An Extension of the OMNeT++ INET Framework for Simulating Real-time Ethernet with High Accuracy

4th international OMNeT++ Workshop

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Hamburg University of Applied Sciences

Agenda

1. Introduction
2. Background
3. Concept & Model
4. Results & Evaluation
5. Conclusion & Outlook

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Motivation

Why a new in-vehicle communication technology?

"Actually ***already today*** *the electrical system in the whole car is* ***not*** *adequately* ***controllable****" and "The complexity continues to increase"* [1]

Richard Bogenberger (2008)
BMW Group Research and Technology

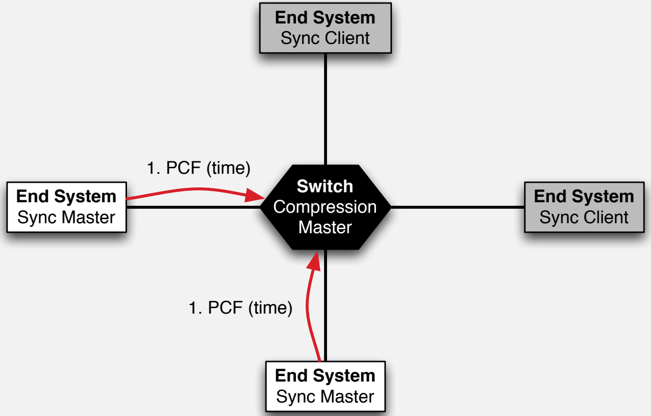
[1] Jens Badstübner: "Kollaps im Bordnetz: Schluss mit Can, Lin und Flexray". 2008.

- Mature technology
- High transmission bandwidth
- Low prices for Ethernet components
- Many development/diagnostic tools and expert developers

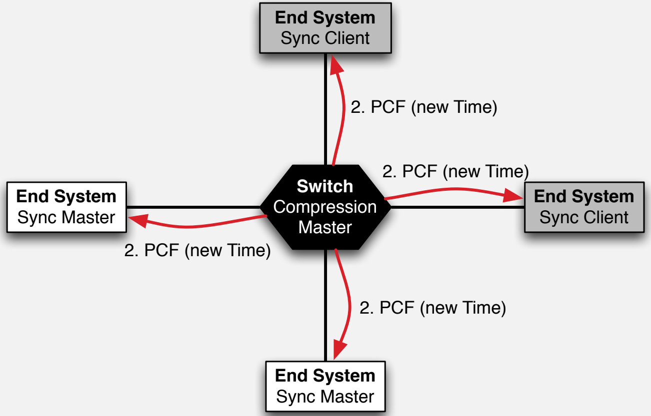
Agenda

- Standard switched Ethernet has no real-time capabilities
- There are extensions of various operational areas
- Extensions can be classified in:
  1. *token-based technologies*
     e.g. EtherCAT
  2. *bandwidth-limiting technologies*
     e.g. Avionics Full DupleX Switched Ethernet (AFDX)
  3. *time-triggered technologies*
     e.g. Profinet, SynqNet, RTnet, POWERLINK, TTEthernet

- Basis by the Technical University Vienna (2004)
  Today development by TTTech Computertechnik
- Currently standardization by the Society of Automotive Engineers
- 3 traffic classes:
  - *Time-triggered (TT)*
    highest priority, time-triggered, cyclic, offline planned, requires synchronised time
  - *Rate-constrained (RC)*
    event-triggered, bandwidth-based (AFDX)
  - *Best-effort (BE)*
    lowest priority, standard Ethernet



End System
Sync Client
1. PCF (time)
End System
Sync Master
Switch
Compression
Master
End System
Sync Client
1. PCF (time)
End System
Sync Master

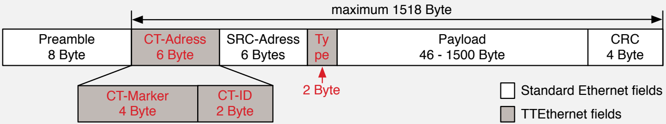

End System
Sync Client
2. PCF (new Time)
2. PCF (new Time)
End System
Sync Master
Switch
Compression
Master
End System
Sync Client
2. PCF (new Time)
2. PCF (new Time)
End System
Sync Master

