

Providing timing guarantees for Ethernet-based networks

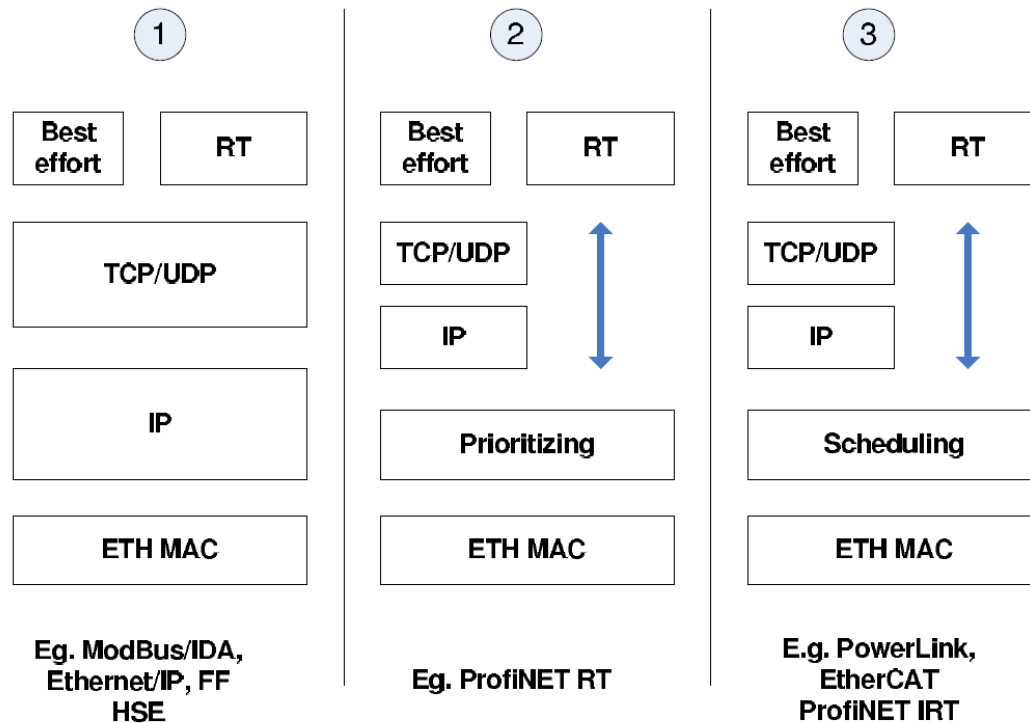
Torino
June 09, 2011



Solutions for Complex
Real-Time Systems

Classification of Approaches for Real-Time over Ethernet

- ❑ 1) Implementations in software using standard ethernet components
- ❑ 2) simple 802.1q VLAN tagging (also COTS), allows latency ~ 1 to 10ms
- ❑ 3) Extensions of frame scheduling in switches (like AVB)



[13] M. Schumacher, J. Jasperneite, and K. Weber. A new Approach for Increasing the Performance of the Industrial Ethernet System PROFINET. In *7th IEEE International Workshop on Factory Communication Systems (WFCS 2008)*, Dresden, Germany, May 2008.

Relevant Domains and Symtavision contribution

□ Avionics

- Advanced prototypes available for AFDX and TTP

□ Industrial

- Cooperation on research level (inITial project in NRW)
- “Meta”-analysis project focused on AVB with major integrator

□ Automotive


- contributions to SEIS project
- Maturing roadmap discussions

□ Research Partnerships

- Technische Universität Braunschweig
- University Erlangen-Nürnberg
- Fraunhofer Institute for Communication Systems (ESK)

