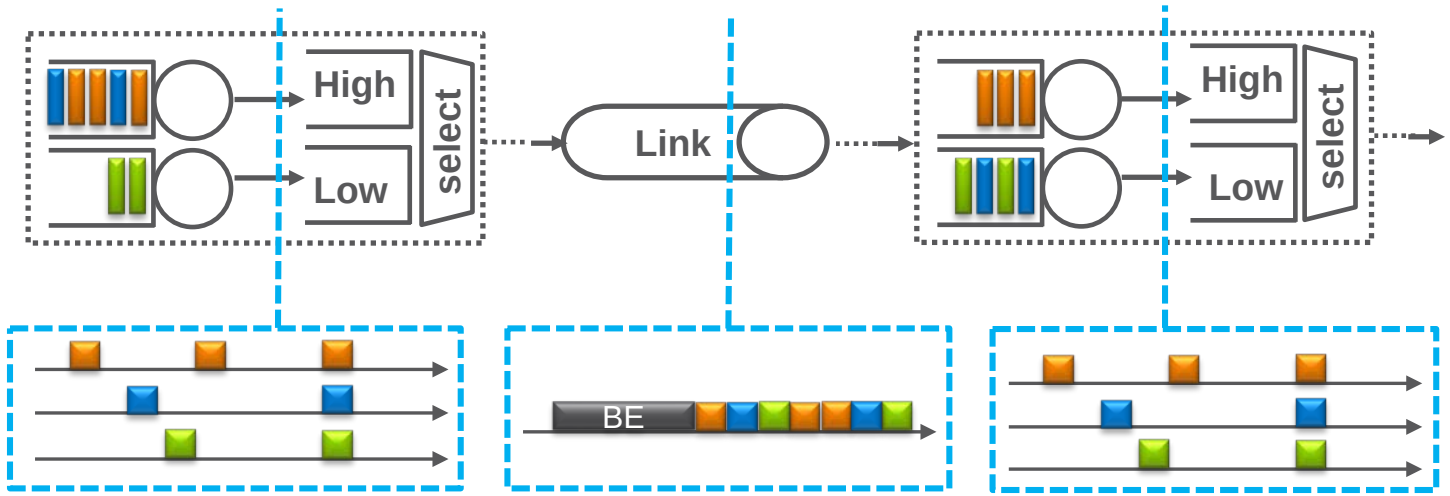


- **Protection against bandwidth violation, malfunctioning, attacks, etc.**
- **Decisions on per-stream, per-priority, etc.**
- **Filter**
  - Filters, Counters
- **Stream Gate**
  - Time scheduled gate
  - Open or Closed
- **Internal Priority Value (IPV)**
  - Bridge internal traffic class of the frame
- **Meter**
  - Bandwidth Profile of MEF 10.3
  - Red/Yellow/Green Marking



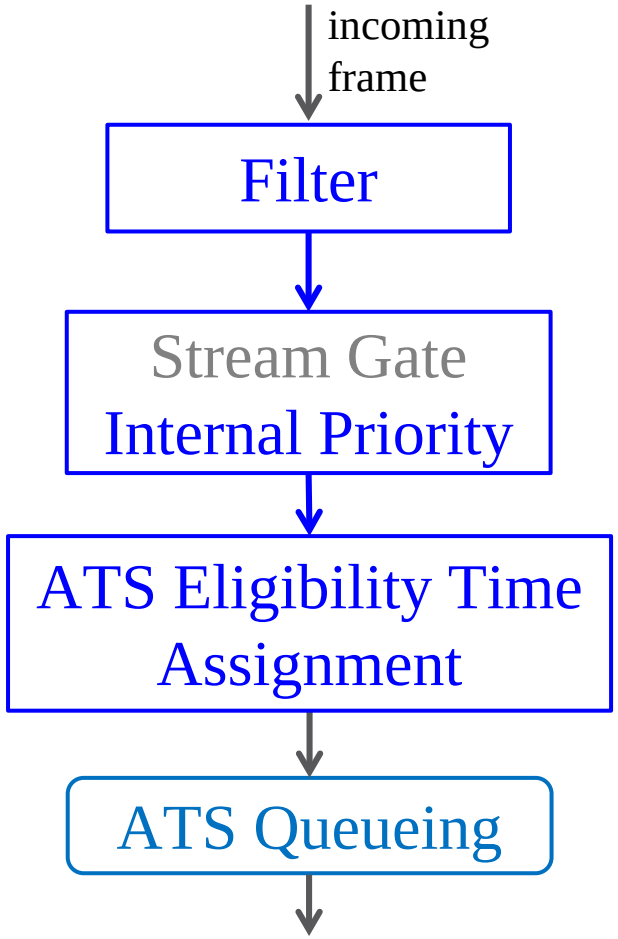
Asynchronous Traffic Shaping (ATS) [P802.1Qcr]

