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 <u>one</u> 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

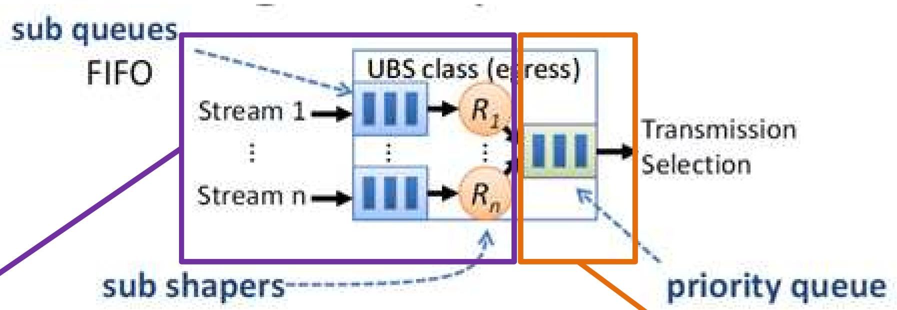
- Merging both to an enhanced UBS variant fulfills Automotive and Industrial needs
- Better scalability from an implementer's perspective without loosing scalability from a user's perspective needs to be addressed

Uncertain

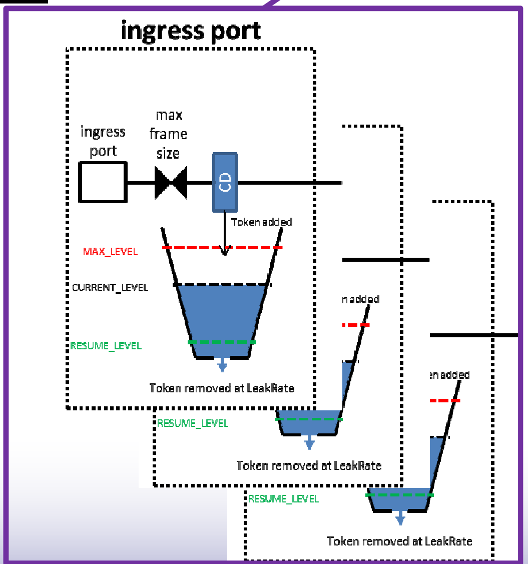
- ***What else is needed from the TSN group's perspective to progress further with the proposal?***

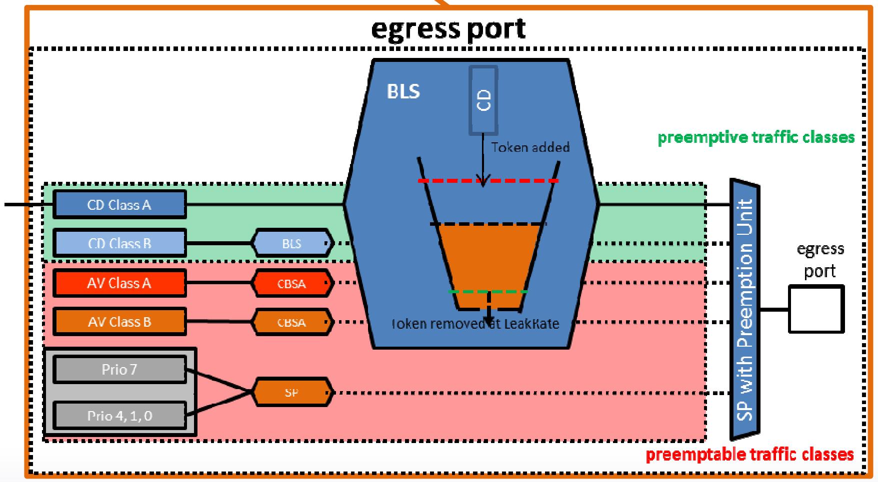
UBS & BLS Proposals (As presented in 802.1TSN)

UBS:



