IEEE 802.1 Time-Sensitive Networking (TSN) for DetNet

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Before We Start

This presentation should be considered as the personal view of the presenters not as a formal position, explanation, or interpretation of IEEE 802.1.

Dictionary

TSN

- Stream
- Talker
- Listener

DetNet

- Flow
- Source
- Destination

Outline

- Introduction
- TSN stream description
- Per stream facilities
- Zero congestion loss
  - Shaping facilities
  - Time-scheduled facilities
- Transmission preemption
- Summary
- Discussion
  - Integrating DetNet and TSN queuing

INTRODUCTION

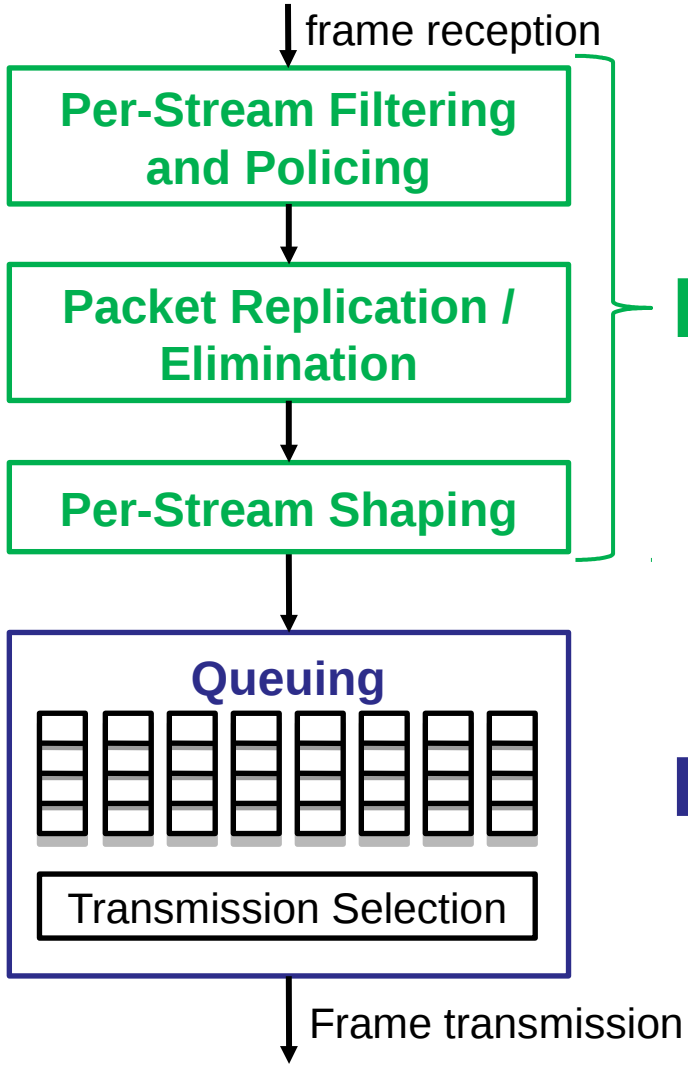
Bounded Latency

- TSN's target applications, real-time networks, require a **guaranteed not-to-exceed end-to-end latency** for critical data
- We are after the worst-case latency
- Average/mean/best-case latencies are irrelevant
- Many ways to accomplish bounded latency:
  - ~~Throw away late packets; grossly overprovision the network; intensive engineering and testing.~~
  - **Provide zero congestion loss**

There is No Free Lunch

- The low-hanging fruit has been picked and eaten.
- TSN is taking two approaches to explore the remaining trade-off space, which is between:
  - Lower worst-case latency
  - Simplicity of implementation
  - Ability to serve a wide range of flow bandwidths
  - Lower latency variation
  - Ability to handle dynamic reservation changes
- TSN is taking two fundamentally different approaches, though there is overlap:
  1. **Per stream traffic shaping**
  2. **Time-based transmission**
- **Resource reservation before use is mandatory.**

Illustration of QoS & Reliability Functions



Per Stream

Per Class

can be viewed as a hierarchical approach

TSN STREAM DESCRIPTION

Stream Description

- Stream (flow) identification in IEEE 802.1 TSN:
  - Destination & Source MAC addresses
  - VLAN ID & Priority Code Point (PCP: L2 priority)
  - DSCP
  - IPv4 5-tuple
  - IPv6 5-tuple