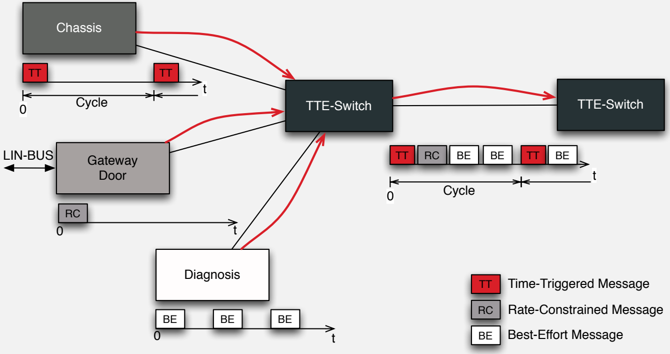
TTEthernet

Critical-Traffic

- Critical-Traffic (time-triggered and rate-constrained) is offline configured

- Critical-Traffic uses Ethernet destination address
- Critical-Traffic is determined by CT-Marker (4 Byte)
- Message is determined by CT-ID (2 Byte)




Chassis
TT
TT
t
0
Cycle
TTE-Switch
TTE-Switch
LIN-BUS
Gateway Door
RC
0
t
TT
RC
BE
BE
TT
BE
t
0
Cycle
Diagnosis
BE
BE
BE
0
t
TT
Time-Triggered Message
RC
Rate-Constrained Message
BE
Best-Effort Message

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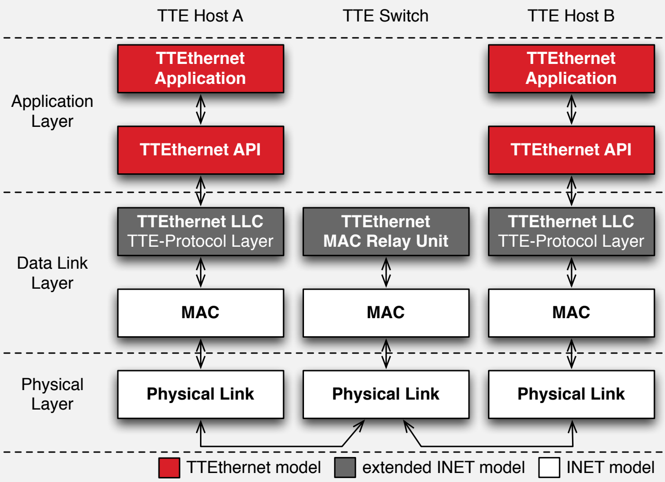
Concept & Model

TTEthernet integration in INET



Clock:

- TTEthernet is a synchronised time-triggered protocol
- Each device has its own clock
- Clocks have inaccuracy (clock drift)
- Clock drift has significant impact on protocol behaviour
- Model of clock drift must be accurate

