AAA2C Discussion Topic:
Types of Traffic in AVB 2

(Best effort traffic, Rate constraint traffic & Scheduled traffic)

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Purpose of Presentation

- Provide Information on:
  - AVB 2 Transmission Selection Algorithms (TSA) for Best Effort Traffic, Rate Constraint Traffic and Scheduled Traffic
  - Reservation mechanisms

- Discuss usage strategies
  - How we take advantage of different TSA's and reservations in automotive applications?
  - How should we use these mechanisms?
  - Where do they fit well? Where not?
  - Is something missing?

"Thought-Starters" for the group discussion !

Questions, rather than answers!

OEMs do not necessarily need to agree on a single usage strategy!

But: Discussing these strategies helps us to identify TSA's & reservation related requirements.

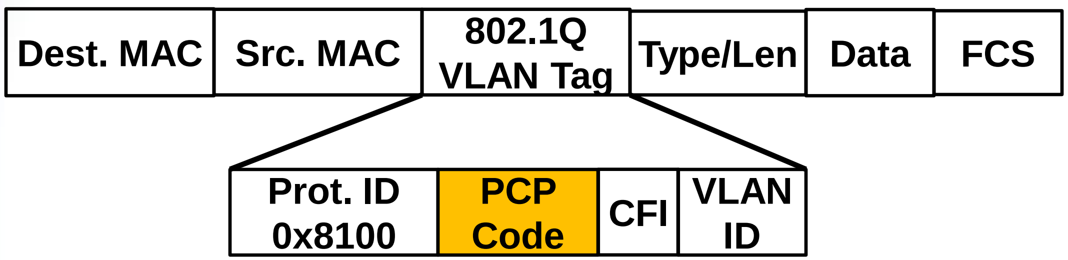
Overview

- Best effort traffic (BE) *TSA = “Strict Priority Algorithm”*
- The big picture: Using different types of traffic in parallel
- Rate constraint traffic (RC) *TSA = “Credit Based Traffic Shaper”*
- Scheduled traffic (TT) *TSA = “Time Aware shaper”*
- Thought Starters:
  Automotive Usage Strategies for different types of traffic and reservations

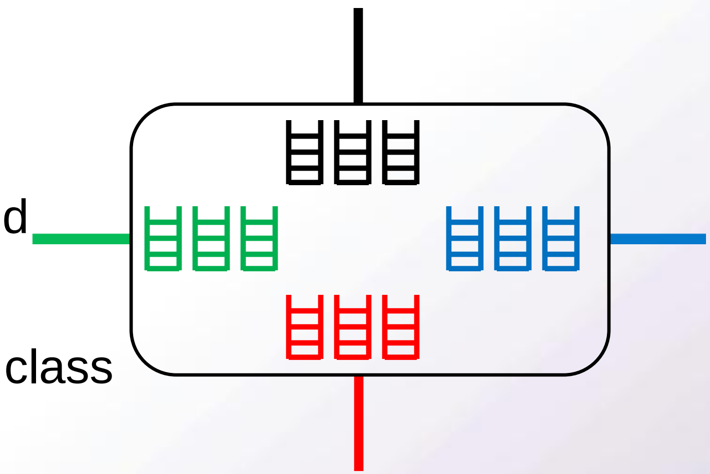
Transmission Selection Algorithms:
“Strict Priority Algorithm”

Strict Priority Algorithm

- ➢ Frames tagged with a 3 bit Priority Code Point value



- ➢ Bridge ports have between 1 and 8 outbound queues.
- ➢ Each outbound queue of a port has a traffic class number assigned (1:1 mapping).
- ➢ Traffic classes numbers range from 0 to N-1. (N = number of the ports outbound queues).



4 Port Bridge with 3 out-bound queues per port

Strict Priority Algorithm

- Port is configured with a mapping: "PCP codes" to "Traffic Classes (queues)".

Example:

PCP Code in Frame	0	1	2	3	4	5	6	7
Traffic class number	0	0	0	0	1	1	2	2

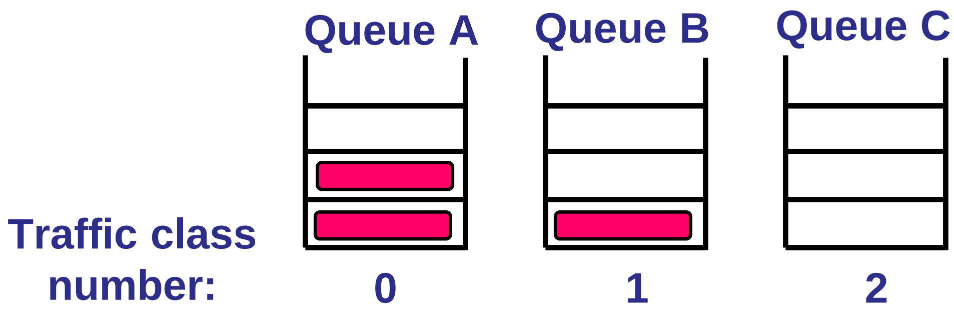
(Recommended mapping for 3 queues in cases where only strict priority scheduling is used)

==> The PCP values of a frame and the mapping will determine the traffic class (= queue into which frame will be placed).

Strict Priority Algorithm

- Strict Priority Algorithm:
  Available for transmission = Queue contains one or more frames.

- Next frame for transmission:
  From queue with the highest traffic class number that has a frame available for transmission.

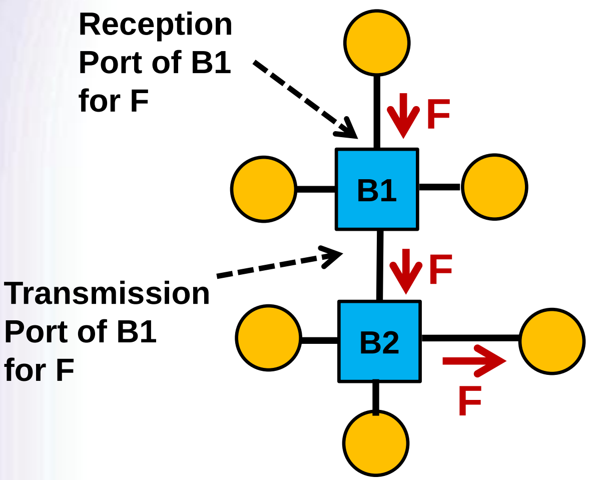


Outgoing frame selected from queue B!