  Flow identification is used for QoS purposes, and for edge encapsulation transformations, NOT for forwarding
- Traffic Specification (next slide)
- Network reply (following slide)

Traffic Specification

- Application's (Talker's) promise:
  - Interval: time period for traffic specification
  - Max Frames per Interval
  - Max Frame Size
  - *This spec is observable and verifiable*
- Talker behavior
  - Transmission Selection Algorithm (shaper)
  - If Time Aware ⊆ Transmit Offsets, Jitter
- Application's needs (user to network requirements):
  - Worst-case end-to-end latency
  - Number of replication/elimination paths

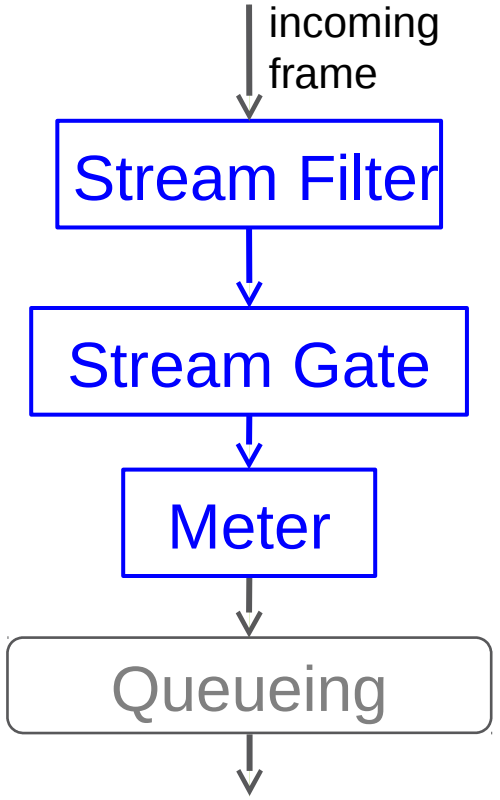
Network Response

- Talker/Listener Status info:
  - none
  - ready
  - failed (with failure code)
- Accumulated Latency = worst-case latency for a frame
  - Response to Listener is about a single path
  - Response to Talker is about the worst path among all Listeners