$$t' = t + \delta * (\Delta t_{Tick} + \Delta t_{Drift})$$

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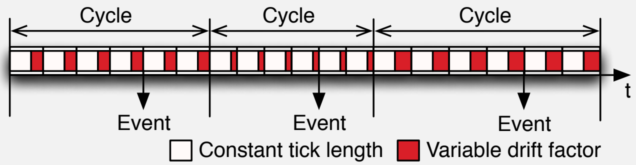
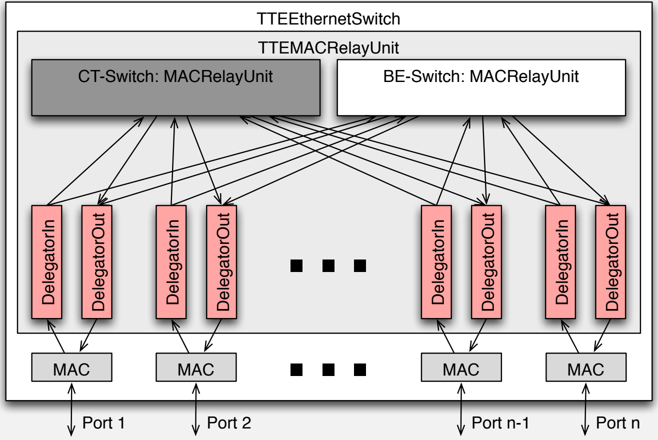
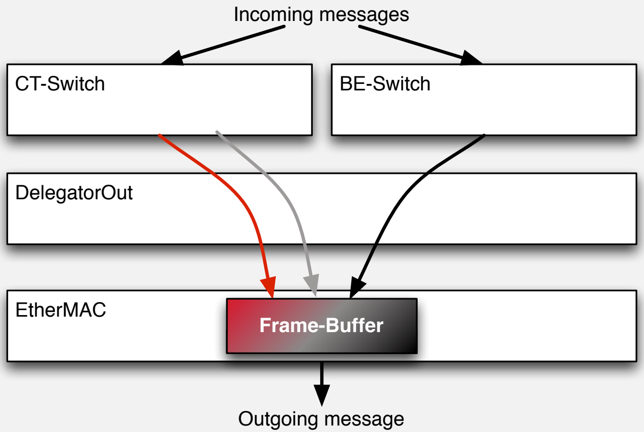


TTEthernet-Switch:

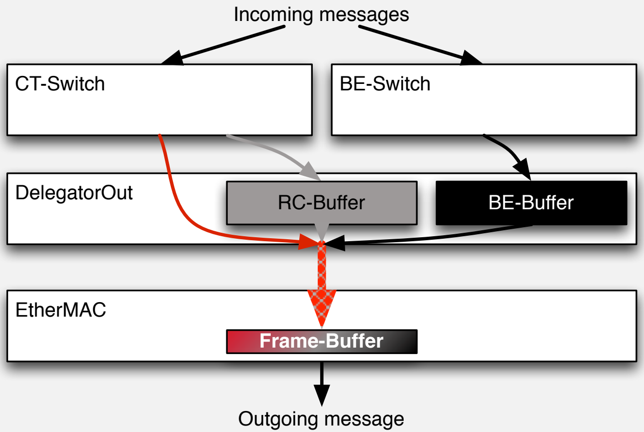
- Usage of the introduced clock model
- Combines standard INET and critical traffic switch
- Bypassing of Buffer in MAC-Layer to preserve priorities

TTEthernet Model — Switch design





Incoming messages
CT-Switch
BE-Switch
DelegatorOut
EtherMAC
Frame-Buffer
Outgoing message



