Tomorrow's In-Car Interconnect?

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

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Agenda

Problem Statement

The heterogeneity of in-car networking

- 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

- 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

Motivation

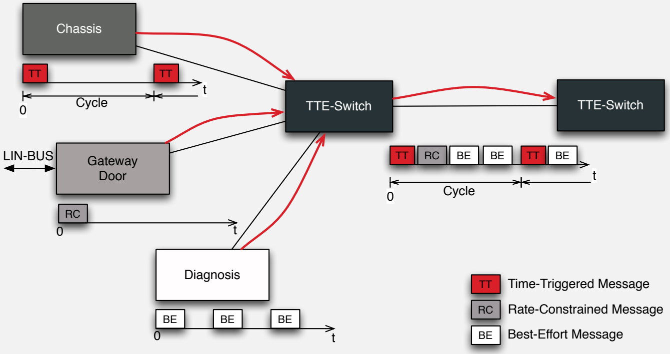
- What if Ethernet could be used as the medium for a uniform homogeneous in-car backbone?

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)

- 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

Time-triggered Ethernet (AS6802)
Ethernet for mixed critical applications



Evaluation

- Discrete event based simulation
  - OMNeT++ Network Simulation Framework
  - Models for TTEthernet[1] and Ethernet AVB[2]
- Simulation of realistic traffic-flows derived from configuration of BMW series car
- Tree based topology

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

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

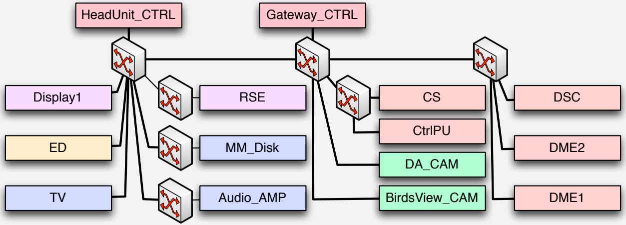
Traffic Model

CoRE

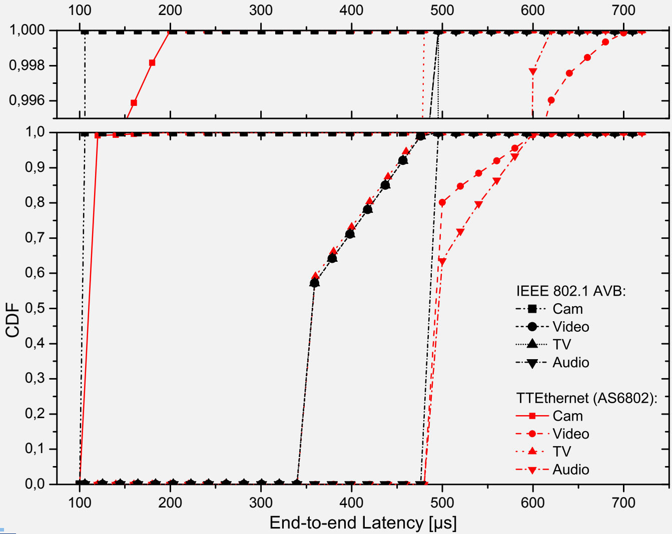
Type	Bandwidth [MBit/s]	IEEE 802.1 AVB Class (Priority)	TTEthernet Class (Priority)
TV	10. . . 20	B (Prio 4)	RC (Prio 7)
Media Audio	8	B (Prio 4)	RC (Prio 7)
Media Video	40	B (Prio 4)	RC (Prio 7)
Camera	25	A (Prio 5)	RC (Prio 6)
Control	$(3.68 \ldots 736) \cdot 10^{-4}$	A (Prio 5)	TT + RC (Prio 0. .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

Topology



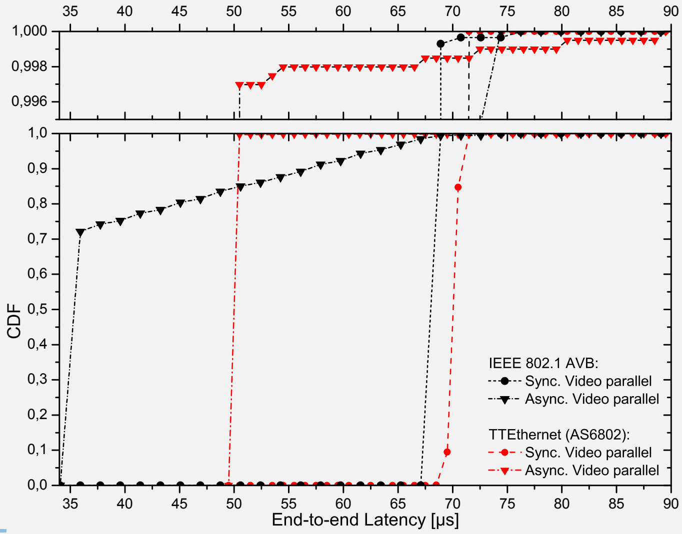
- 22 Nodes, 7 Switches, 21 Links
- Tree structure with one root switch
- Domain specific regions in the network


100
200
300
400
500
600
700
1,000
0,998
0,996
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
CDF
End-to-end Latency [µs]
IEEE 802.1 AVB:
Cam
Video
TV
Audio
TTEthernet (AS6802):
Cam
Video
TV
Audio

Multimedia Traffic
Results in Detail

Type of Stream	IEEE 802.1 AVB Latency [µs]	IEEE 802.1 AVB Jitter [µs]	TTEthernet Latency [µs]	TTEthernet Jitter [µs]
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



Hops	Type	IEEE 802.1 AVB Latency [µs]	IEEE 802.1 AVB Jitter [µs]	TTEthernet Latency [µs]	TTEthernet Jitter [µs]
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 µs)
- Synchronous traffic in TTE is most precise (Jitter $<$4 µs)

Conclusion

- 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

Outlook

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

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

Literatur I

[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.