PER STREAM FUNCTIONS

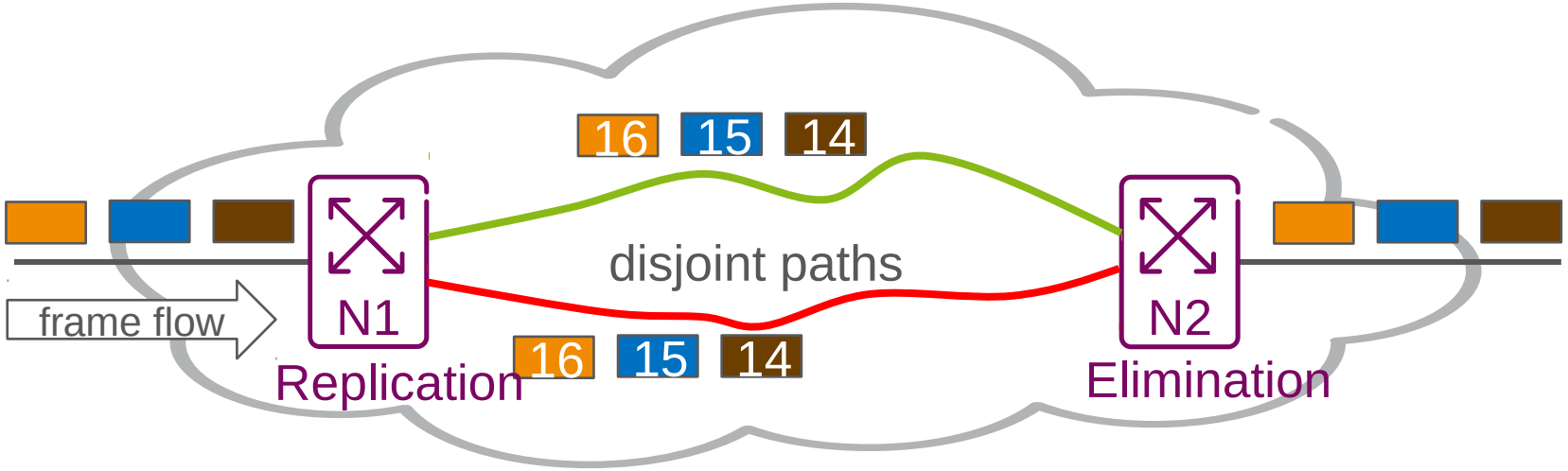
Per-Stream Filtering and Policing

- Protection against bandwidth violation, malfunctioning, malicious attacks, etc. (802.1Qci)
- Decisions on per-stream, per-priority, etc.
- Stream Filter
  - Filters, Counters
- Stream Gate
  - Open or Closed
  - can be time-scheduled
- Meter
  - Bandwidth Profile of MEF 10.3
  - Red/Yellow/Green Marking



Frame Replication and Elimination

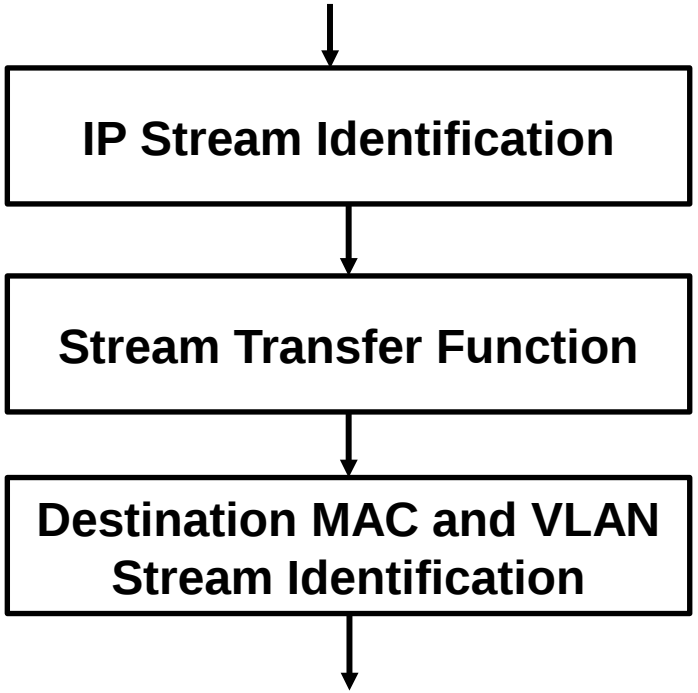
- Avoid frame loss due to equipment failure (802.1CB)
- Per-packet 1+1 (or 1+n) redundancy
  - NO failure detection / switchover
- Send packets on two (or more) disjoint paths, then combine and delete extras



Stream Transformation

- Stream transformation (802.1CB) can provide Stream identification transformation
- Stream transformation can be applied if the network and the user use different Stream identification

- Example:

