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- Where IT meets Automation -

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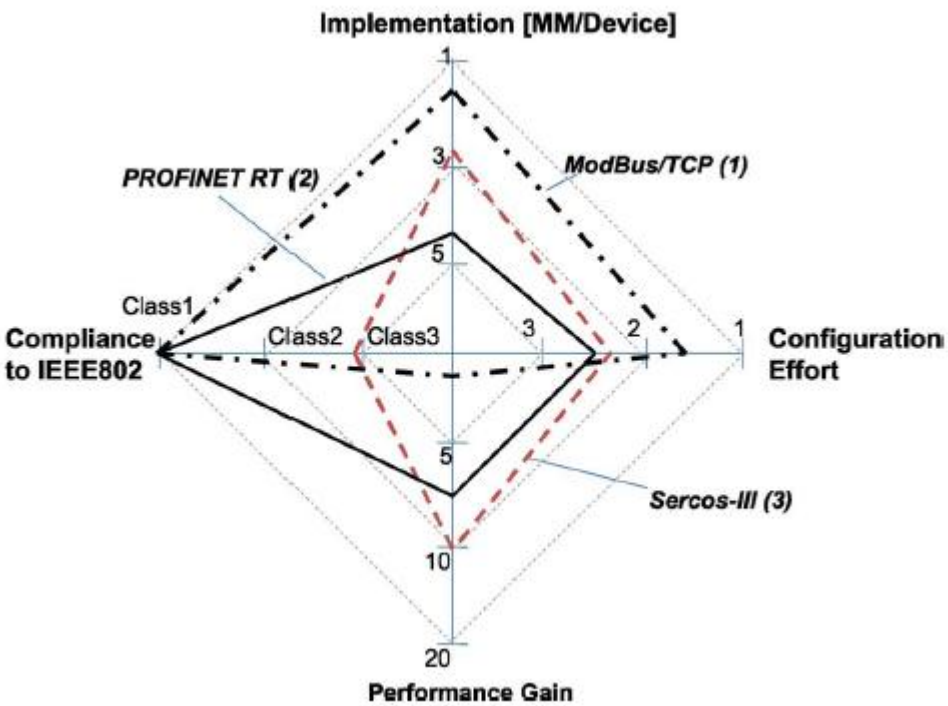
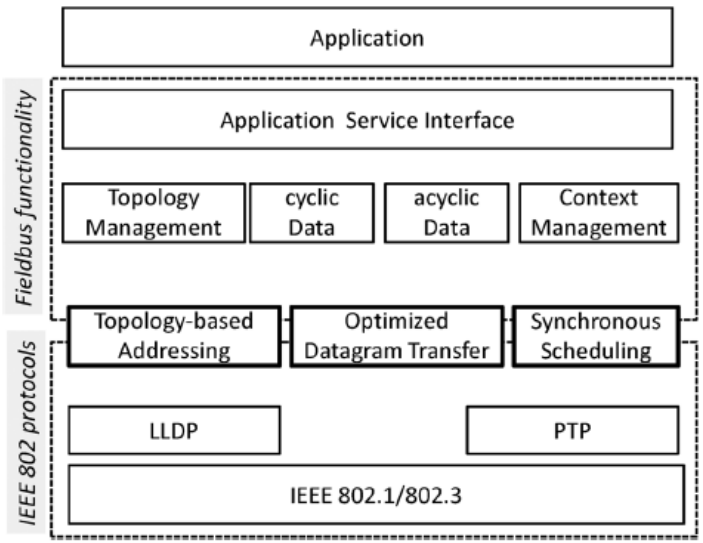
- Fraunhofer Application Center
- Systems Engineering for Automation
- Ready-to-Use System Technologies (HW, SW) for Automation Products

Real-time Ethernet Requirements for Automation Applications



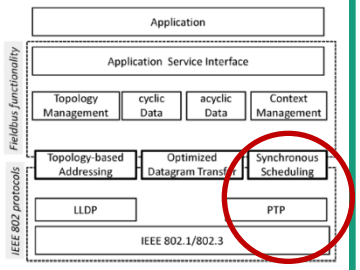
A common reference architecture



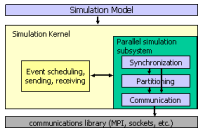
Exploring AVB for being a potential candidate for some building blocks?