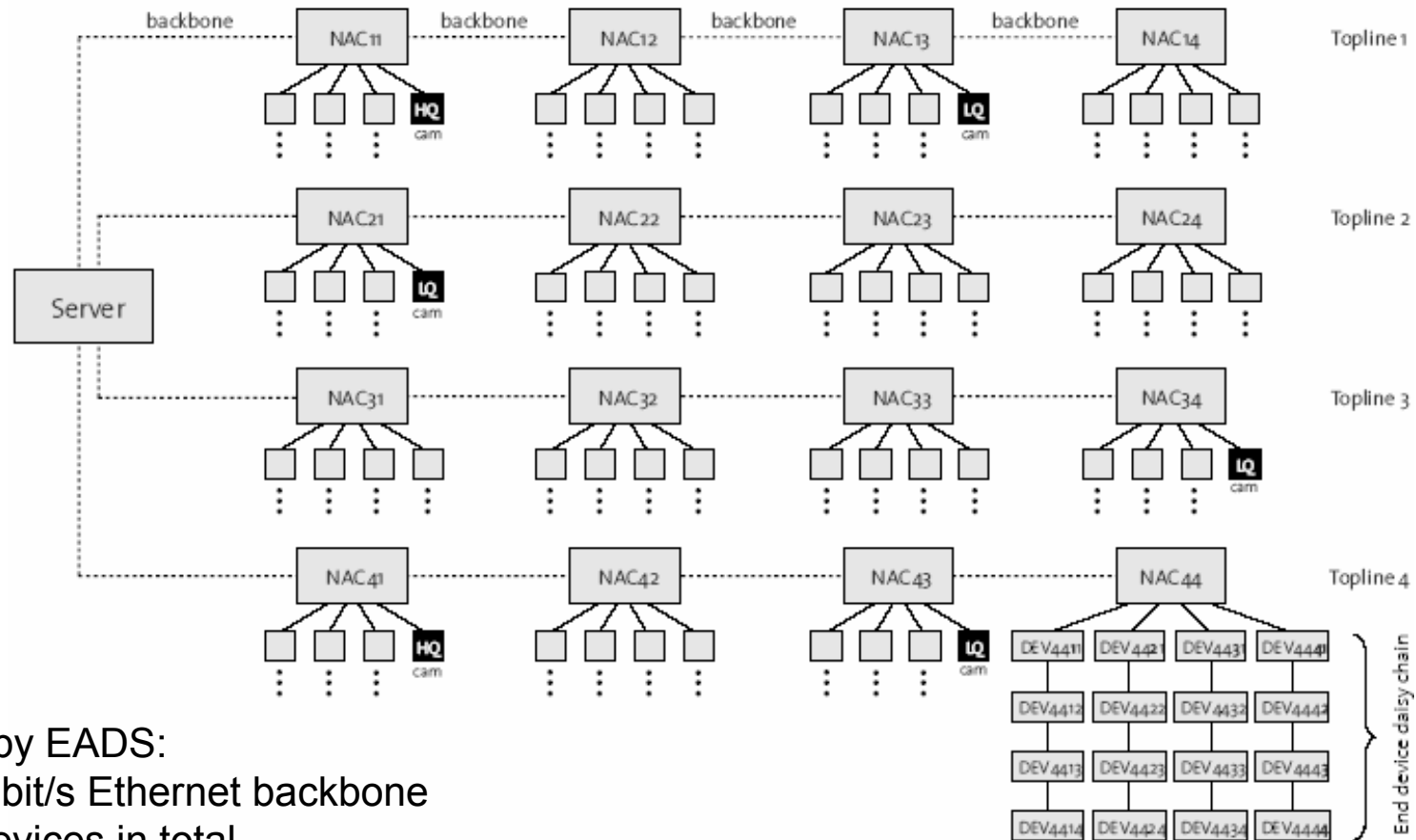
Example I

Avionics Example: Cabin Communication System
(TU Braunschweig)