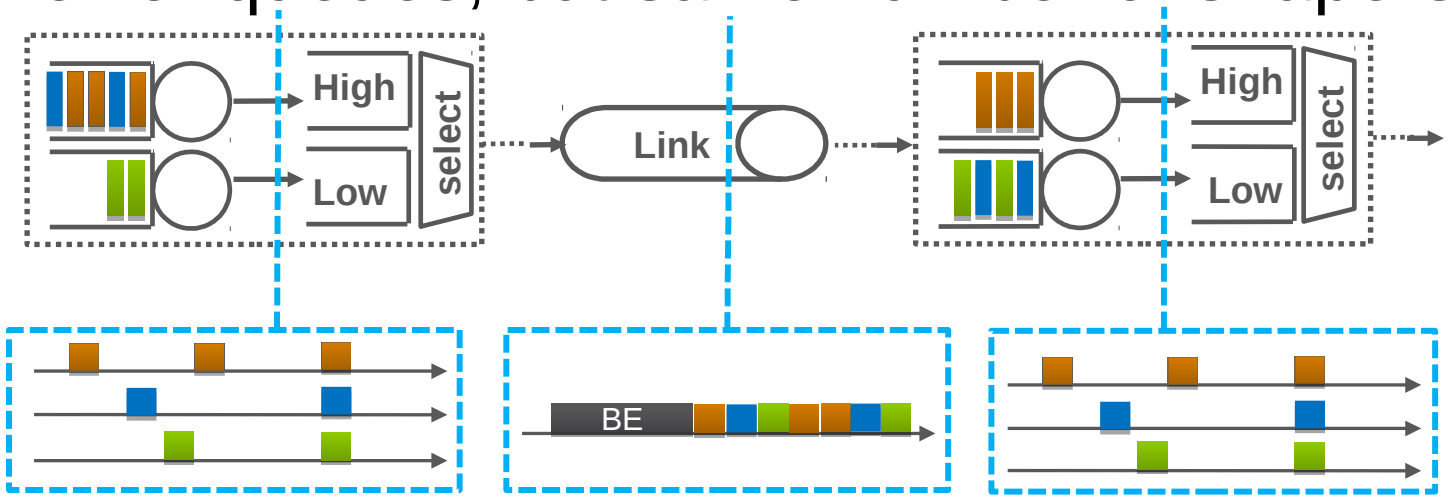


ZERO CONGESTION LOSS

1. Shaper-based approaches
2. Time-scheduled approaches

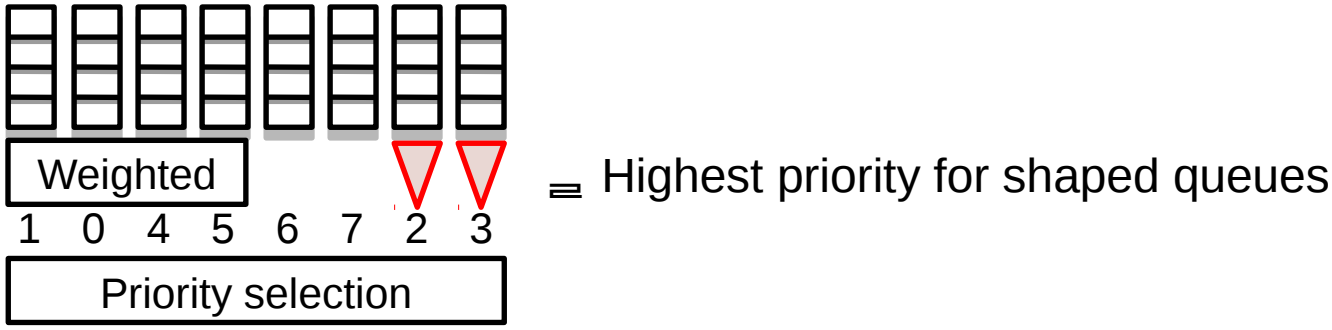
Asynchronous Traffic Shaping

- Zero congestion loss without time sync (P802.1Qcr)
- Similar to per-flow IntServ shaping, except that:
  - All flows from one input port to same output port share the same queue
  - One shaper state machine per flow, and the right shaper applied to the packet upfront of the queue
- Fewer queues, but same number of shapers



Credit Based Shaper

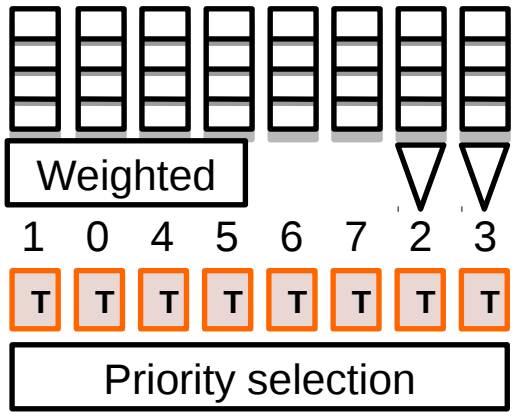
- Credit Based **Shaper** (CBS - 802.1Qat)
  - Shaped queues have higher priority than unshaped queues
  - Shaping still guarantees bandwidth to the highest unshaped priority (7)



- CBS is similar to the typical run rate/burst rate shaper, but with really useful mathematical properties
  - Only parameter = bandwidth (Max burst size is a consequence)
  - The impact on other queues of any number of adjacent shapers is the same as the impact of one shaper with the same total bandwidth.