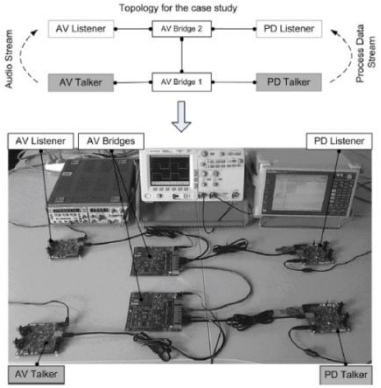
Jasperneite, Jürgen; Imtiaz, Jahanzaib; Schumacher, Markus; Weber, Karl: A Proposal for a Generic Real-time Ethernet System. In: IEEE Transactions on Industrial Informatics(5) S.: 75 -85, May 2009.

Exploring AVB for being a potential candidate for some building blocks



- AVB TG aims developing standard Ethernet towards real-time capable Ethernet
- AVB Gen 2 topics: Latency, Preemption, Redundancy, Configuration





One objective: an AVB test-bed for technology evaluation!

Key RTE Requirements:

Implementation Costs

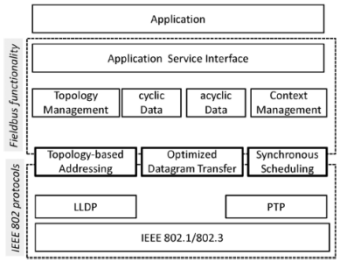
IEEE802 Compliance

Configuration Effort

Real-Time Performance

- Imtiaz, Jahanzaib; Jasperneite, Jürgen; Han, Lixue: A Performance Study of Ethernet Audio Video Bridging (AVB) for Industrial Real-time Communication. In: 14th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA 2009) Palma de Mallorca, Spain, Sep 2009.
- Imtiaz, Jahanzaib; Jasperneite, Jürgen; Schriegel, Sebastian: A Proposal to Integrate Process Data Communication to IEEE 802.1 Audio Video Bridging (AVB). In: 16th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA 2011) Toulouse, France, Sep 2011.

Preemption



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Latency Requirements

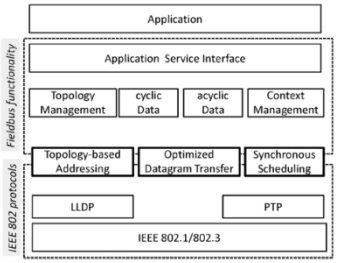
- Use Case: Low-latency real-time Control Loop use cases in Automotive and Industrial, converged onto rest of Ethernet network infrastructure. Payload size and bandwidth limited.
- Automotive -- 100 uS over five bridge hops @ 100 Mb/s and above – (from March & Sept 2011, 802.1:
  in public area: http://www.ieee802.org/1/files/public/docs2011)
  - new-avb-KimNakamura-automotive-network-requirements-0311.pdf
  - new-avb-nakamura-automotive-backbone-requirements-0907-v02.pdf (revised)
- Industrial -- <5 uS per hop, ~32 bridge hops @ 1000 Mb/s and above – (from January 2011, 802.1). 125 uS over 32 hops desired.
  - new-goetz-avb-ext-industrcom-0113-v01.pdf
  - ba-goetz-industrial-profile-0509.pdf ← /docs2009
- Problem Statement:
  (Ignoring the bridge and other delay for the moment)
  - Max Length Ethernet Frame @ 100 Mb/s =~120 uS – greater than automotive requirements.
  - Max Length Ethernet Frame @ 1000 Mb/s =~12 uS – greater than industrial requirements.
  - "Head of Line" blocked behind Max Length Frame exceeds the requirements above.

802.1 Nov 2011 Plenary | IEEE 802.1 Low Latency Packet Delivery Requirements | Page 3

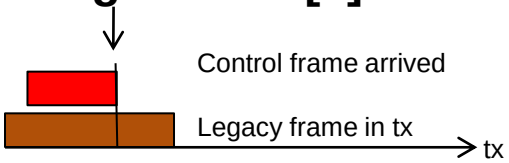
- http://www.ieee802.org/1/files/public/docs2011/new-avb-kim-very-low-latency-packet-delivery-problem-statements-1111-v01.pdf