Solutions for Complex
Real-Time Systems

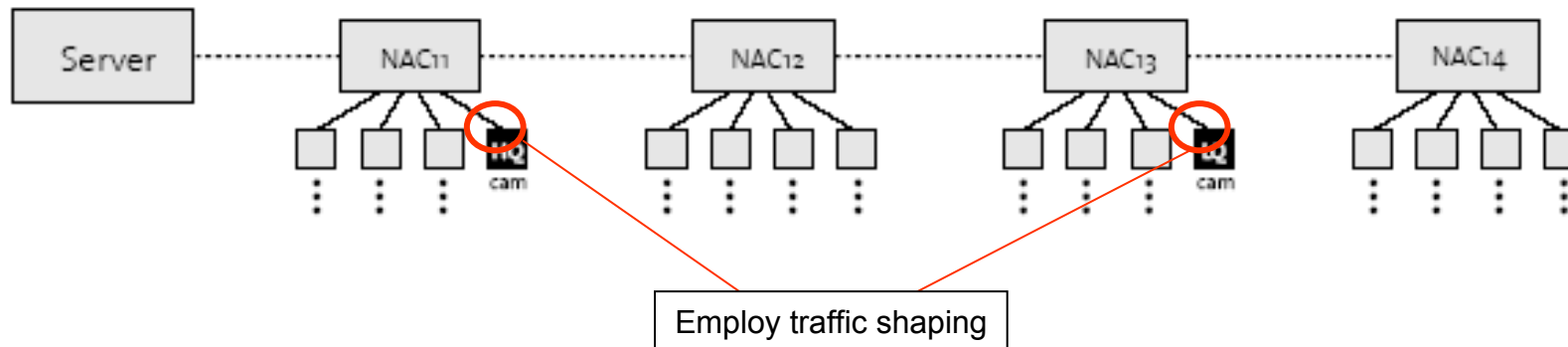
Avionics Example: Cabin Communication System



Provided by EADS:

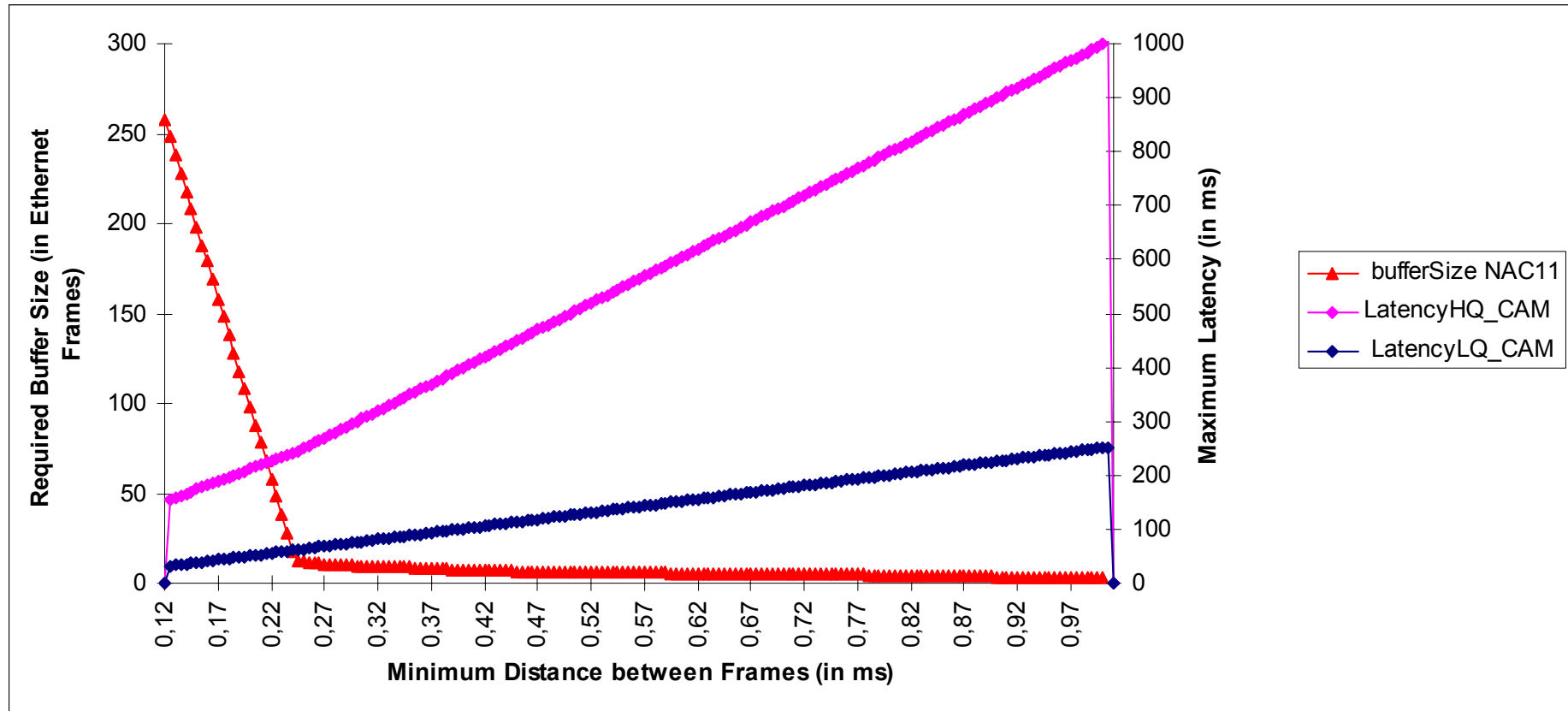
- 100 Mbit/s Ethernet backbone
- 232 devices in total
- 3 HQ and 3 LQ Cameras
- 4 separated top lines
- Mix of weighted fair queuing and priority based scheduling in the switches