Scheduled Traffic

- Reduces latency variation for Constant Bit Rate (CBR) streams, which are periodic with known timing
- Time-based control/programming of the 8 bridge queues (802.1Qbv)
- Time-gated queues
- Gate: Open or Closed
- Periodically repeated time-schedule
- Time synchronization is required

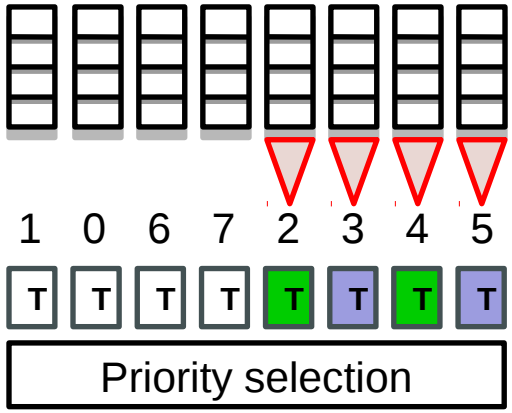


Uses of Output Scheduler

- Scheduling queues can control latency to nanosecond precision (if the implementation is accurate)
  - But, with only a few queues, it is not trivial to isolate streams or packets
- Other uses
  - Link or network time-sharing
  - Cyclic Queuing and Forwarding

Cyclic Queuing and Forwarding

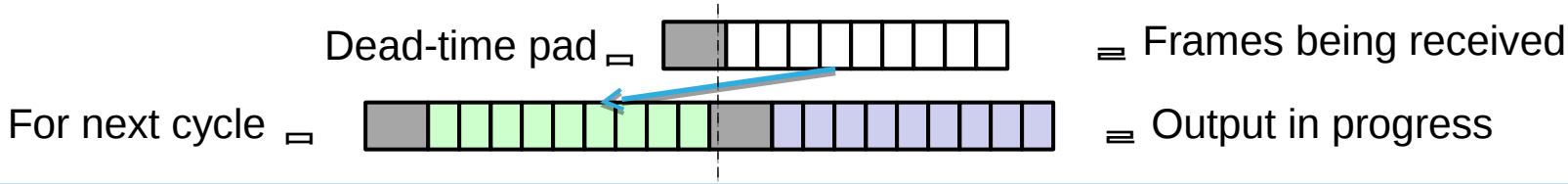
- **Double buffers** (802.1Qch) are served alternate using time-gated control
- Two pairs: 2–3 and 4–5 in this example



Shapers ensure fair access for 0, 1, 6, 7 traffic

Alternately open green and purple

- If the wire length and bridge transit time are negligible compared to the cycle time, double buffers are sufficient:

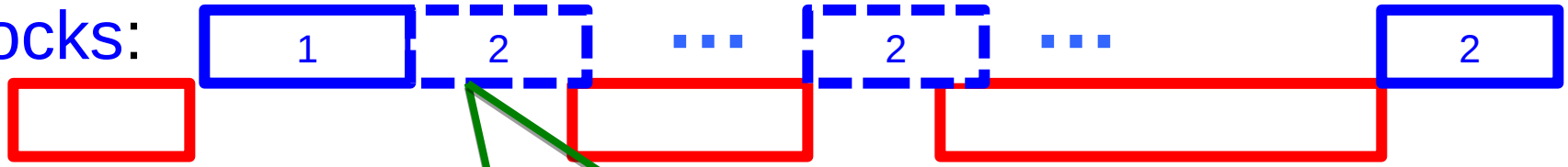


TRANSMISSION PREEMPTION

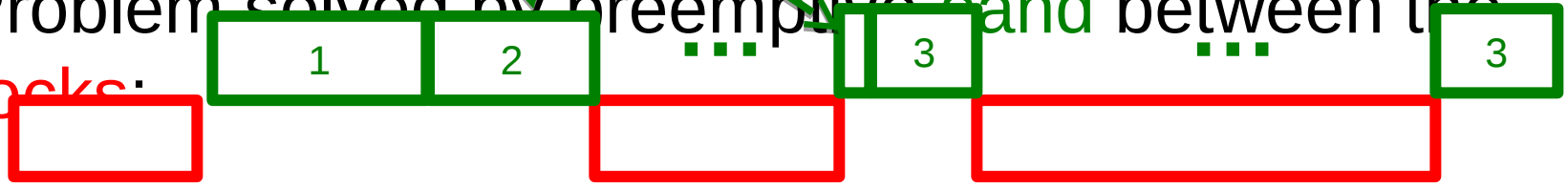
Frame Preemption

- Express frames suspend the transmission of preemptable frames (802.3br and 802.1Qbu)
  - It is link local per hop, i.e., it is not IP fragmentation
- Scheduled rocks of critical packets in each cycle:

- Conflict excessively with non-guaranteed packet rocks:

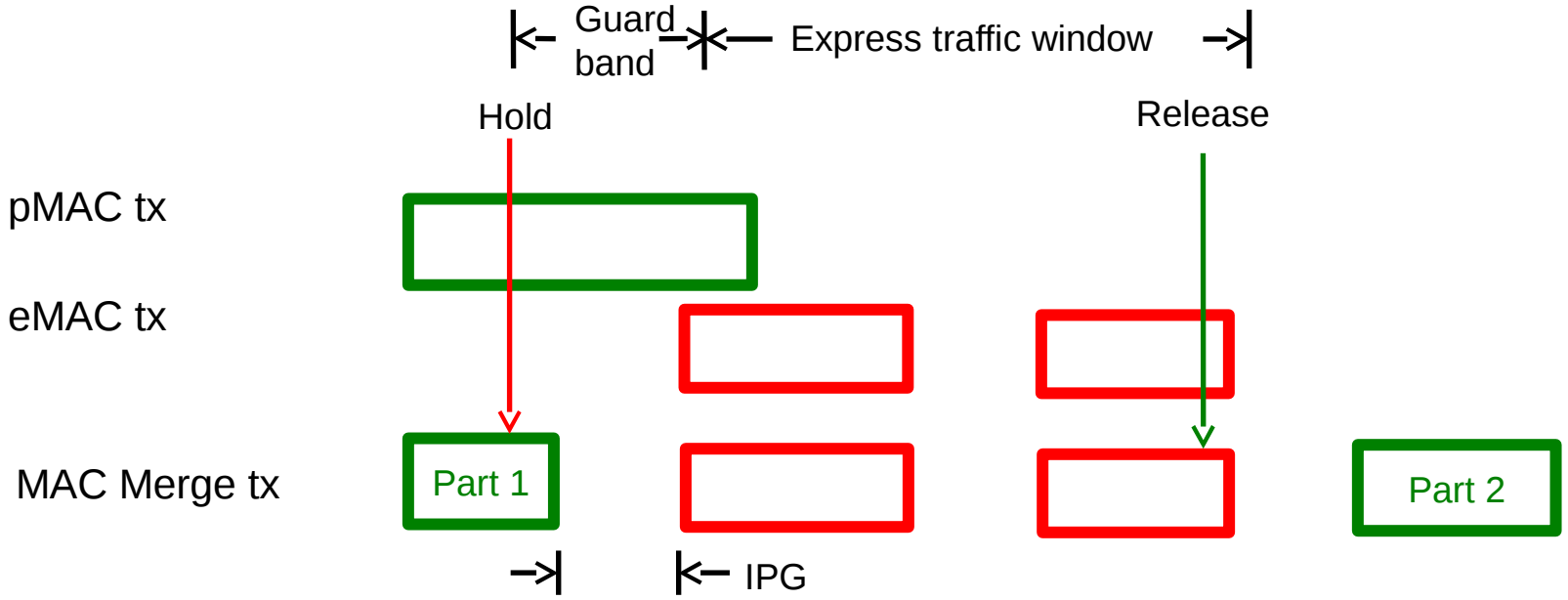


- Problem solved by preemptive gand between the rocks:

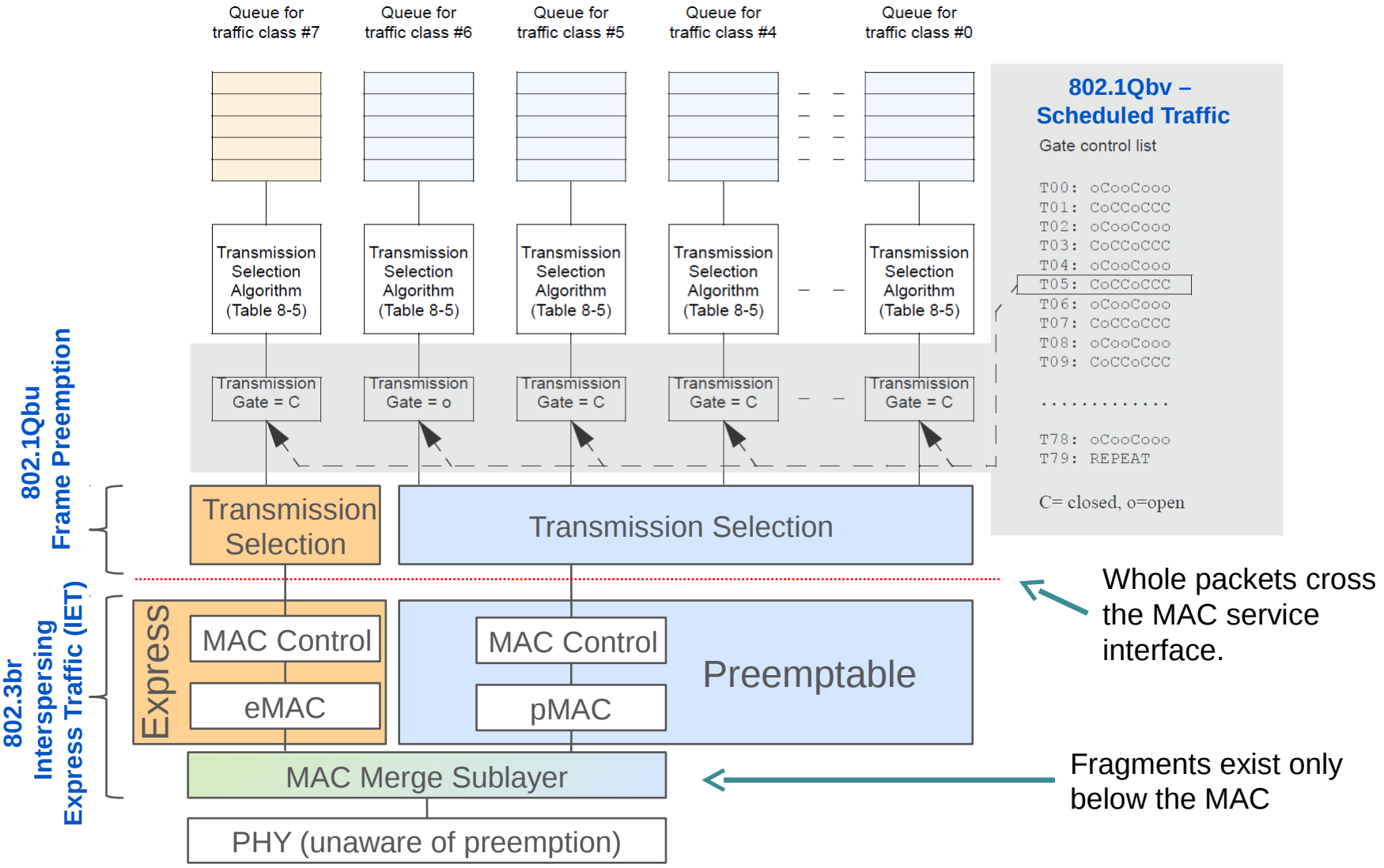


Preemption + scheduling

- Output scheduling makes nanosecond latency variation possible
- Preemption minimizes the amount of guard band required to ensure availability of the link for a scheduled transmission