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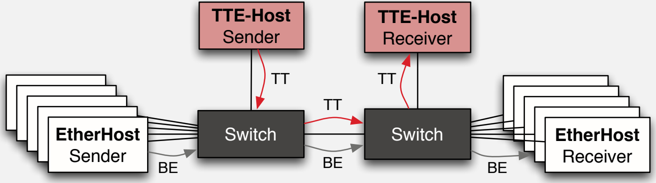
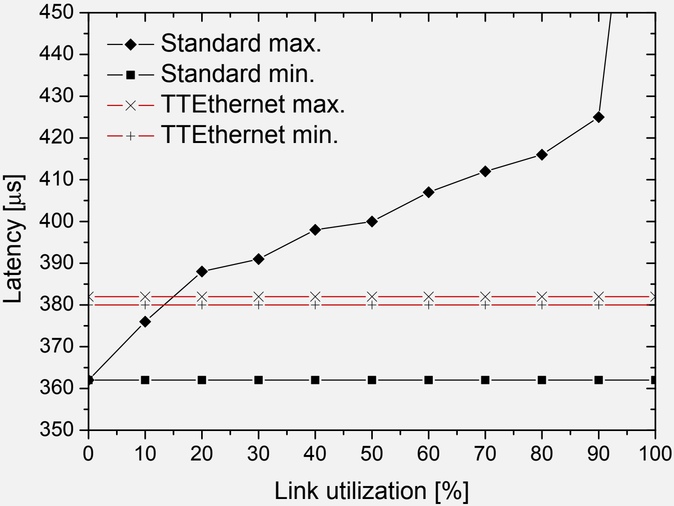
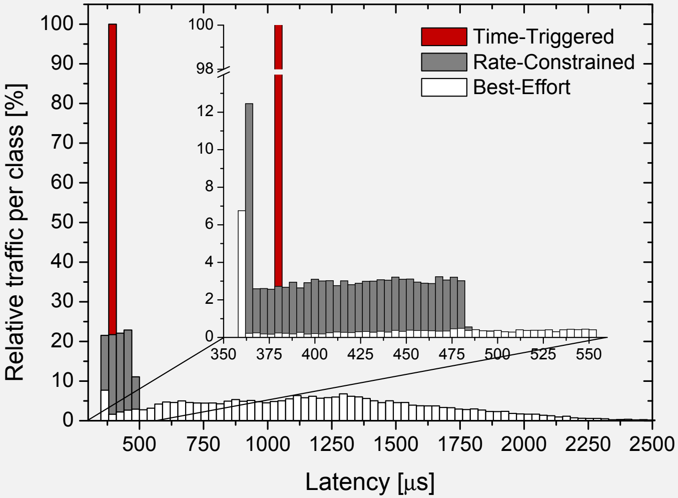


TTE-Host
Sender
TTE-Host
Receiver
TT
TT
TT
EtherHost
Sender
Switch
Switch
EtherHost
Receiver
BE
BE
BE


Standard max.
Standard min.
TTEthernet max.
TTEthernet min.
Latency [µs]
Link utilization [%]
450
440
430
420
410
400
390
380
370
360
350
0
10
20
30
40
50
60
70
80
90
100

Results

Latency distribution



Frame payload	simulation model	analytical model	hardware measurement
350 µs Schedule			
minimum	360.5 µs	360.245 µs	360 µs
maximum	593.0 µs	592.885 µs	592 µs
9 µs Schedule			
minimum	19.5 µs	19.245 µs	-
maximum	252.0 µs	251.885 µs	-

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Conclusion & Outlook

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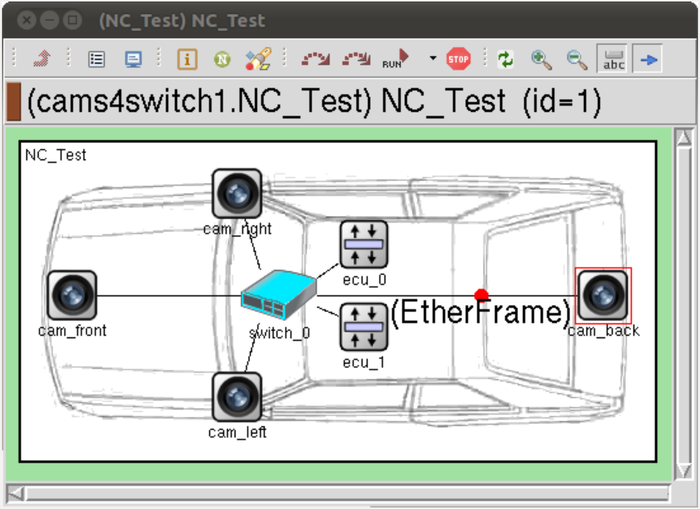
- Real-time Ethernet is a realistic candidate for in-vehicle backbone
- Presented model tightly conforms to
  - TTEthernet specification
  - Analytical model
  - Hardware measurements
- Simulation results have been carefully evaluated

- Framework is currently being prepared for a first public release
- If you are interested visit:

http://www.informatik.haw-hamburg.de/tte4inet.html

Outlook
Simulating camera based vehicle-environment detection



Thank you!

Thank you for your attention!

- Website of research group:
  http://www.informatik.haw-hamburg.de/core.html
- Website for simulation model:
  http://www.informatik.haw-hamburg.de/tte4inet.html

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