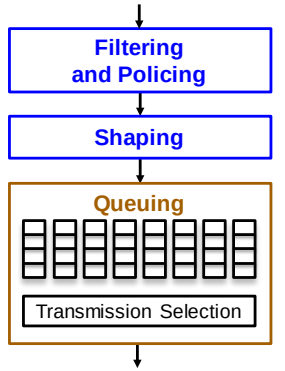
- **Zero congestion loss without time sync**
  - Similar to per-flow IntServ shaping, except that:
  - All streams from one input port to the same output port share the same queue
- **A shaper state machine for a set of streams, and the right shaper applied to the packet upfront of the queue**
- **Smoothen traffic patterns by re-shaping per hop**
- **Prioritize urgent traffic over relaxed traffic**



ATS Components [P802.1Qcr]

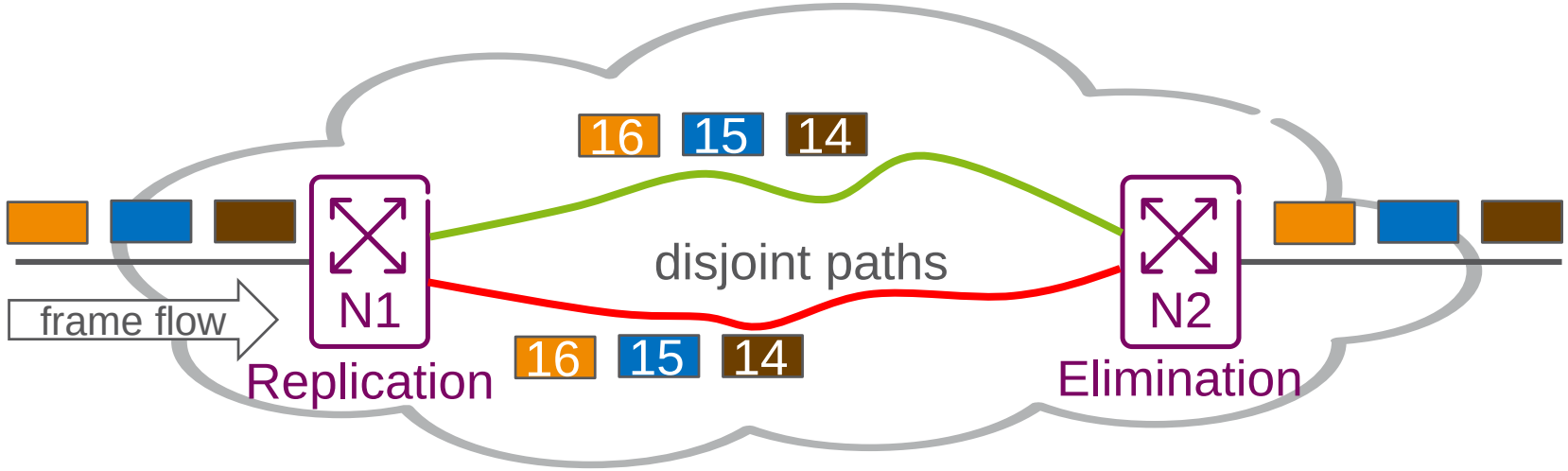
- **Filter**
  - Selects treatment for frames of a stream, e.g., IPV, shaper
- **Internal Priority Value (IPV)**
  - Bridge internal traffic class of the frame
  - Used for ATS operations
- **ATS Shaper**
  - Applies a token bucket algorithm
  - Uses bridge local time variables
  - Pre-computes and assigns local eligibility times to frames
  - Eligibility time becomes effective in the queueing
  - Transmit frames that reached their Eligibility Time





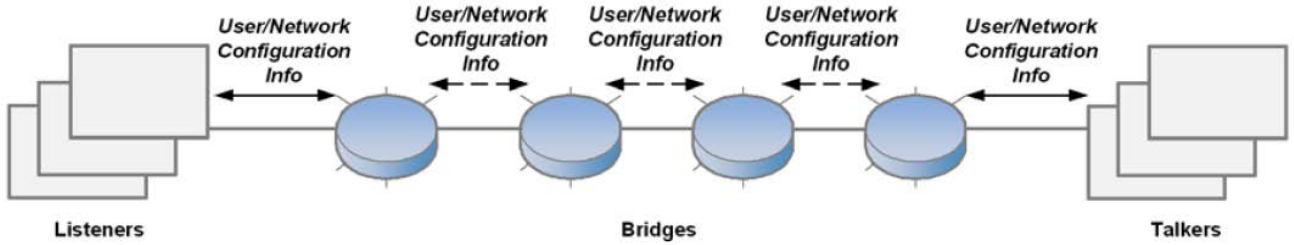
Frame Replication and Elimination for Reliability (FRER) [802.1CB]