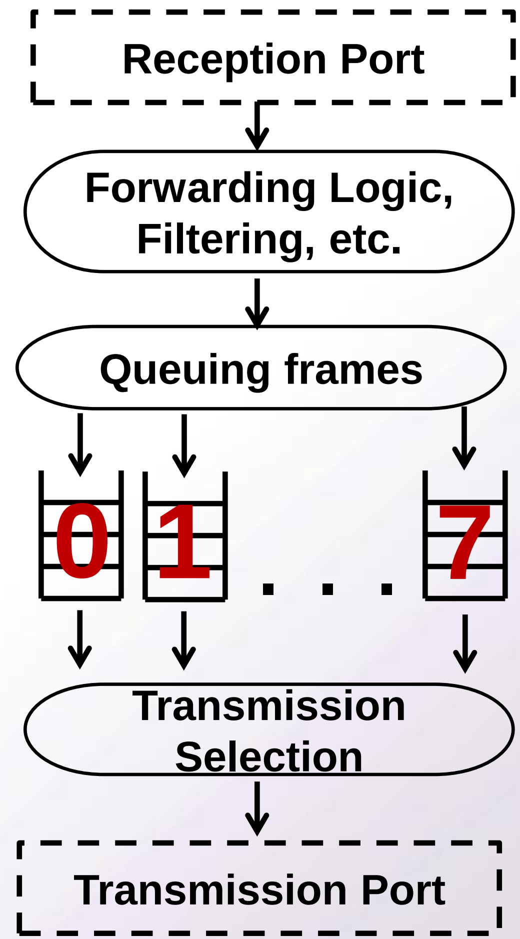
- Note: For other TSAs, the fact that a queue contains a frame does not automatically imply that the frame is available for transmission.

The big picture: Using different types of traffic in parallel

Using multiple TSA’s



Forwarding process within the bridge:



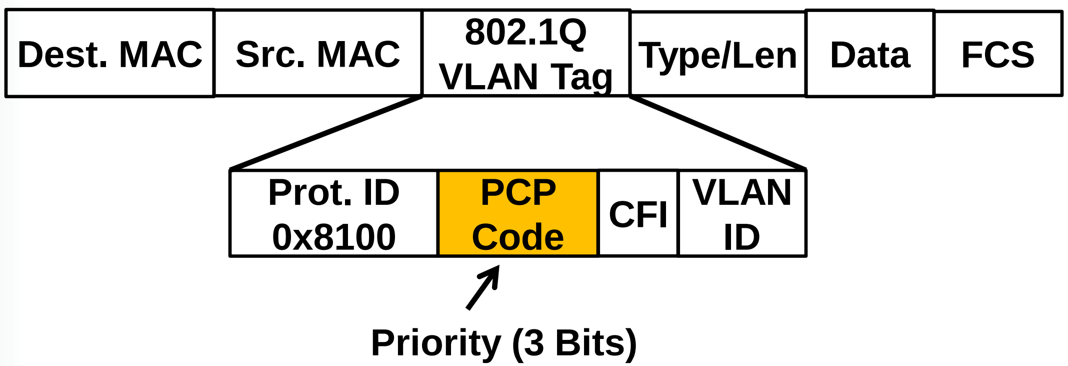
- Up to 8 outbound queues for each bridge port.
- Each queue configured with a TSA.

E.g.: **7** = Time Aware Shaper for scheduled traffic
5, 6 = Credit Based Shaper for RC traffic
0, …,4 = Strict Priority for BE traffic

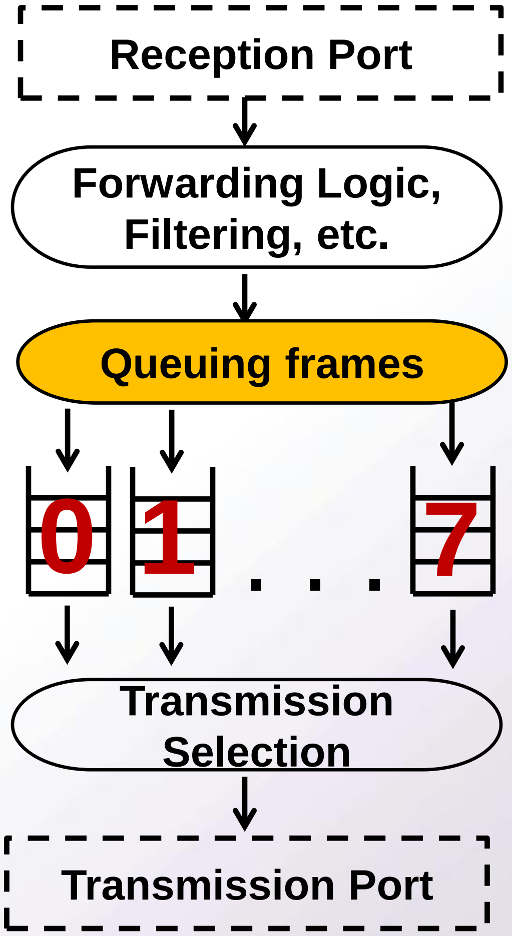
Queuing Function

- "Queuing frames" function:
  Decide into which queue F needs to be placed.

- Frame format:



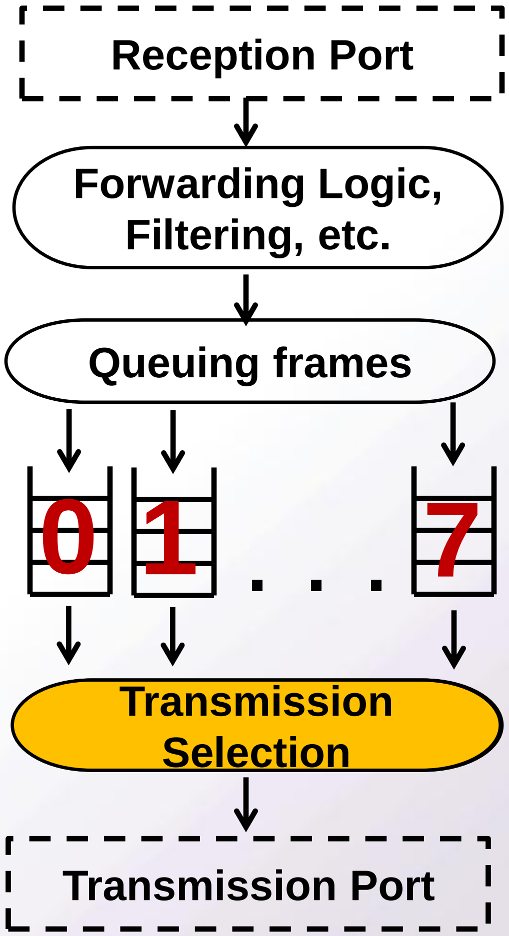
Selection of queue based on (PCP) and mapping of PCP codes to traffic class numbers.