Preemption

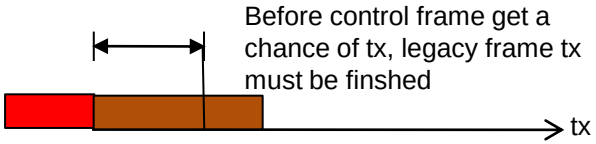
Options to reduce effects of long interfering frames [1]



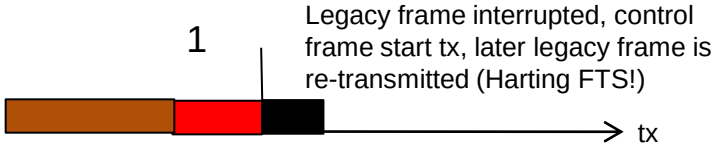
1. Interrupt long legacy Frames



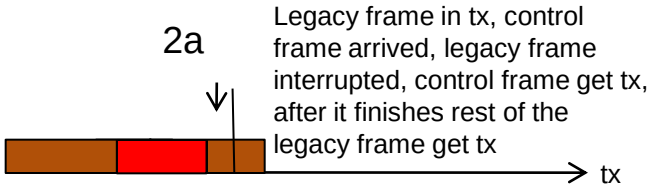
2. Make long Frames smaller

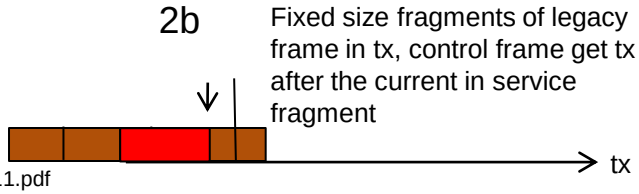


a) Transmission interruption and recovery mechanism at 802.3!



b) Always fragmentation (Overhead)





Key RTE Requirements:

Implementation Costs

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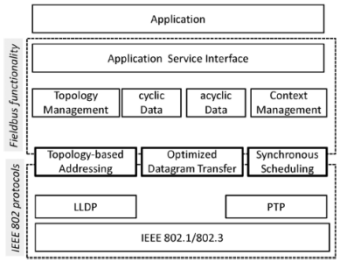
Configuration Effort

Real-Time Performance

- http://www.ieee802.org/1/files/public/docs2011/new-imtiaz-goetz-fragmentation-0511.pdf

Preemption



Key RTE Requirements:

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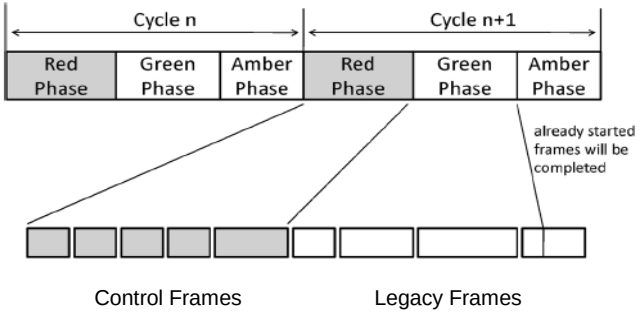
Real-Time Performance

Options to reduce effects of long interfering frames [2]



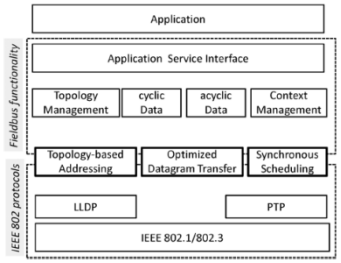
3. Avoid conflict situation: zero legacy frame interference latency
   - Time aware shaper
   - Use fixed time slots for RT traffic and stop legacy traffic before
   - Zero impact of legacy frames
   - Only work with homogenious networks, and need synchronized bridges/ no legacy bridges
   - High configueraton effort

…. both concepts can be combined

- http://www.ieee802.org/1/files/public/docs2011/new-imtiaz-goetz-fragmentation-0511.pdf

Preemption

A simulation to study the effects of fragmentation



Key RTE Requirements:

Implementation Costs

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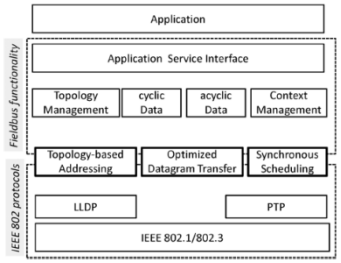
Configuration Effort