Analysis of Topline 1



- Each topline modeled and analyzed separately with SymTA/S
- **Problem:** Cameras can produce large bursts of data, up to 1000 maximum sized Ethernet frames per second
 - ➔ This leads to large buffer requirements in the NACs
- **Idea:** Use traffic shaping on the output streams of the cameras
 - ➔ Tradeoff between buffer requirements and latency

Effect of shaping the camera traffic



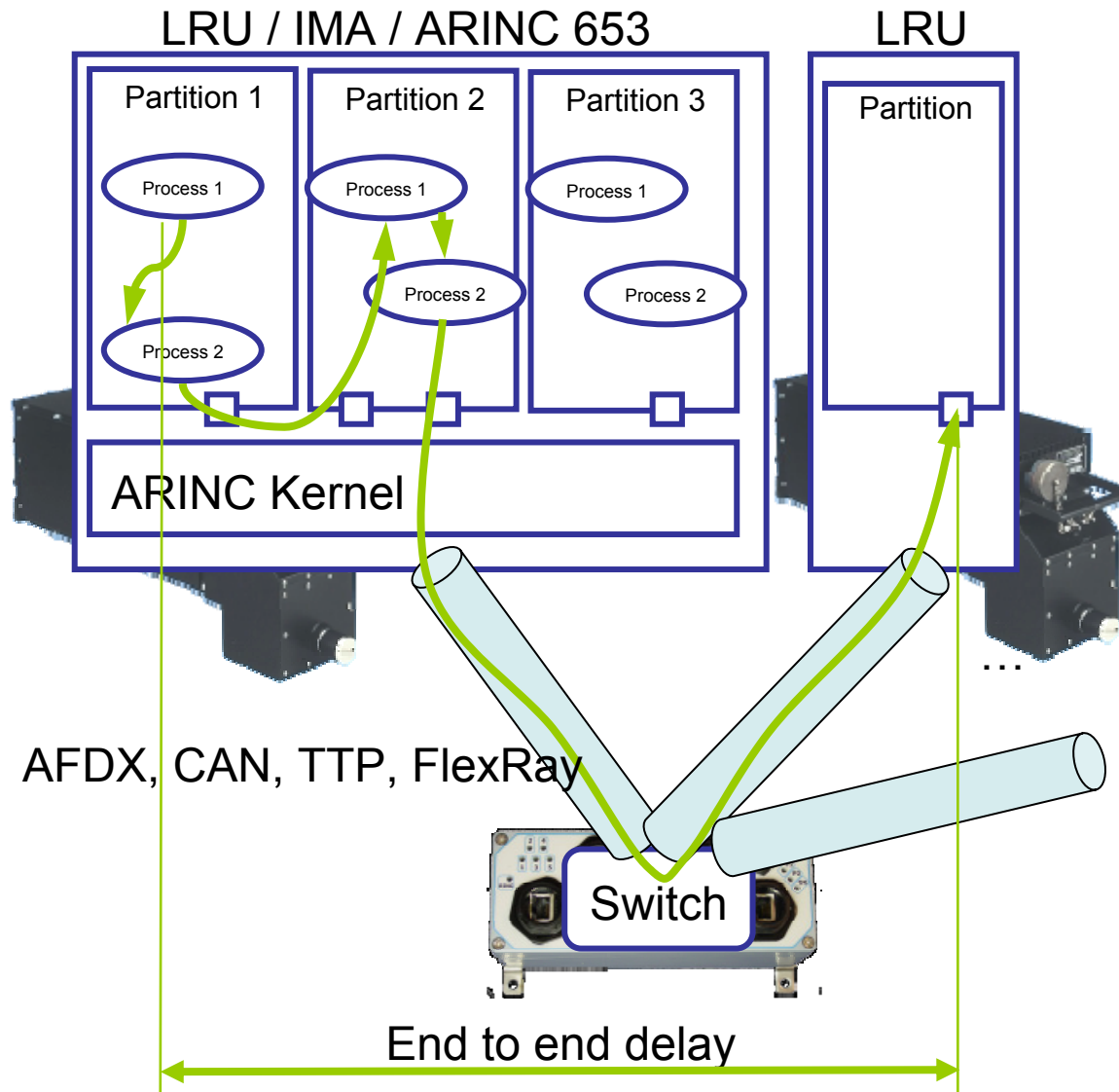
Example II

Avionics Example: Switched AFDX System
(Symtvision)

Solutions for Complex
Real-Time Systems



System Timing Issues in Avionics Systems



Scope:

- single partition
- one LRU / IMA
- network end system
- switched network

Measure:

- load / utilization
- delays / deadlines
- communication / end-to-end

Use Case:

- design
- integration
- optimization
- verification

+ Design process integration

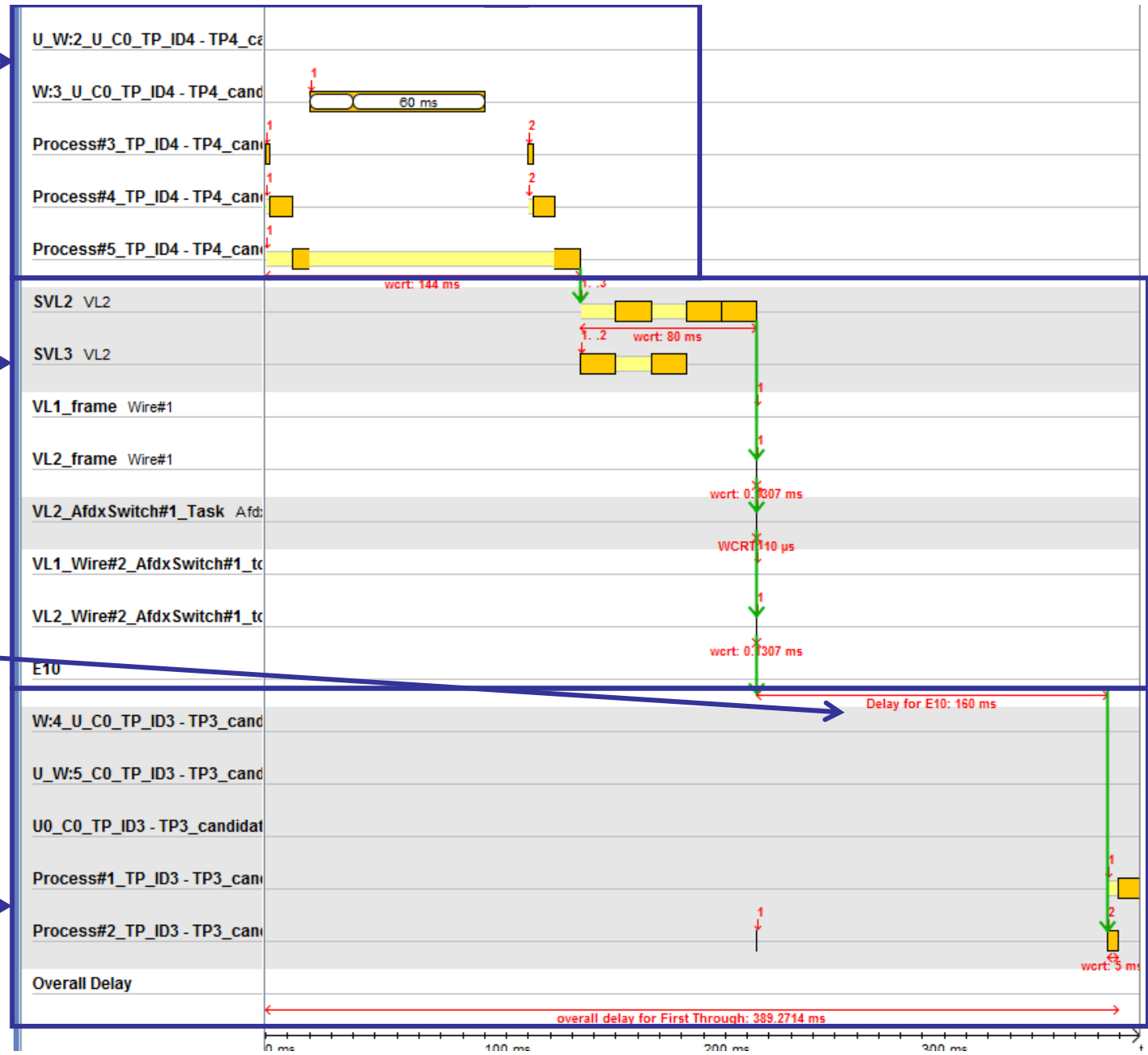
□ Sending IMA/Partition

□ AFDX

□ Sampling delay

→ Asynchronous execution

