Urgency Based Scheduler – Status Update

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Contents

About
• This slide set results of joint work in progress of Siemens and University of Duisburg-Essen to:
  – Define one shaper proposal for both, automotive and industrial control use-cases
  – Enhance the proposal to become part of 802.1

This slide set
• Recap & Background
• Technical Update/Work in Progress
• Discussion Appreciated:
  – Implementation Complexity
  – Standardization in 802.1
  – Other topics?
RECAP & BACKGROUND
General Background Information for Industrial Automation Applications

*Within industrial we have to differentiate two Systems:*

- **Closed Systems**
  Typical used for “Closed-Loop-Applications” like motion control systems
  - One network for one application – this application is fixed
  - Fix topology – adapted to application
  - Guaranteed QoS & guaranteed low latency by
    - Highly optimized scheduling
    - Harmonized transmission period
    - Coordinated windows
  - Computed in a “manager” device to meet high performance requirements

- **Open Systems**
  Typical used for “Control-Applications” like assembly lines
  - Multiple applications share one network
  - Topology can change when applications are added, changed or removed at runtime
  - Multiple transmission periods
  - Guaranteed QoS & guaranteed low latency
  - Requires hot network reconfiguration of a flexible traffic class
  - Undesired side effects on already established control-data-traffic must avoided

*One industrial network can also consist of „Closed“ and „Open Systems“*
Industrial Applications/Transmission Modes

Typical exiting applications/transmission modes for control-data

- **Event based transmission of control-data-streams**
  (knowledge about max rate)

- **Periodical transmission of control-data-streams**
  (Talkers are not synchronized)

- **Scheduled transmission of control-data-streams**
  (Talkers are synchronized)

- **Scheduled and coordinated transmission of control-data-streams**
  (Talkers are synchronized)

- **Seamless failover for high reliability**
  (Redundant transmission and receiving of control-data-streams)

➢ A time sensitive network for industrial automation has to support the typical application modes
Automotive Applications and Networks

Broad range of streams sharing one network
• Several stream types: Periodic, event-based, rate constrained (AV), ...
• Varying, application dependent, End-to-End latency requirements
• Some streams with safety requirements: 802.1CB, policing, ...

Small low speed topologies
• Rather one hundred end stations than thousands (or even more)
• Low link speeds (typical 100Mbit/s)
• Topology design driven by requirements on safety, economic wiring, physics, etc. – not only high throughput

Need
• Best achievable mapping of streams, their characteristics and requirements ...
  → low resource blocking (e.g. less over-reservation)
  → high utilization of wires
Automotive Network Engineering

**Network Engineering**
- Networks are completely scheduled before series production
- Involves multiple parties:
  - Different OEM divisions
  - Component suppliers delivering “building blocks” (e.g. brake- or steering-systems) comprising single end stations or partial networks
  - ...
- Needs coordination between those parties during development

**Need**
- Small and simple interfaces between parties
- Low scheduling/network configuration dependencies across applications
- Avoid multiple “scheduling iterations”
Shaper Proposals

Presented in 802.1TSN

- UBS
  - Shaper proposal, primary for Automotive Systems
  - Univ. Duisburg-Essen, General Motors
- BLS
  - Shaper proposal, primary for Industrial Control Systems
  - Siemens

Goals of both proposals

- Support broad range of streams
- Guaranteed QoS guarantees & guaranteed latency
- Low planning/scheduling effort

Assumptions

- Merging both to an enhanced UBS variant fulfills Automotive and Industrial needs
- Better scalability from an implementer’s perspective without losing scalability from a user’s perspective needs to be addressed

Uncertain

- What else is needed from the TSN group’s perspective to progress further with the proposal?
UBS & BLS Proposals
(As presented in 802.1TSN)

**UBS:**

![UBS diagram]

**BLS:**

![BLS diagram]
Changes/Updates

1. **Decouple Sub Priorities from Sub Shapers**
   - **Goals:**
     - Get rid of non-FIFO queue operation
     - Allow less Sub Priorities than Sub Shapers
   - *discussed on next slides...*

2. **Replace Leaky Bucket with Token Bucket Algorithm**
   - **Goals:**
     - Maximize stream aggregation without undesired side effects (e.g. worsened latency)
     - Minimize the number of Sub Shapers
   - **Assumption:**
     - Nearly equal implementation complexity of both algorithms (Leaky Bucket and Token Bucket)
   - *ongoing analysis...*
One sub priority – No Latency Mapping

Example

• 4 equal streams (max. rate, max. frame length) with different latency requirements
• 3 Hops (from device A to device D)

(No-)Mapping with one sub priority

<table>
<thead>
<tr>
<th>Stream</th>
<th>Latency Req.</th>
<th>Max. Latency (calc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>1 ms</td>
<td>1.57 ms</td>
</tr>
<tr>
<td>S2</td>
<td>1.33 ms</td>
<td>1.57 ms</td>
</tr>
<tr>
<td>S3</td>
<td>1.66 ms</td>
<td>1.57 ms</td>
</tr>
<tr>
<td>S4</td>
<td>2.33 ms</td>
<td>1.57 ms</td>
</tr>
</tbody>
</table>