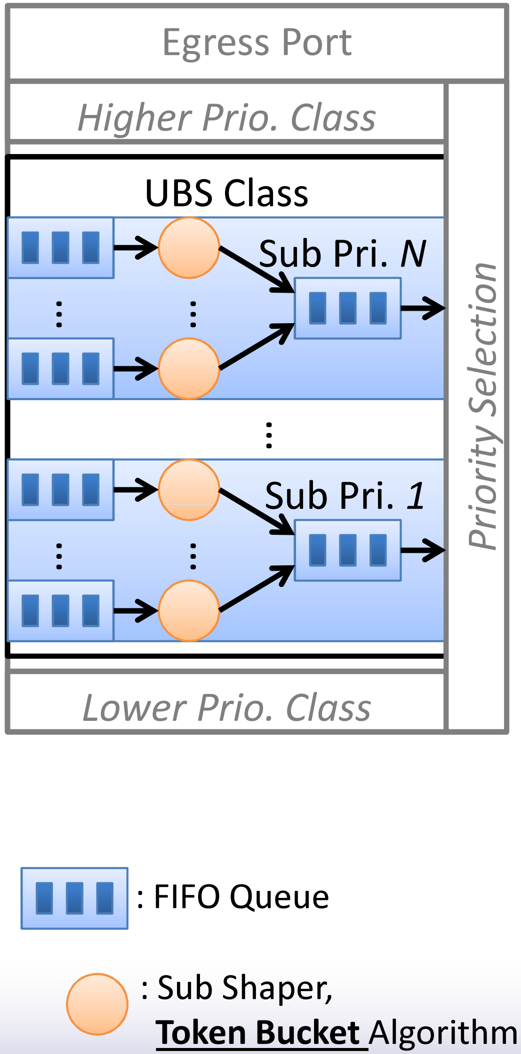
BLS:





TECHNICAL UPDATE

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

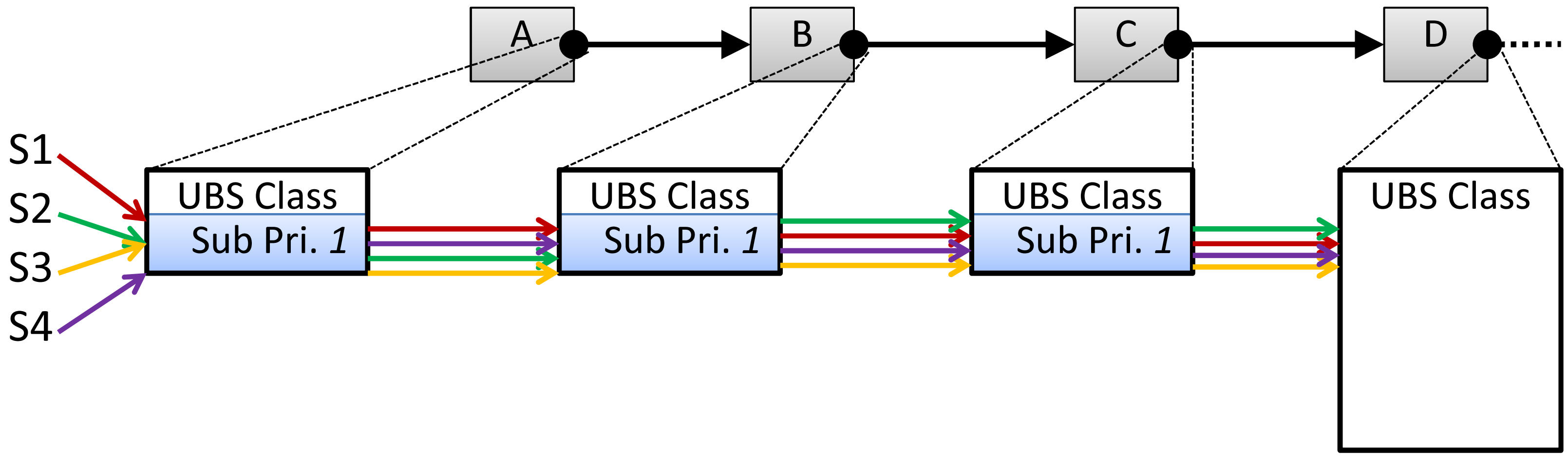
- Goals:
  - Maximize stream aggregation without undesired side effects (e.g. worsened latency)
  - Minimize the number of Sub Shapers
- Assumption:
  - Nearly equal implementation complexity of both algorithms (Leaky Bucket and Token Bucket)

… 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

Stream	Latency Req.	Max. Latency (calc.)
S1	1 ms	1.57 ms
S2	1.33 ms	1.57 ms
S3	1.66 ms	1.57 ms
S4	2.33 ms	1.57 ms

No Latency Requirement Mapping Possible

- Per stream per hop latency defined by per port utilization
- "Equalizes" stream latency

Other Parameters:

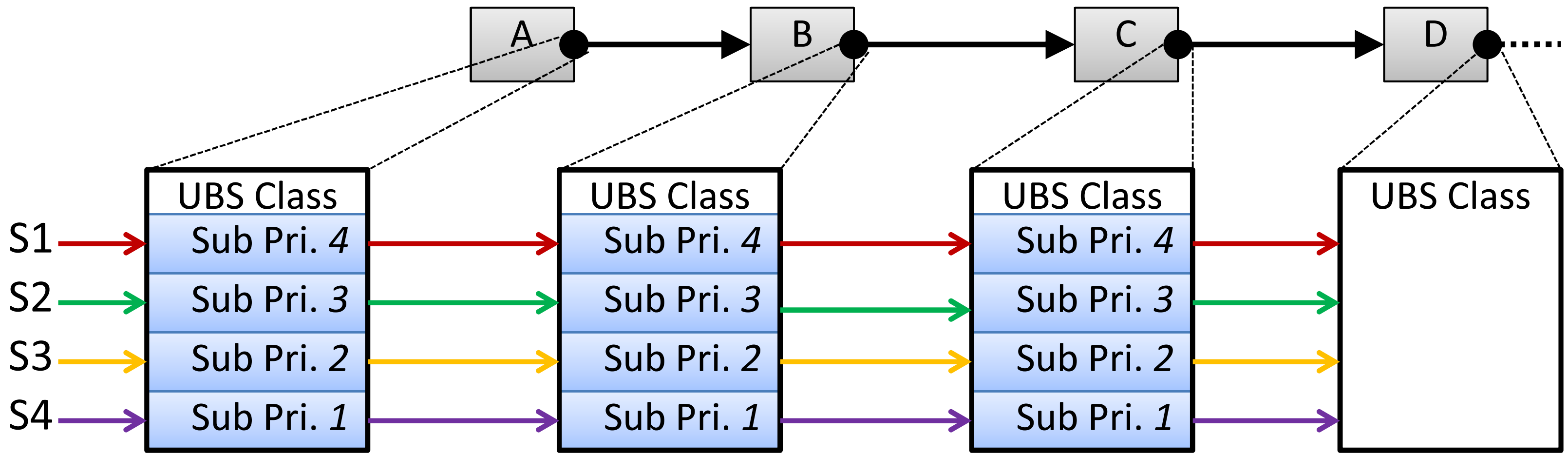
No Higher Traffic Class; Lower Traffic Class Max. Frame= 1544 Byte; Max. Frame of all Streams = 1000 Bit; Rate of all Streams = 10MBit/s; Link Speed = 100MBit/s; Store & Forward Operation

Latency math found in http://www.ieee802.org/1/files/public/docs2013/new-tsn-specht-ubs-perfchar-1113-v1.pdf

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")

Stream	Latency Req.	Max. Latency (calc.)
S1	1 ms	0.67 ms
S2	1.33 ms	1.05 ms
S3	1.66 ms	1.51 ms
S4	2.33 ms	2.11 ms

Latency Mapping by Sub Priorities

•Many sub priorities → fine grained latency requirement mapping

Other Parameters:

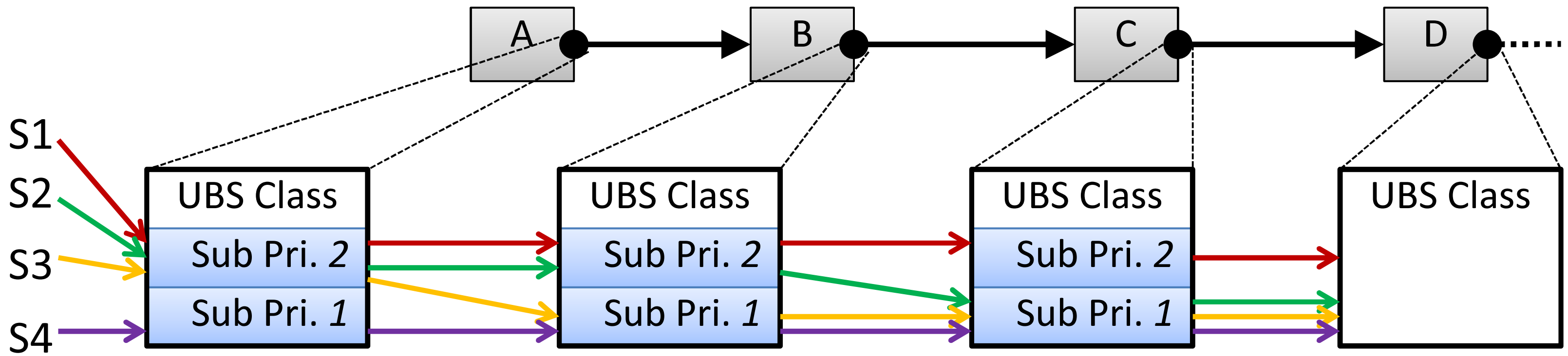
No Higher Traffic Class; Lower Traffic Class Max. Frame= 1544 Byte; Max. Frame of all Streams = 1000 Bit; Rate of all Streams = 10MBit/s; Link Speed = 100MBit/s; Store & Forward Operation