□ Receiving IMA/Partition



Example III

AVB

(Symtvision, TU Braunschweig)



Solutions for Complex
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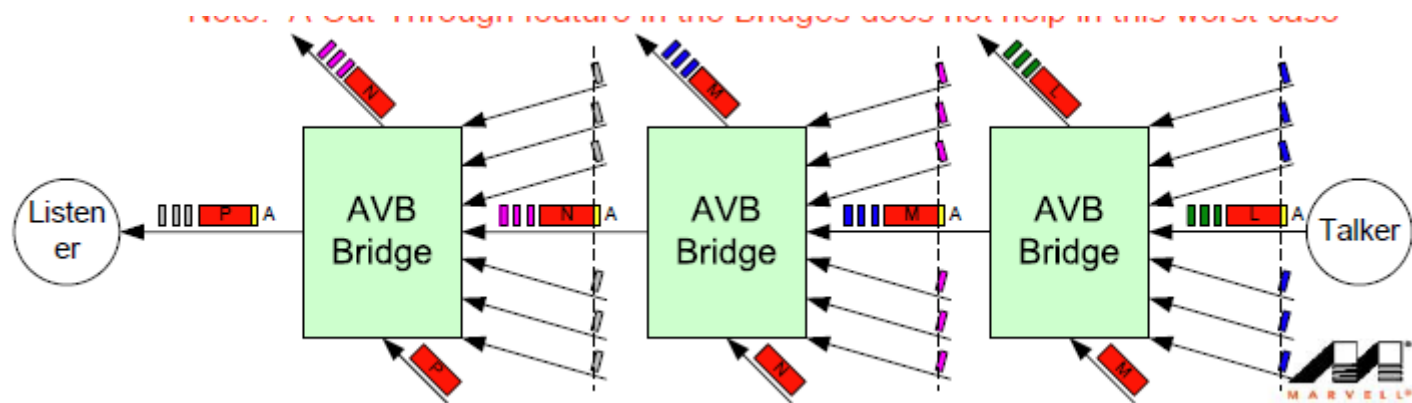
Introduction AVB

