

Tomorrow's In-Car Interconnect?

A Competitive Evaluation of IEEE 802.1 AVB and Time-Triggered Ethernet (AS6802)

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2 Background & Related Work

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Problem Statement

The heterogeneity of in-car networking



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- The in-car network grew over the past decades
- Increasing demand continuously required introduction of new technologies
- Today, extremely heterogeneous network formed of domain specific systems
 - CAN, FlexRay, MOST ...
- Abstraction layers (e.g. AUTOSAR) introduced interface to applications
- On the transport layer still very high complexity

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- Ethernet offers:
 - Mature technology
 - High transmission bandwidth
 - Low prices for components
 - Many development/diagnostic tools and expert developers
- Ethernet considered for (or already used):
 - On-Board Diagnosis (OBD)
 - Multimedia
 - Image transmission (Camera)
- But: Ethernet as additional transport technology cannot reduce complexity

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- What if Ethernet could be used as the medium for a uniform homogeneous in-car backbone?

IEEE 802.1 Audio Video Bridging Protocol suite

- Stream Reservation Protocol
 - Online signaling protocol for traffic flows
 - reserves required bandwidth for a specific stream
- Queuing and Forwarding Rules
 - Based on IEEE 802.1Q, Mapping of priority values to AVB classes
 - Strict Priority Algorithm for Legacy Ethernet
 - Credit Based Shaper Algorithm for AVB
 - Maximum latency of 2ms over 7 Hops (Class A) or 50ms (Class B)

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IEEE 802.1 AVB
Time-triggered Ethernet

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Time-triggered Ethernet (AS6802)

Mixed critical applications through IEEE 802 networks



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- Extension to standard switched Ethernet
- SAE standardized in 2011 (AS6802)
- 3 traffic classes:
 - 1** Time-triggered (TT)
highest priority, time-triggered, cyclic, offline
planned, requires synchronised time
 - 2** Rate-constrained (RC)
event-triggered, bandwidth-based (AFDX)
 - 3** Best-effort (BE)
lowest priority, standard Ethernet

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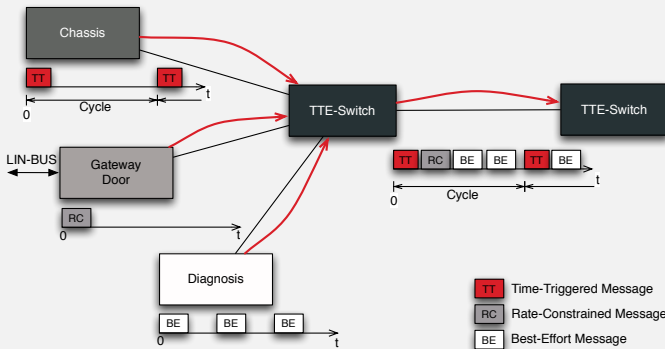
Time-triggered Ethernet (AS6802)

Ethernet for mixed critical applications



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- Discrete event based simulation
 - OMNeT++ Network Simulation Framework
 - Models for TTEthernet¹ and Ethernet AVB²
- Simulation of realistic traffic-flows derived from configuration of BMW series car
- Tree based topology

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¹ **Till Steinbach et al.**: "An Extension of the OMNeT++ INET Framework for Simulating Real-time Ethernet with High Accuracy". 2011.

² **Hung-Taek Lim et al.**: "Performance analysis of the IEEE 802.1 ethernet audio/video bridging standard". 2012.

Type	Bandwidth [MBit/s]	IEEE 802.1 AVB Class (Priority)	TTEthernet Class (Priority)
TV	10...20	B (Prio 4)	RC (Prio 7)
Media Audio	8	B (Prio 4)	RC (Prio 7)
Media Video	40	B (Prio 4)	RC (Prio 7)
Camera	25	A (Prio 5)	RC (Prio 6)
Control	$(3.68...736) \cdot 10^{-4}$	A (Prio 5)	TT + RC (Prio 0...5)

- High bandwidth multimedia traffic flows with low timing requirements
- High bandwidth driver assistance camera traffic flows with medium timing requirements
- Low bandwidth control traffic flows with high timing requirements

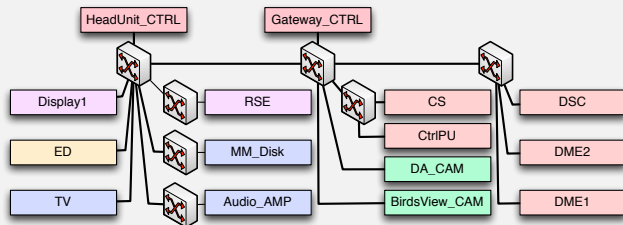
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- 22 Nodes, 7 Switches, 21 Links
- Tree structure with one root switch
- Domain specific regions in the network

