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) \( TSA = \text{“Strict Priority Algorithm”} \)
- The big picture: Using different types of traffic in parallel
- Rate constraint traffic (RC) \( TSA = \text{“Credit Based Traffic Shaper”} \)
- Scheduled traffic (TT) \( TSA = \text{“Time Aware shaper”} \)
- 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

<table>
<thead>
<tr>
<th>Dest. MAC</th>
<th>Src. MAC</th>
<th>802.1Q VLAN Tag</th>
<th>Type/Len</th>
<th>Data</th>
<th>FCS</th>
</tr>
</thead>
</table>

- 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 outbound queues per port
Strict Priority Algorithm

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

<table>
<thead>
<tr>
<th>PCP Code in Frame</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic class number</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

(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.

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

Traffic class number:

- Queue A: 0
- Queue B: 1
- Queue C: 2

Outgoing frame selected from queue B!
The big picture: Using different types of traffic in parallel
Using multiple TSA’s

- 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 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.”
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

- 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:
    i. `MaxFrameSize`
    ii. `MaxIntervalFrame` (= frames per SR class measurement interval)

- 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
Phase one of a reservation is a “talker advertise” that tests the path and leaves behind a “breadcrumb” trail to the talker
Phase two of a successful reservation actually locks down the needed resources
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.
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.
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.)