Real-Time Performance

- A case study using a simple layer 2 fragmentation approach (based on principles of IP fragmentation) to observe effects on the AVB traffic shaping with different interference sizes

- Also industrial Ethernet protocols like PROFINET IRT (v2.3) and EtherCAT, introduces the layer 2 fragmentation of IP frames for industrial automation applications to improve the performance and reduce the update time

Preemption



Key RTE Requirements:

Implementation Costs

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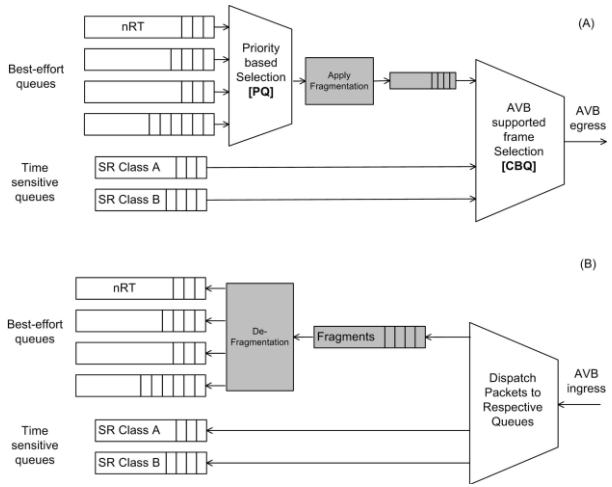
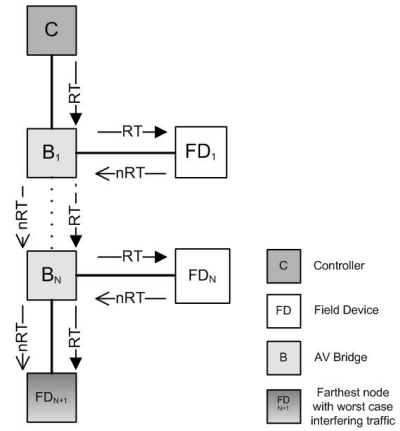


Egress/Ingress port model with fragmentation



e.g. Linear topology

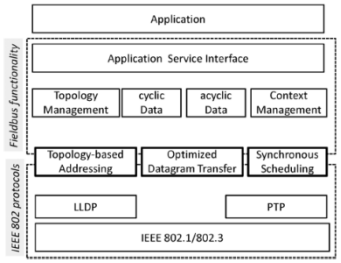
Assumptions:

- Store and Forward principle
- Only small changes in architecture required
- Maintain basic framing rules (min Frame, IFG...)

- RT frame: 88B @125µs
- AVB → nRT Frame: 1542B
- AVB+ → nRT Frame: 1542B @128B (funtion of fragment size)

Imtiaz, Jahanzaib; Jasperneite, Jürgen; Karl, Weber: A Performance Evaluation of the 802.1 AVB Traffic Shaping with Preemption. In: 9th IEEE International Workshop on Factory Communication Systems COMMUNICATION in AUTOMATION (WFCS 2012) Lemgo, Germany, May 2012. (Submitted)

Preemption



Key RTE Requirements:

Implementation Costs

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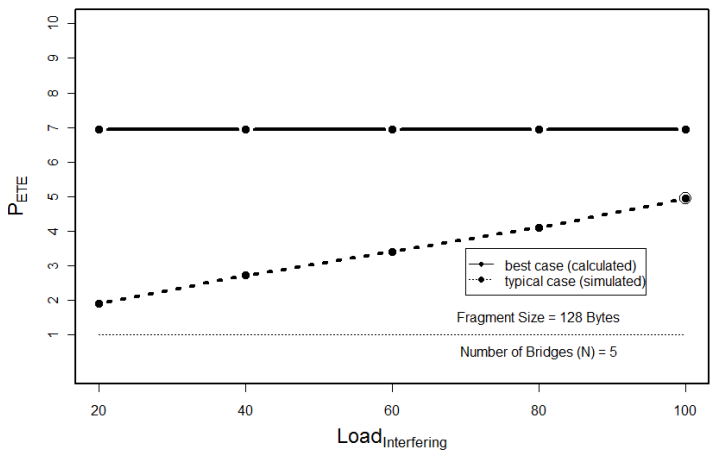
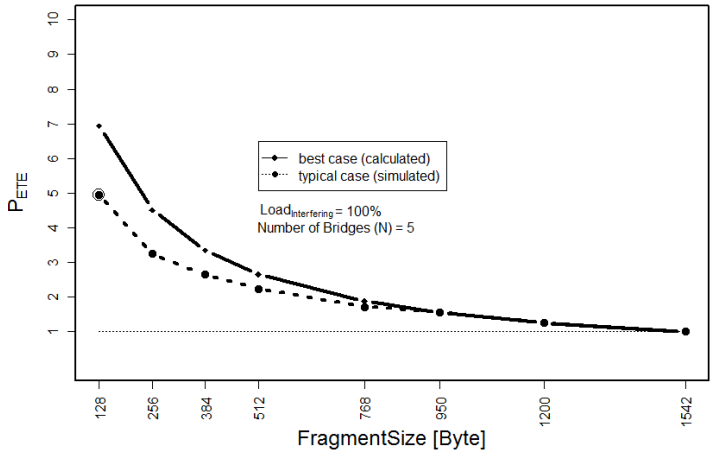
Configuration Effort