Transmission Selection

- Transmission Selection Function:
  Frame selected from a queue for transmission if :
  a. TSA associated with queue determines that there is a frame available for transmission. ???
  b. No queue with a higher traffic class number has a frame available for transmission.

- Traffic class numbers:
  Queues associated with the "Credit based Shaper" must be configured to have a higher traffic class number than queues associated with "Strict priority Algo."



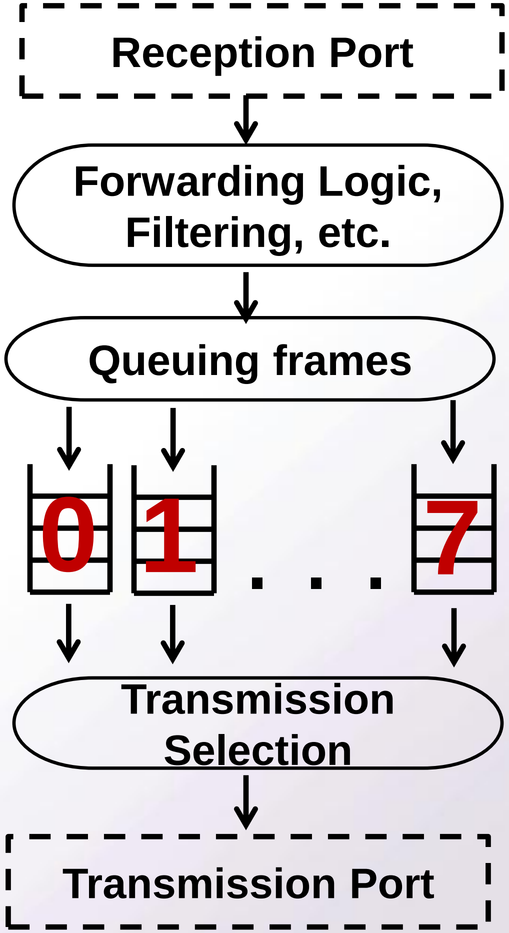
Available for Transmission

- What “Frame available for transmission” means, depends on the TSA associated with the queue.

- “Strict priority Algo.”:
  a) frame is present in the queue.

- “Credit based shaper Algo.”:
  a) a frame is present in the queue and
  b) credit ≥ 0.

- “Time aware shaper Algorithm”:
  a) a frame is present in the queue and
  b) a timing condition is fulfilled.
  (To be defined within AVB 2)



Transmission Selection Algorithms:
“Credit Based Shaper Algorithm”

Concepts / Terminology

- Concepts in this section:
  - Time sensitive Streams
  - Credit based shaper for RC Traffic
  - Stream reservations

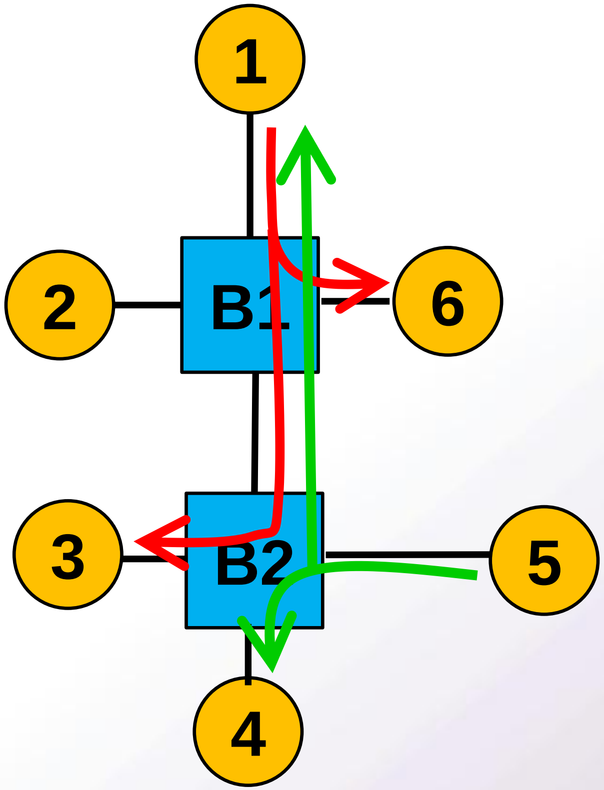
Part of AVB 1.

Support of Audio / Video.

- AVB Terminology:
  - ECU or Node = End System
  - Sending Node = Talker, Receiving Node = Listener
  - Stream:
    Unidirectional flow of data from a Talker to one or more Listener.
  - Time sensitive stream: Guaranteed bounded latency.

Streams

- Example:
  - Node 1 is talker of a stream **X** received by listeners 6 and 3
  - Node 5 is talker of a stream **Y** received by listeners 1 and 4
- Stream Reservation Protocol (SRP) registers streams.
- Once Streams are OK'd by the system, bandwidth and latency bounds are guaranteed.



Stream Reservation Classes

- Traffic Specification (T-Spec):
  - Characterizes bandwidth a stream can consume.
  - For each stream a T-Spec defines:
    1. *MaxFrameSize*
    2. *MaxIntervalFrame*
       (= frames per SR class measurement interval)

So what are SR classes and measurement intervals ?

- Two Stream Reservation Classes: Class A & Class B
  - Class measurement intervals: Class A: 125 µs Class B: 250 µs

- During stream registration SRP checks:
  Sufficient resources for a stream of desired class / desired T-Spec / desired set of listeners?

  Yes? = Stream is OK'd **No?** = Stream reservation not accepted.