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Multimedia Traffic

Cumulative Distribution



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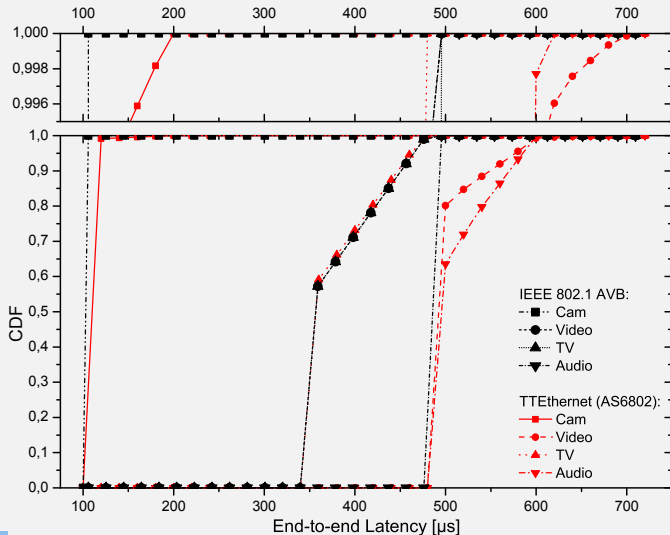
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Type of Stream	IEEE 802.1 AVB		TTEthernet	
	Latency [μ s]	Jitter [μ s]	Latency [μ s]	Jitter [μ s]
Camera	115.40	6.69	209.77	90.98
TV	674.32	135.80	485.18	117.27
Media Audio	497.67	6.11	610.49	117.28
Media Video	503.68	130.70	725.37	232.15

Control Traffic

Cumulative Distribution



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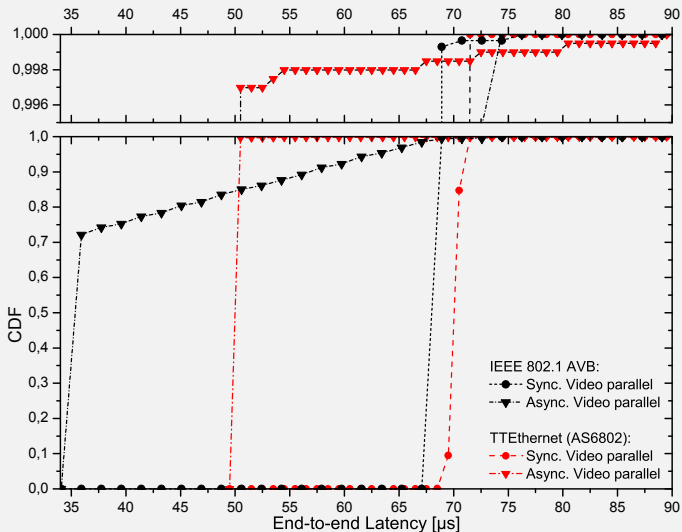
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Hops	Type	IEEE 802.1 AVB	TTEthernet		
		Latency [μ s]	Jitter [μ s]	Latency [μ s]	Jitter [μ s]
4	sync.	75.69	6.58	71.53	2.70
	async.	75.07	39.19	84.79	33.81
2	sync.	31.90	5.50	31.37	3.25
	async.	32.83	6.19	30.31	15.57

- Both protocols have almost equally low latency (Latency $< 100 \mu$ s)
- Synchronous traffic in TTE is most precise (Jitter $< 4 \mu$ s)

- Both technologies are able to fulfill the requirements
 - for camera and multimedia traffic
 - for control traffic
- With the tree-based topology and today's amount of traffic flows the protocols perform almost equally well
- Light advantages for Ethernet AVB for multimedia and camera streams
- Light advantages for TTEthernet for control traffic

In our ongoing and future work we will ...

- ... analyse how cross-traffic will influence the performance of the backbone network
- ... analyse whether a backbone with coexistence of both concepts can improve performance and flexibility
 - Time-triggered traffic class and strict priority scheduling for control traffic
 - Credit based shaping and online stream reservation for multimedia streams

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Thank you for your attention!

- Website of CoRE research group:
<http://www.haw-hamburg.de/core>
- Website of TTEthernet simulation model:
<http://tte4inet.realmv6.org>

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- [1] **Hyung-Taek Lim et al.** "Performance analysis of the IEEE 802.1 ethernet audio/video bridging standard". In: *Proceedings of the 5th International ICST Conference on Simulation Tools and Techniques*. SIMUTOOLS '12. Desenzano del Garda, Italy: ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2012, pp. 27–36.
- [2] **Till Steinbach et al.** "An Extension of the OMNeT++ INET Framework for Simulating Real-time Ethernet with High Accuracy". In: *Proceedings of the 4th International ICST Conference on Simulation Tools and Techniques*. SIMUTools '11. Barcelona, Spain: ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2011, pp. 375–382.