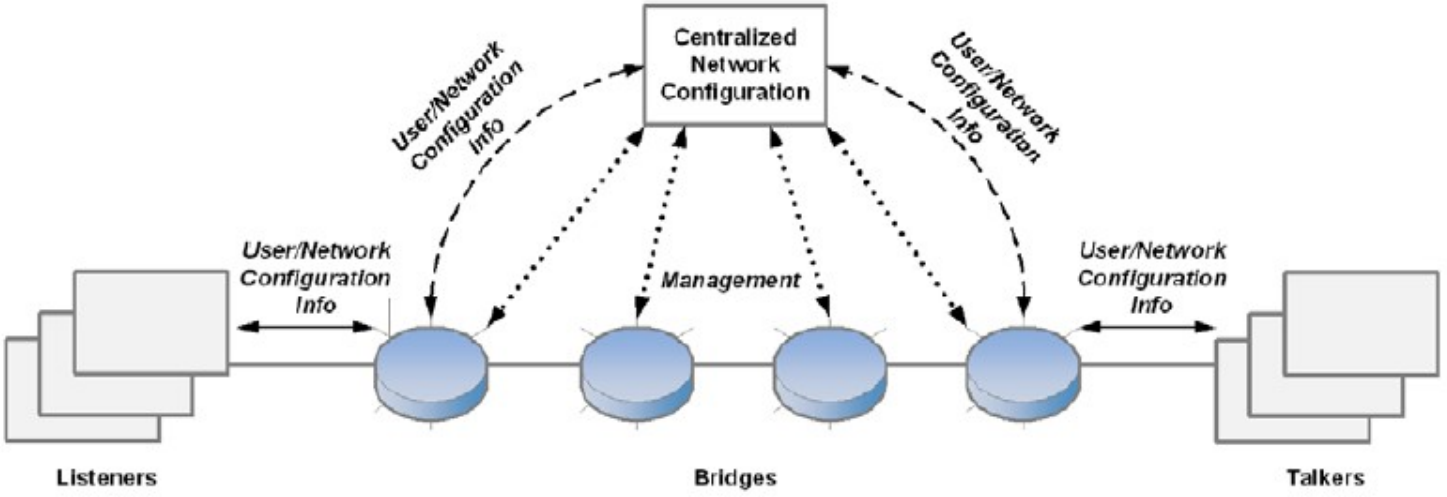
Preemption with Scheduling



NO TIME TO TALK ABOUT

TSN Configuration

- TSN configuration (P802.1Qcc)
- Information model & YANG
- Configuration Models
  - Fully Distributed Model
  - Fully Centralized Model
  - Centralized Network / Distributed User Model



Reservation Protocol

- Stream Reservation Protocol (SRP - 802.1Qat)
  - Advertises streams
  - Registers the path of streams
  - Calculates the worst-case latency
  - Establishes an AVB domain
  - Reserves the bandwidth for streams
- SRP enhancements (P802.1Qcc)
- Link-local Registration Protocol (LRP - P802.1CS)
  - Replicate a registration including changes
  - Optimized for databases on the order of 1 Mbyte
  - Not tied to bridges

SUMMARY

Summary

- TSN brings some new queuing techniques to the party
- TSN combines two fundamentally different approaches
  - Per stream traffic shaping, policing
  - Time-based transmission
- TSN techniques should be available to DetNet in order to meet some requirements

DISCUSSION

Integrating DetNet and TSN

- A flow needs the same treatment in DetNet and TSN
  - All of the above methods are equally applicable to bridges, routers, label switches, hosts, etc., should be available to both TSN and DetNet
  - Only the traffic class selection differs (L2 priority vs LSP priority vs DSCP …)
- We need a set of YANG modules to select and govern the use of these queuing strategies for all node types

FURTHER READING

Further Reading

- http://www.ieee802.org/1
- http://www.ieee802.org/1/pages/tsn.html
- TSN Tutorial at IETF 99: slides & video
- Introduction to IEEE 802.1 TSN
- Tutorial on IEEE 802 Ethernet Networks for Automotive
- IEEE 802.1 TSN for Automotive – flyer
- IEEE 802.1 TSN for Industrial Networks – flyer
- A Time-Sensitive Networking Primer: Putting It All Together
- Heterogeneous Networks for Audio and Video: Using IEEE 802.1 Audio Video Bridging
- Tutorial on IEEE 802.3br Interspersing express traffic (IET) and
  IEEE 802.1 Time-Sensitive Networking
- Tutorial on Deterministic Ethernet