Relation between “Streams” and “Credit Based Shaper”

- Note:
  - The TSpec “promises” bandwidth.
  - But the TSpec implicitly also promises bounded latency.
    (By promising a frame rate per class measurement interval)

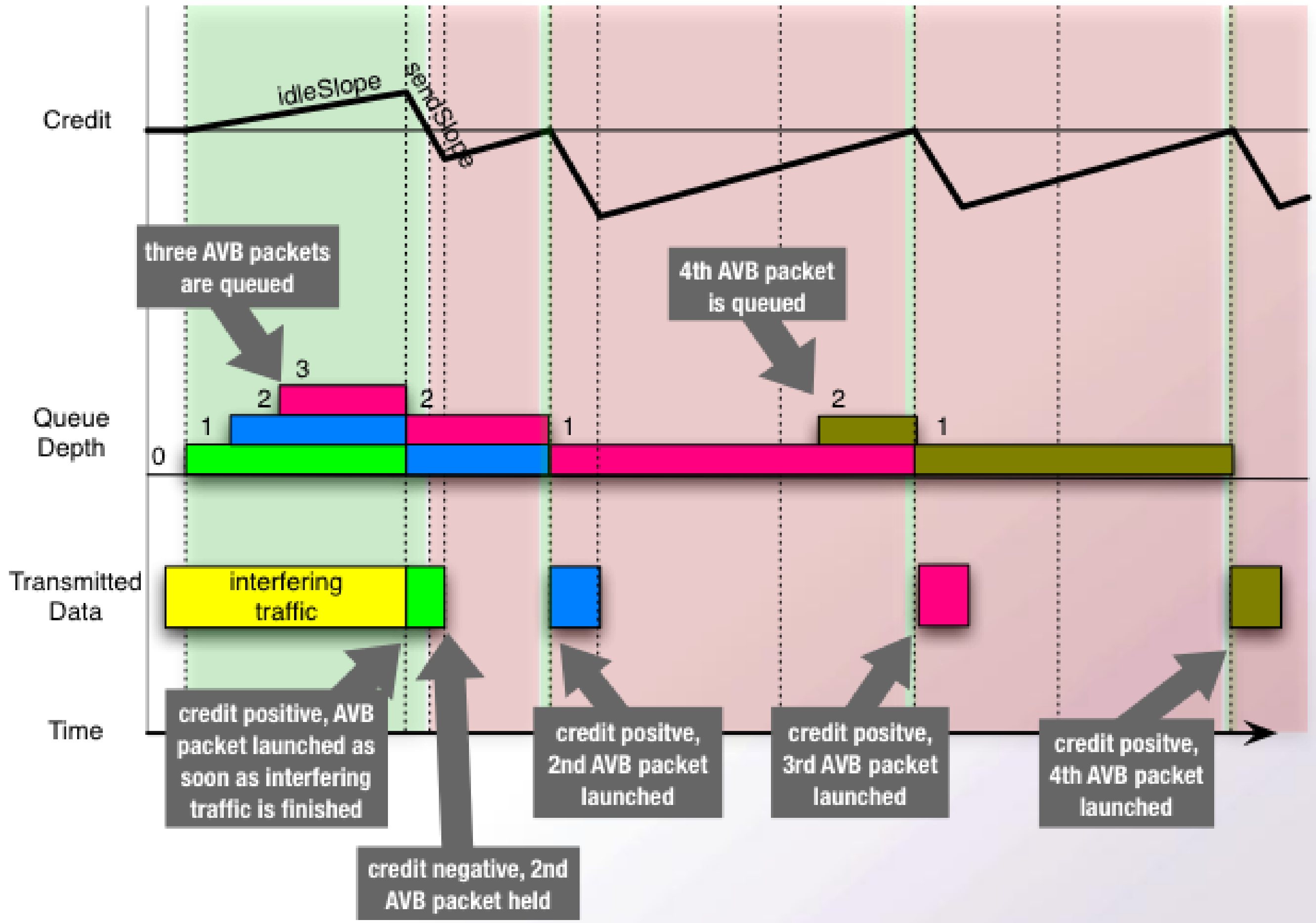
- What mechanism ensures that the “TSpec promises” are kept during operation of the system?

- Answer: The Credit Based Traffic Shaper !

- Recall:
  - The Credit Based Traffic Shaper is a Transmission Selection Algorithm (TSA).
  - Therefore:
    An outbound queue can be configured to use the Shaper!

Credit Based Shaper Algorithm

- Devices in AVB network must “shape traffic”
- Schedule transmission of packets to prevent bunching, which causes overloading of network resources.



Idle Slope & TSpec

- Question:
  Why would the Shaper Algorithm on the previous slide ensure compliance with the TSpec ?

- Rough answer:
  The main configuration parameter of the Shaper is *idleSlope*.
  A proper value of *idleSlope* will ensure that the TSpec is in effect.

Relation between “Streams” and “Credit Based Shaper” (again)

Example “Class A streams”:

- Many class A streams can be configured.
- Several end systems can act as talkers of class A streams.
- Every node can act as a talker for several class A streams.

However:

- At the outbound port of a bridge, all class A frames will be sorted into only a single queue that is configured to use the credit based shaper as TSA.

AVB takes all that into account! T-Spec’s will be intact for all streams!