- ❑ AVB adds predictability quality of service through stream reservation protocols (802.1Qat) → guaranteed bandwidth
- ❑ provides low-latency (guarantees < 2ms over 7 hops) through 802.1Qav
- ❑ enables precise global synchronization (802.1AS Precision Time Protocol)
- ❑ In addition to Ethernet benefits:
 - ❑ High bandwidth, simplified cabling
 - ❑ allows mixing different link speeds (→ backwards compatibility)
 - ❑ Multi-supplier through standard technology (e.g. as opposed to MOST)

- ❑ AVB is not without alternative: AFDX, Standard Ethernet with SW extensions (+ VLAN tagging prioritization), ... MOST, ...

AVB Study

- ❑ AVB promises 2ms maximum latency over 7 hops for Class A traffic
- ❑ This can not be kept when legacy traffic is involved



- ❑ Then, what is the worst-case?
- ❑ What can be done to ameliorate the situation?

Phase 1: Modeling

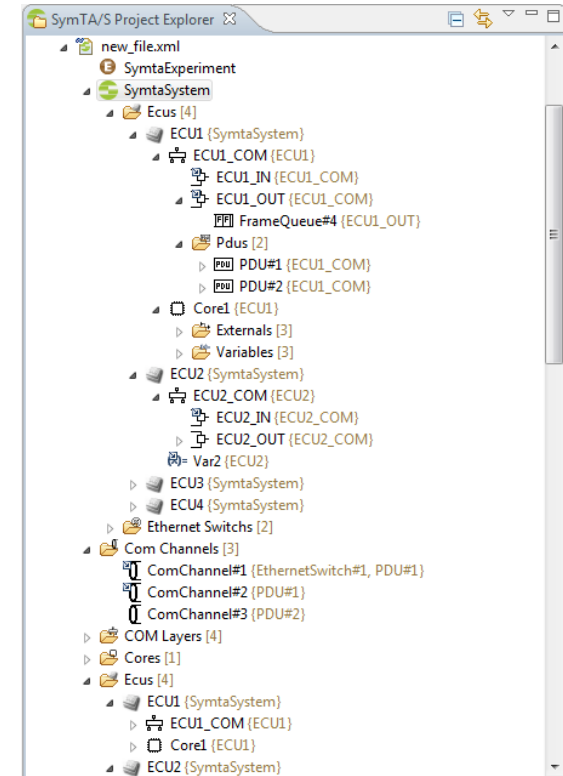
- ❑ Modeling of network architecture
- ❑ Modeling of individual system structure
- ❑ Modeling of data streams

List of all Output Ports

	Element		Output Port		
	Name	Parents	Connected Port	Link Speed	Arbitration Policy
1	ECU1_OUT	ECU1_COM	SW1_IN1	100.0 Mbit/s	CustomArbitrationPolicy
2	ECU2_OUT	ECU2_COM	SW1_IN2	100.0 Mbit/s	WeighedFairQueueingArbitrationPolicy
3	ECU3_OUT	ECU3_COM	SW2_IN2	100.0 Mbit/s	PriorityArbitrationPolicy
4	ECU4_OUT	ECU4_COM	SW2_IN3	100.0 Mbit/s	PriorityArbitrationPolicy
5	SW1_OUT1	EthernetSwitch#1	ECU1_IN	100.0 Mbit/s	CustomArbitrationPolicy
6	SW1_OUT2	EthernetSwitch#1	ECU2_IN	100.0 Mbit/s	WeighedFairQueueingArbitrationPolicy
7	SW1_OUT3	EthernetSwitch#1	SW2_IN1	100.0 Mbit/s	WeighedFairQueueingArbitrationPolicy
8	SW2_OUT1	EthernetSwitch#2	SW1_IN3	100.0 Mbit/s	WeighedFairQueueingArbitrationPolicy
9	SW2_OUT2	EthernetSwitch#2	ECU3_IN	100.0 Mbit/s	PriorityArbitrationPolicy
10	SW2_OUT3	EthernetSwitch#2	ECU4_IN	100.0 Mbit/s	PriorityArbitrationPolicy