Latency math found in http://www.ieee802.org/1/files/public/docs2013/new-tsn-specht-ubs-perfchar-1113-v1.pdf

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)



Mapping with 4 sub priorities ("many")

Stream	Latency Req.	Max. Latency (calc.)
S1	1 ms	0.67 ms
S2	1.33 ms	1.05 ms
S3	1.66 ms	1.51 ms
S4	2.33 ms	2.11 ms

Mapping with 2 sub priorities ("few")

Stream	Latency Req.	Max. Latency (calc.)
S1	1 ms	0.97 ms
S2	1.33 ms	1.32 ms
S3	1.66 ms	1.62 ms
S4	2.33 ms	1.91 ms

Other Parameters:

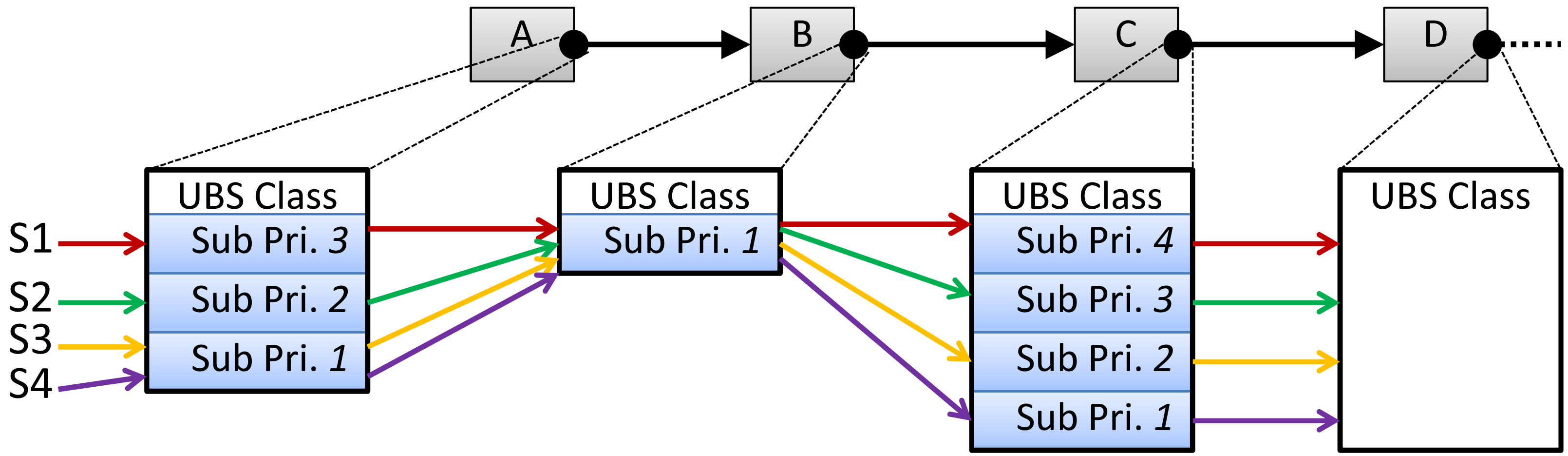
No Higher Traffic Class; Lower Traffic Class Max. Frame= 1544 Byte; Max. Frame of all Streams = 1000 Bit; Rate of all Streams = 10MBit/s; Link Speed = 100MBit/s; Store & Forward Operation

Latency math found in http://www.ieee802.org/1/files/public/docs2013/new-tsn-specht-ubs-perfchar-1113-v1.pdf

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")

Stream	Latency Req.	Max. Latency (calc.)
S1	1 ms	0.67 ms
S2	1.33 ms	1.05 ms
S3	1.66 ms	1.51 ms
S4	2.33 ms	2.11 ms

Mapping with varying sub priorities ("mixed")

Stream	Latency Req.	Max. Latency (calc.)
S1	1 ms	0.97 ms
S2	1.33 ms	1.22 ms
S3	1.66 ms	1.66 ms
S4	2.33 ms	1.85 ms

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 math found in http://www.ieee802.org/1/files/public/docs2013/new-tsn-specht-ubs-perfchar-1113-v1.pdf

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")

Stream	~~Latency Req~~	Max. Latency (calc.)	Aggressive Latency Req.
S1	~~1 ms~~	0.67 ms	0.67 ms
S2	~~1.33 ms~~	1.05 ms	1.05 ms
S3	~~1.66 ms~~	1.51 ms	1.51 ms
S4	~~2.33 ms~~	2.11 ms	2.11 ms

→ 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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