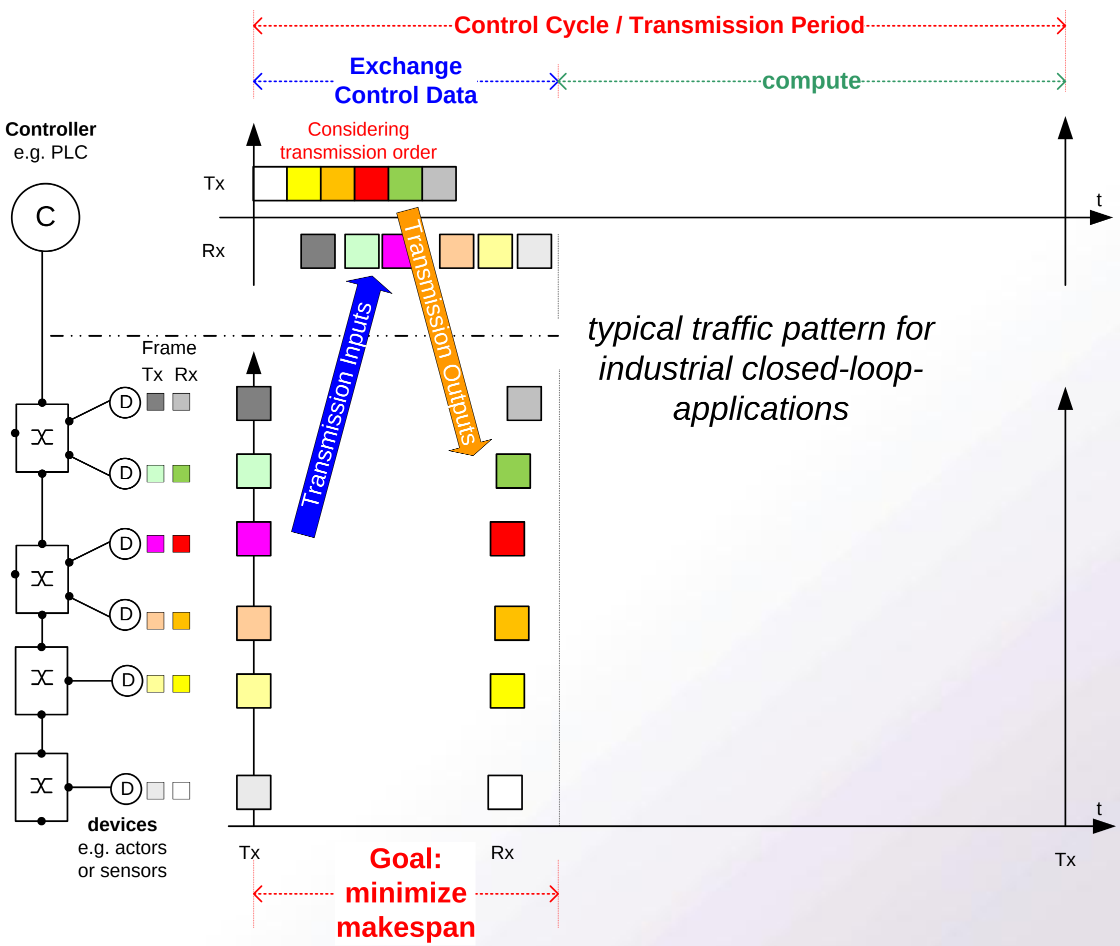
Transmission Selection Algorithms: “Time Aware Shaper”

Why another shaper?

- The credit-based shaper reduces “bunching”
  - Smooths out the traffic flow to greatly reduce the possibility of dropped packets due to congestion
- Average delay is actually increased
  - Only the worst case is better
  - Control traffic needs *small-as-possible* delays

Control systems application

- Typically closed-loop, fixed cycle
  - 30 µs to several ms, typical is 125 µs
- Credit-based shaper delays can be too high
  - 250 µs delays per hop!



Interfering traffic!

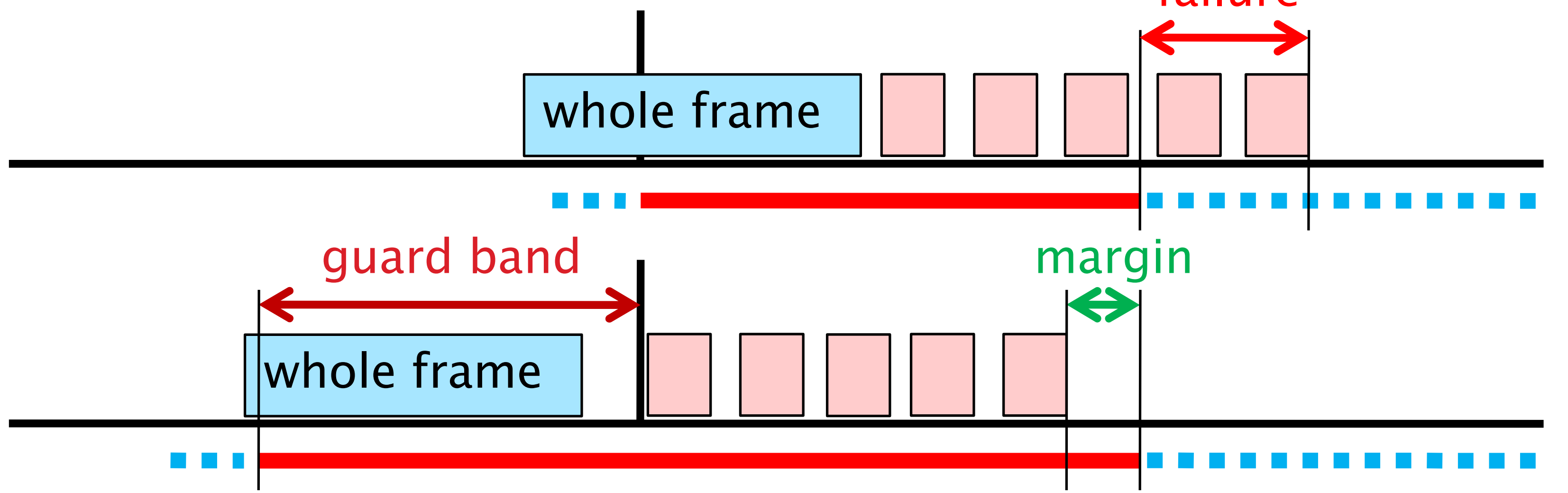
- If a packet has just started being transmitted on a particular egress port, then all traffic, regardless of the priority, must wait until the egress port has completed transmitting that packet

Avoiding interfering traffic

- Make switches aware of the cycle time for control traffic
  - Block non-control traffic during particular windows of time to ensure that the egress port for a control stream is idle when the control traffic is expected
  - Each egress port could have a separate schedule
- Non-trivial calculation in non-trivial networks
  - Requires a fully managed network
  - This is a well understood, but difficult problem, currently implemented in proprietary networks such as Siemens’ “Profinet”