- **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**

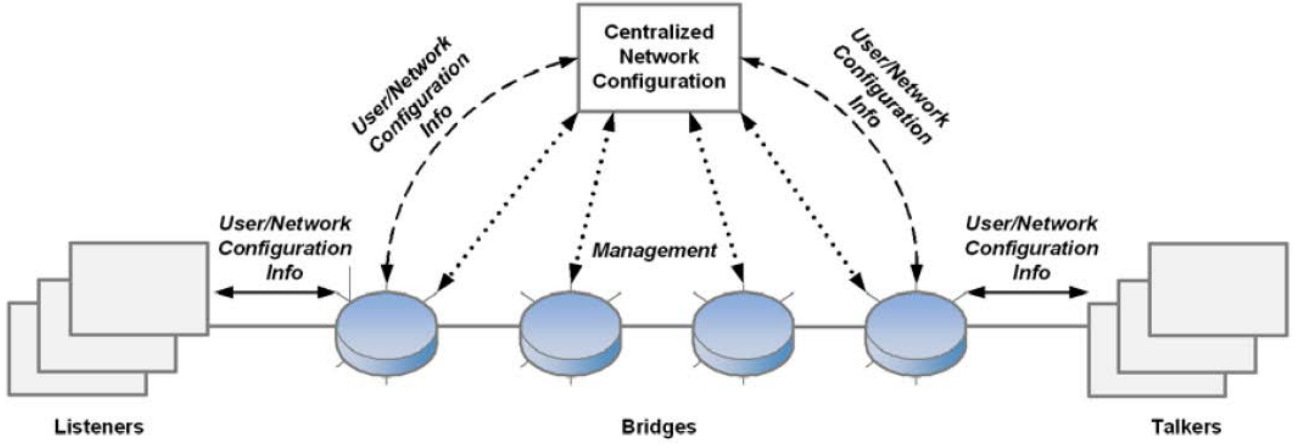


TSN Configuration [802.1Qcc]

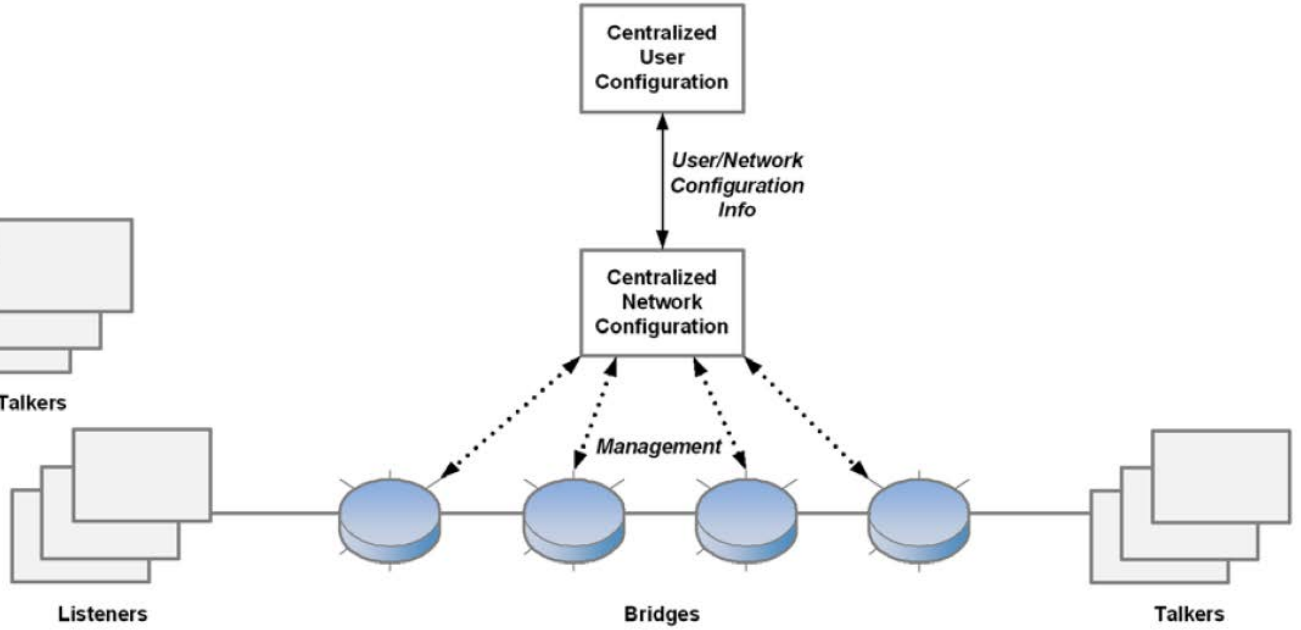
Fully distributed



Centralized network & distributed user



Fully centralized



Summary

- **TSN provides deterministic service**
- **Multiple TSN tools provide bounded low latency**
  - Time-based control of queueing provides deterministic behavior
    - Time synchronization is required
  - Asynchronous Traffic Shaping
- **High availability / ultra reliability**
- **Configuration and resource reservation**

Further Reading

http://www.ieee802.org/1/tsn

TSN feature topic of the June 2018 Issue of IEEE Communications Standards Magazine
https://ieeexplore.ieee.org/document/8412457

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

"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 802.3br 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://www6.ietf.org/meeting/86/tutorials/86-IEEE-8021-Thaler.pdf

Paper on 802.1Q bridging https://arxiv.org/ftp/arxiv/papers/1405/1405.6953.pdf