No Latency Requirement Mapping Possible

• Per stream per hop latency defined by per port utilization
• “Equalizes” stream latency

Other Parameters:
No Higher Traffic Class; Lower Traffic Class Max. Frame= 1544 Byte; Max. Frame of all Streams = 1000 Bit; Rate of all Streams = 10MBit/s; Link Speed = 100MBit/s; Store & Forward Operation
Latency Mapping: Many Sub Priorities

Example

- 4 equal streams (max. rate, max. frame length) with different latency requirements
- 3 Hops (from device A to device D)

Mapping with 4 sub priorities ("many")

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<tbody>
<tr>
<td>S1</td>
<td>1 ms</td>
<td>0.67 ms</td>
</tr>
<tr>
<td>S2</td>
<td>1.33 ms</td>
<td>1.05 ms</td>
</tr>
<tr>
<td>S3</td>
<td>1.66 ms</td>
<td>1.51 ms</td>
</tr>
<tr>
<td>S4</td>
<td>2.33 ms</td>
<td>2.11 ms</td>
</tr>
</tbody>
</table>

Latency Mapping by Sub Priorities

- Many sub priorities → fine grained latency requirement mapping
Nearly the same: Few Sub Priorities

Example
- 4 equal streams (max. rate, max. frame length) with different latency requirements
- 3 Hops (from device A to device D)

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<td>1.51 ms</td>
</tr>
<tr>
<td>S4</td>
<td>2.33 ms</td>
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Other Parameters:
- No Higher Traffic Class; Lower Traffic Class Max. Frame = 1544 Byte; Max. Frame of all Streams = 1000 Bit; Rate of all Streams = 10MBit/s; Link Speed = 100MBit/s; Store & Forward Operation

5/15/2014 IEEE Interim Meeting, May 2014, Norfolk
Nearly the same: “mixed” Network

Example

- 4 equal streams (max. rate, max. frame length) with different latency requirements
- 3 Hops (from device A to device D)

Mapping with 4 sub priorities (“many”)

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<tbody>
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<td>1.33 ms</td>
<td>1.05 ms</td>
</tr>
<tr>
<td>S3</td>
<td>1.66 ms</td>
<td>1.51 ms</td>
</tr>
<tr>
<td>S4</td>
<td>2.33 ms</td>
<td>2.11 ms</td>
</tr>
</tbody>
</table>

Mapping with varying sub priorities (“mixed”)

<table>
<thead>
<tr>
<th>Stream</th>
<th>Latency Req.</th>
<th>Max. Latency (calc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>1 ms</td>
<td>0.97 ms</td>
</tr>
<tr>
<td>S2</td>
<td>1.33 ms</td>
<td>1.22 ms</td>
</tr>
<tr>
<td>S3</td>
<td>1.66 ms</td>
<td>1.66 ms</td>
</tr>
<tr>
<td>S4</td>
<td>2.33 ms</td>
<td>1.85 ms</td>
</tr>
</tbody>
</table>

Other Parameters:
No Higher Traffic Class; Lower Traffic Class Max. Frame = 1544 Byte; Max. Frame of all Streams = 1000 Bit; Rate of all Streams = 10MBit/s; Link Speed = 100MBit/s; Store & Forward Operation
Conclusions (1)

Latency Requirement Mapping requires sub priorities, BUT:

- Few sub priorities can “emulate” more along multiple hops
  ➔ That’s Ok – Good mapping is more important on long paths than on short paths
- Mixed networks possible, i.e. limitations of bridges with one sub priority can be compensated by bridges with more sub priorities
- Limits of few sub priorities would only be reached in case of “aggressive” (close to the limits) latency requirements of all streams

### Mapping with 4 sub priorities (“many”)

<table>
<thead>
<tr>
<th>Stream</th>
<th>Latency Req</th>
<th>Max. Latency (calc.)</th>
<th>Aggressive Latency Req.</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>1 ms</td>
<td>0.67 ms</td>
<td>0.67 ms</td>
</tr>
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<td>S2</td>
<td>1.33 ms</td>
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</table>

➔ Expected to be rather unlikely in real systems
Conclusions (2)

Number of Sub Priorities
• Limitations like number of classes in AVB-Gen1 seem to be reasonable, e.g.:  
  – One sub priority mandatory  
  – Two sub priorities recommended (explicit or implicit stated)  
  – More sub priorities possible  
• Exact number could be managed by profiles

Sub Priorities vs. Traffic Classes
• Latency mapping requires independent per port priority configuration, e.g.  
  – One stream can belong to ...  
  – two different sub priorities at ...  
  – two different egress ports of a bridge  
• Multiple UBS classes without internal sub priorities wouldn’t be flexible enough for this requirement, doing this via PCP encoding/decoding (as currently specified) is not possible
  
→ Per port sub priority association could be located in the filtering database “close” to port maps
Thank you for your Attention!

Questions, Opinions, Ideas?

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