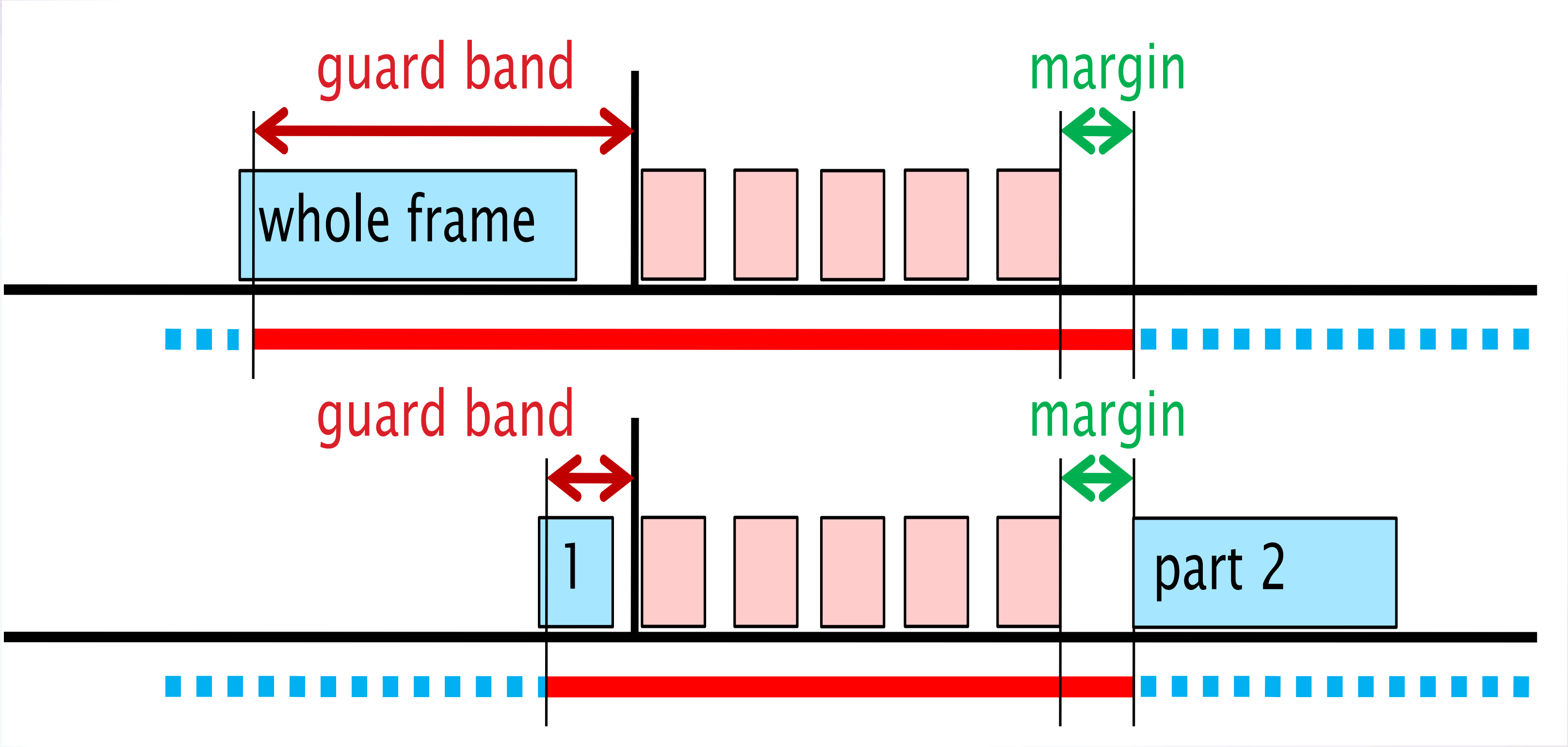
Time aware shaper issues

A “guard band” is necessary



- If an interfering frame starts transmission just before the start of a reserved time period, it can extend critical transmissions outside the window.
- Therefore, a guard band is required before the window starts, equal in size to the largest possible interfering frame.

Preemption to reduce the guard band



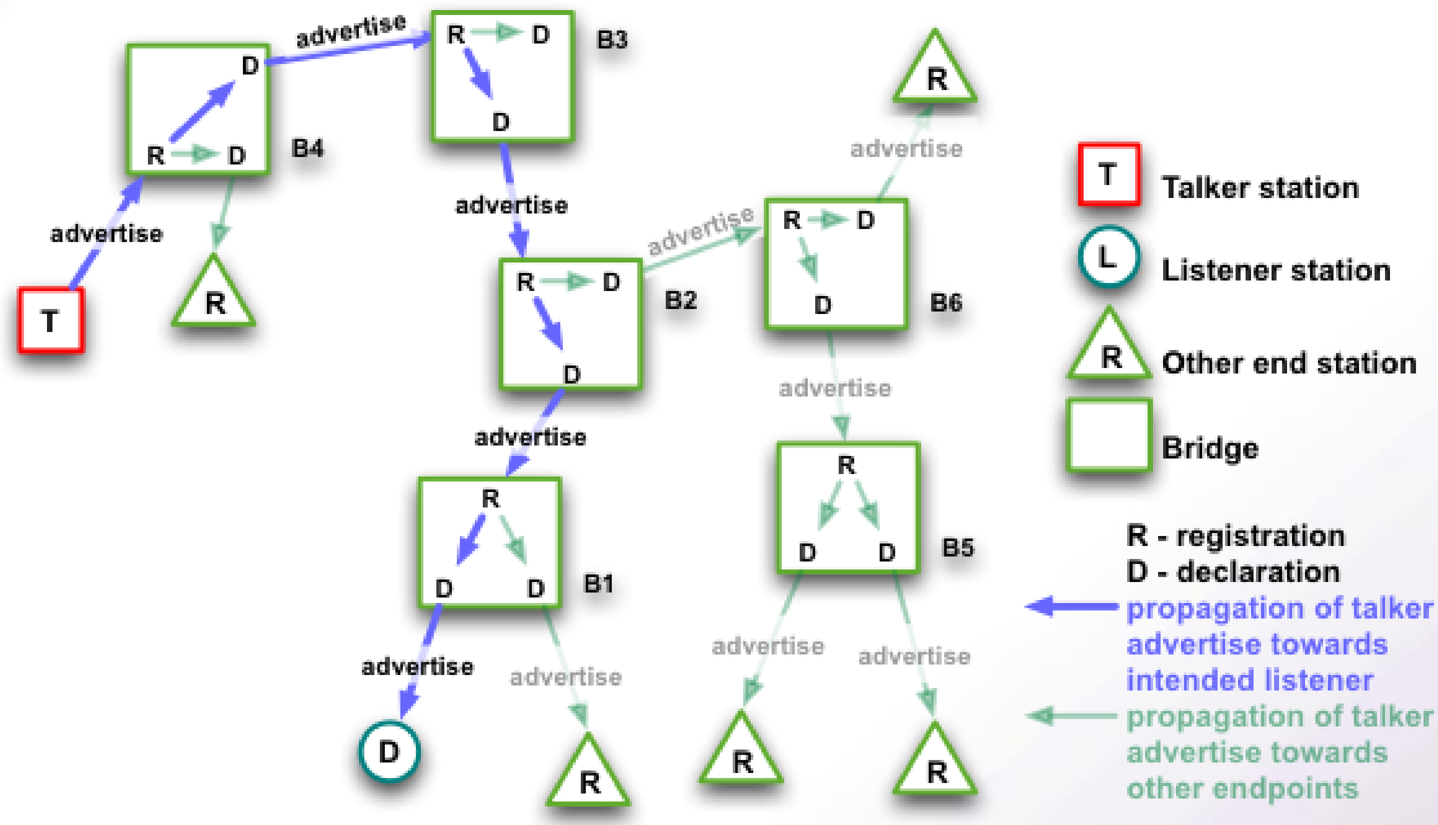
- If preemption is used, the guard band need only be as large as the largest possible interfering fragment, instead of the largest possible interfering frame.
- It is easy to see that the smaller the size of the time-reserved windows, the larger the impact of preemption.