Real-Time Performance

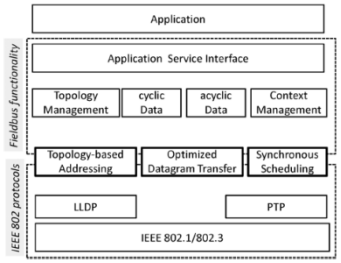
Simulation results: performance gain

$$P_{ETE} = \frac{T_{ETE_{AVB}}}{T_{ETE_{AVB+}}}$$





Preemption



Key RTE Requirements:

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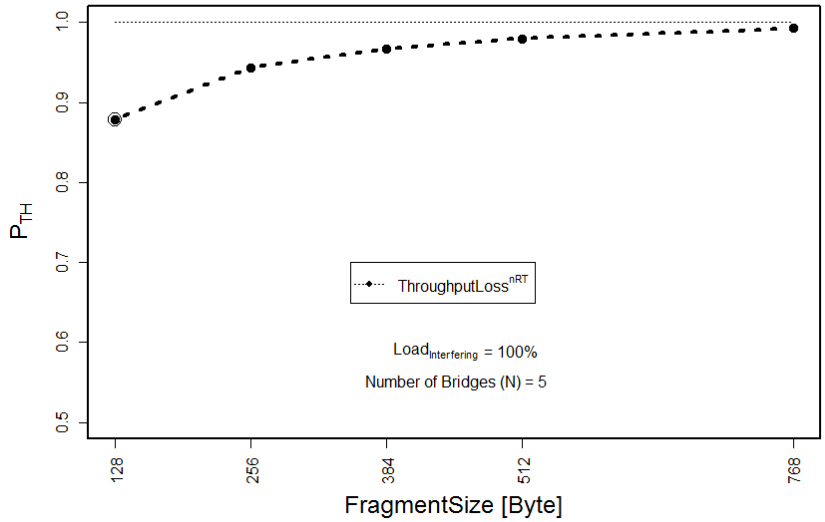
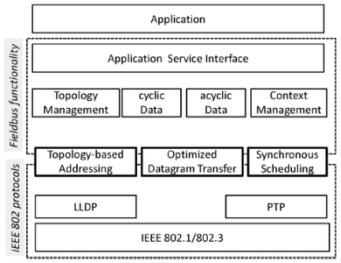
Simulation results: throughput loss for best-effort traffic

$$P_{TH} = \frac{Throughput_{AVB+}}{Throughput_{AVB}}$$



The average frame size of the nRT traffic (e.g. internet) is approximately 200 bytes.

Conclusion



Key RTE Requirements:

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Preemption policy considerations

- Fragmentation have advantages for applications require high nRT traffic bandwidth
- Fragmentation! On demand or by default?
  - Fragmentation can only reduce the impact, by an order of magnitude
  - Fragmentation on demand can reduce fragmentation overhead but not latency
- Implementation aspects
  - Require more engineering to offer fragmentation
  - Different topologies or traffic pattern have effect on fragmentation
  - Throughput planning for best effort traffic
- What will be the implications on different control methods?
  - Centralized control systems
  - Decentralized control systems
- Where should the fragmentation polity work (switches or end nodes?)
  - Should it be included in software
  - What will happen with existing standard control switches?
- How does it adhere to the key RTE requirements?

Thank you very much!