Urgency Based Scheduler
- Automotive Use -

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Contents

Brief Recap (May 2014)
• Discussion on further proceeding with the UBS proposal
• Technical Updates:
  – Proposed token-bucket algorithm in sub-shapers instead of leaky-bucket to increase aggregation capabilities
  – Limited number of sub priorities/removal of priority queue

Received Feedback
• TSN Members need more information on the purpose of UBS

This Slide Set
• UBS in Automotive Networks
AUTOMOTIVE NETWORKS
Topologies

Now/Near Future

Backbone + Domains by purpose
- Active Safety, Infotainment, Chassis,...

Wiring
- Bus-like chains Easy physical placement in cable channels
- Short overall wire length
- Single Twisted Pair @ 100 Mbit/s
- Fault tolerance requirements

Gateways to other technologies
- CAN, CAN-FD, FlexRay, LIN, ...

May Include Small Subnets
- Single- / multi-ECU Tier-1 building blocks

Future (as far as we can imagine ...)

Optimized Topologies ...
- Defined by physics/car structure
- Fading domain boundaries (domains and local gateways migrate from CAN/FlexRay to switched Ethernet)
- Rings/Redundancy

Economic Impact
- Even shorter overall wire length
- Single Twisted Pair @ 1 Gbit/s

Other technologies
- Less Gateways – use Ethernet in more Areas
Streams & Applications

Now/Near Future

Traffic Types in automotive networks
• Sensor Values (radar, lidar, ultrasonic, video camera/or smart camera sending object data)
• Control Loops
• Diagnosis
• Notifications
• Infotainment
• …

Routes
• Within domains by purpose
  – A/V Streams in Infotainment
  – Engine Control Loops
• Inter-domain
  – Sensor values from “everywhere” for Active Safety

Future (as far as we can imagine …)

More Safety Critical Traffic
• Higher ASIL (ISO 26262), fail operational
• Sensor-Fusion, Autonomous Driving, by-wire systems, Replacement of mechanical Systems, …
• Mode Changes/Partial Network Reconfiguration, …
• Actuation over Ethernet

Routes
• Arbitrary, i.e. in line with the topology which is itself defined by car structure/physics (cmp. prev. slide)
URGENCY BASED SCHEDULER
Flexible Traffic Class for Automotive Control Traffic

- UBS attempts to fulfill the needs of a flexible traffic class for automotive control streams:
  - Fast enough to fulfill the E2E latency requirements most automotive control applications
  - Not as strict as time triggered traffic
- Co-existent to time-triggered scheduled traffic, i.e. TAS:
  - TAS needed for applications which require “close to zero” E2E latency
UBS – Quick overview

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<th>Max. frame length</th>
<th>Datarate</th>
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<tbody>
<tr>
<td>672 bit</td>
<td>672 bit/sec</td>
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<tr>
<td>2048 bit</td>
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UBS operation is based asynchronous Shapers (similar to CBSA*)

- Streams are mapped to **sub-shaper** parameters of the UBS class egress ports along the paths:
  - **datarate** and **max. frame length**
- Sub-shapers regulate the traffic at every hop per stream/stream-aggregate allowing moderate low latency and **independent per hop latency guarantees** (cmp. [UPC]).
- Sub-shapers in egress ports can be assigned to different **sub-priorities** to map latency requirements of each stream.

**So why is this good for automotive networks?**

*CBSA is a special case of leaky-bucket shaper, leaky-bucket shaper is a special case of token bucket shaper*
Automotive Control Streams

Event Stream
- max. 1 frame/sec.
- Max. 84 byte/frame
- 1ms max. E2E latency

Periodic Stream
- Period: 5 ms
- 128 byte/frame
- 2ms max. E2E latency

Rate constrained Stream
- Rate: 5 Mbit/sec
- Max. 256 byte/frame

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UBS Class

Within some egress port

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Automotive Control Streams in UBS

- Automotive networks need to transport control stream (cmp. [FCTC]):
  - Periodic Control Streams
  - Event-based Control Streams

  **Both are supported** by UBS and treated as **rate constrained streams**, i.e. there is no differentiation between stream types.