Using Traffic Shapers: “Stream Reservation Protocol”

Admission controls
(IEEE Std 802.1Qat – added to 802.1Q)

- Priorities and shaping work only if the network resources are available along the entire path from the talker to the listener(s)
  - AVB “talkers” guarantee the path to the listener is available and reserve the resources
- Done via a new 802.1ak “Multiple Registration Protocol” application: SRP (“Stream Reservation Protocol”)
  - Registers streams as a source MAC address combined with a higher level ID (frequently the IP port address)
  - Reserves resources for streams based on bandwidth requirements and latency class
- Dynamic management of shaper parameters

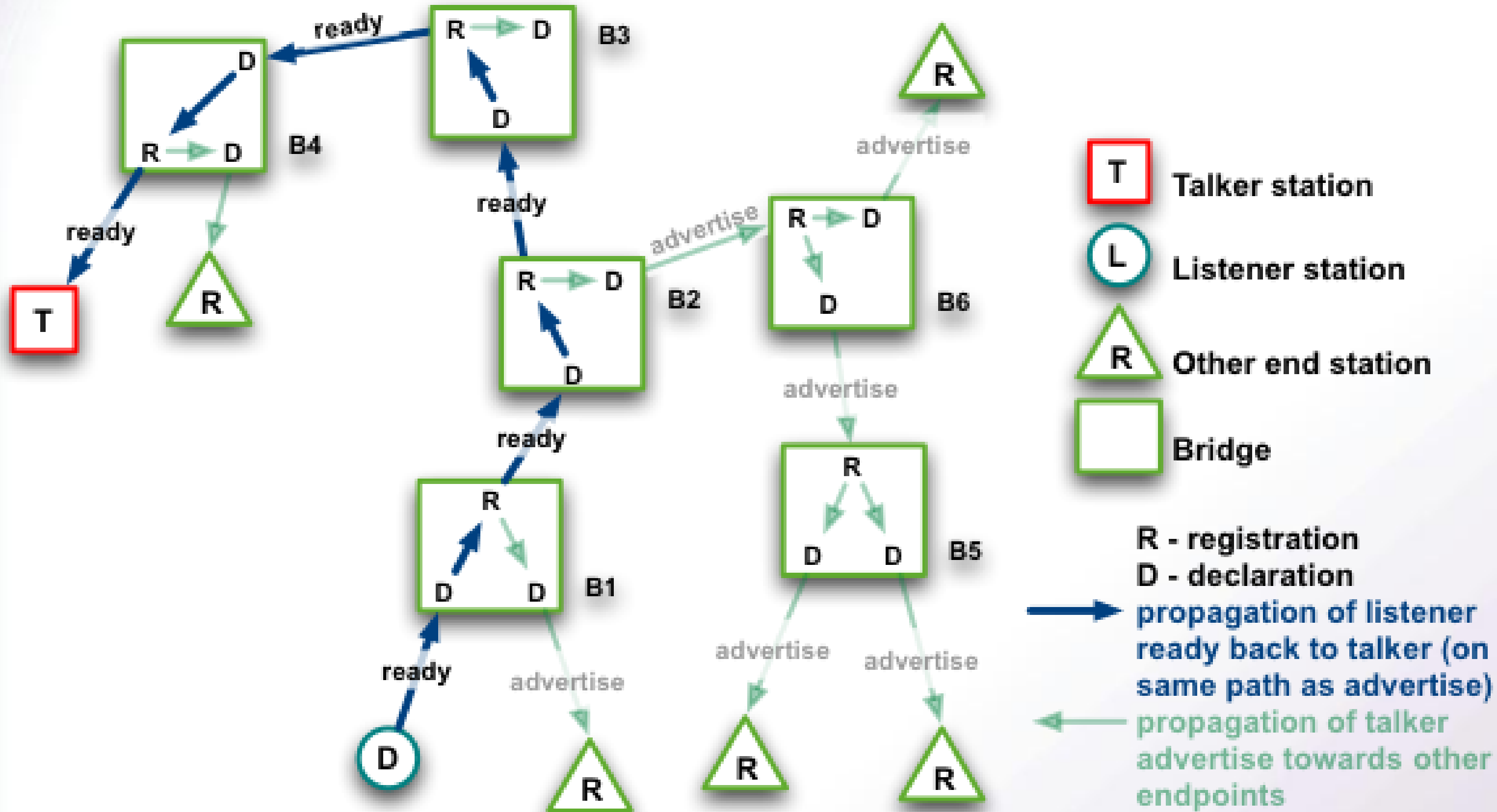
Admission control (1)
(creating a path)



- Phase one of a reservation is a "talker advertise" that tests the path and leaves behind a "breadcrumb" trail to the talker