- Streams transferred via UBS get **automotive grade E2E latency guarantees** (cmp [FCTC]) - even without latency-requirement-to-priority mapping (i.e. use UBS unscheduled) and at 100MBit/s link speed (cmp. [UWC])
Maximum Link Utilization

**Event Stream**
- max. 1 frame/sec.
- Max. 84 byte/frame
- 1ms max. E2E latency

**Periodic Stream**
- Period: 5 ms
- 128 byte/frame
- 2ms max. E2E latency

**Rate constrained Stream**
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Using Asynchronous Shapers

- Automotive: high link utilization allows to put more data on the (slow) wires – topologies not built for highest E2E throughput in first place.
- Sub-shapers operate asynchronous: Talkers decide when to send – as long as talkers don’t exceed their rate limit, there is no penalty in latency.
- There is no need for any kind of oversampling to achieve E2E latencies for
  - Event-based control streams
  - Periodic control streams with asynchronous talkers

UBS Class
Within some egress port

\[ \text{UBS Class} \]

\[ \text{Within some egress port} \]
### Periodic Control Streams

**Event Stream**
- max. 1 frame/sec.
- Max. 84 byte/frame
- 1ms max. E2E latency

**Periodic Stream**
- Period: 5 ms
- 128 byte/frame
- 2ms max. E2E latency

**Rate constrained Stream**
- Rate: 5 Mbit/sec
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**Sub-shaper parameters**

**Arbitrary periods for Periodic Control Streams**

- By mapping all stream types to rate constrained streams, the period of periodic control streams get’s lost ...
  ... and that’s ok and desired(!):

  - It does not matter whether multiple streams at one path shall be transmitted at 1ms, 1.93ms, 2.03ms, 13.23ms
  - The rate-based operation allows every periodic control stream in the network to transmit at any period desired by the applications (cmp. [FCTC]).

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A BIGGER PICTURE
Automotive networks can be considered entirely scheduled ... BUT:

- Multiple parties build domains in automotive networks:
  - OEM divisions (backbone, active safety, infotainment,...)
  - Tier1 suppliers (steering system, engine control, ...)
  - ...
- These parties doesn’t have/want to care about intra-domain details of their neighbors.
Why should they use Ethernet?

Providing an Ethernet-based QoS solution with ...

- little inter-domain dependencies
- good performance
- low configuration complexity/easy to use

That’s the goal of UBS!

makes direct use of Ethernet more attractive for domain designers, instead of ...

- using their “favorite” technology (e.g. CAN-FD),
- doing their own thing and
- connecting it to the neighbors via Gateways
Inter-domain Interfaces

- Streams are classified just by datarate and max. frame length (both should to be known by communication peers across domain boundaries).
- E2E Latency can be split at domain boundaries, e.g. “Stream x requires n µs to the domain boundary”

No inter-domain interfaces

- Other bridges and end-stations along the path and in other domains are not forced to e.g. aligning and harmonizing cycle lengths or cycle offsets of their streams on each others streams...
- ... It would even not be necessary to care about a common clock sync.

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Late changes in the network

End Station Software and Configuration

• If changes (periods, etc.) of the End-Station Software of one Application can’t be avoided, consequently changes of other end-station Software may be problematic:
  – Software is already certified
  – There is not enough processing power to just change the task schedules

• It may be possible to change bridge configuration (unsure)
**Low configuration complexity**

**Mandatory**
- Domain designers need to map their individual streams to the parameters datarate and max. frame length.

**Optional**
- If (and only if) streams would violate their E2E latency requirements, domain designers may start prioritizing streams. But they are not forced to do so if streams are fast enough!

**Latency Math**
- Calculating whether a priority setup fulfills the E2E Latency is done by a independent per hop calculations (cmp. [UPC],[UWC]) and the sum of it along the paths.
Performance of End- Stations

End Station Software

- Asynchronous transfer UBS does not enforce that OS-tasks are aligned to network time or the tasks of non-communication peers.
- Full time alignment may not be possible easily:
  - End Stations are tiny, i.e. embedded systems – there’s no processing power left for waiting
  - The End Station Software doesn’t like it (this experience was made with FlexRay)
Thank you for your Attention!

Questions, Opinions, Ideas?

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## References

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