Admission control (2)

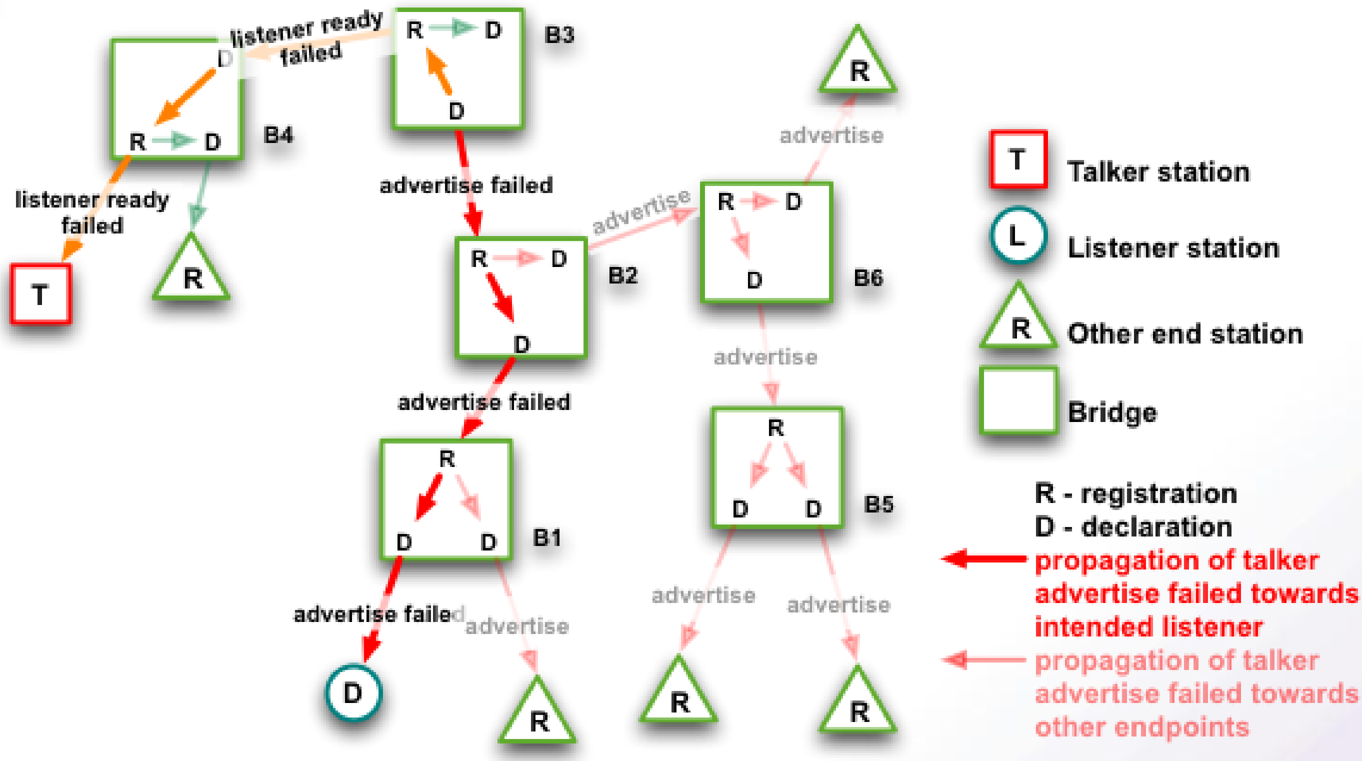
(listener ready)



- ➢ Phase two of a successful reservation actually locks down the needed resources

Admission control (3)

(failed advertise)



- If resources are not available, the “talker advertise” is propagated as “failed”
  - No reservation is made, this is done to allow a listener to know that a reservation is not possible now
- A “listener ready failed” is propagated back towards the talker from the bridge that is unable to make the reservation
  - The talker knows that at least one listener cannot get the reservation

Thought Starters:
Automotive Usage Strategies for different types of traffic and reservations

- The following slides reflect some statements and thoughts we occasionally hear when different types of traffic (BE, RC, TT) and reservation mechanisms are discussed in the auto industry.
- Some of them are neither right nor wrong but reflect opinions that are based on previous experience.
- We have listed all these statements to stimulate a discussion independently of whether or not the authors agree with the individual statements.

Statements “Best effort” (1/2)

- **BE traffic is all we need !**
  - BE is similar to CAN. Proven in use!
  - TT is difficult to handle. (FlexRay experience).
  - E2E latency of TT is high, if we miss a slot (wait for next cycle)
    (Unless task scheduler synched with network time)
  - RC spreads messages out in time. (Adds latency).
  - We know our (typically static) traffic.
    - Simulation can show if we dropping messages.
    - Underutilizing links will help.

Statements “Best effort” (2/2)

- **BE alone is not sufficient !**
  - There is value in isolating traffic:
    - Multiple use cases on a link
    - If overall traffic changes, guarantees granted to critical applications will still be in place (Simplifies Safety Cases).
  - Latency and bandwidth guarantees!
  - Simulations do not cover worst cases.

Statements “Stream Reservation Protocol” (1/2)

- **We don’t need SRP:**
  - Static reservations are sufficient.
  - Engineering our networks ensures that all resources are in place.
  - SRP bears the risk that requested reservations are not OK’d.
  - How much cost will SRP drive into switches?

- **SRP makes sense:**
  - Statically preconfigure streams. Use SRP to add optional streams.
  - Future applications will be more complex & dynamic.
    We cannot statically engineer these systems.

Statements “RC for Audio/Video” (2/2)

- **AVB is a great solution for Audio/Video streams !**
  - Reserve max. bandwidth required by Audio/Video
  - If the actual bandwidth is lower: BE will benefit.
  - Time synch. & ‘presentation time’ concept reduce buffer requirements.

Statements "Future architectures" (1/2)

- AVB's mechanisms and performance will enable new applications !
- Trend towards more critical control applications:
  - E.g. autonomous driving.
  - Isolation & Determinism required.
- Future architectures:
  - Less static traffic.
    (Difficult to engineer)
  - Higher levels of abstraction.
    (More dynamic powerful middleware. Less manual engineering.)
  - Network should not constraint the location of an ECU
    (E.g.: Run critical apps over a converged backbone.)