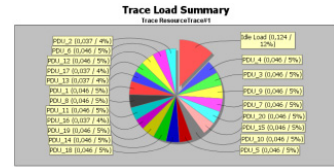
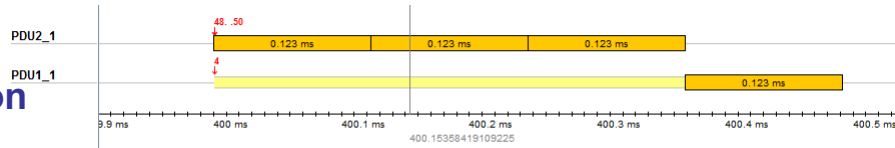
List of all Frame Queues

	Element	
	Name	Parents
1	FrameQueue#1	SW1_OUT1
2	FrameQueue#2	SW1_OUT1
3	FrameQueue#3	SW1_OUT1
4	FrameQueue#4	ECU1_OUT
5	FrameQueue#6	ECU3_OUT
6	FrameQueue#7	ECU4_OUT
7	FrameQueue#8	SW1_OUT2
8	FrameQueue#9	SW1_OUT3
9	Frame...ue#10	SW2_OUT1
10	Frame...ue#11	SW2_OUT2
11	Frame...ue#12	SW2_OUT3
12	FrameQueue#13	<empty>
13	TrafficClass1	ECU2_OUT
14	TrafficClass2	ECU2_OUT
15	TrafficClass3	ECU2_OUT

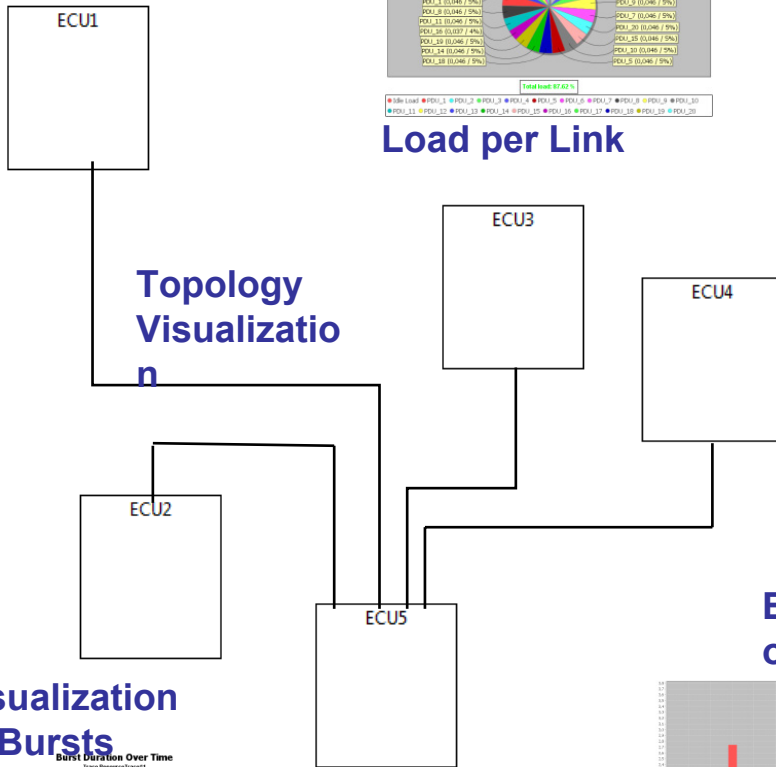


Example Results (Phase 1)

Visualization of Traffic per Link

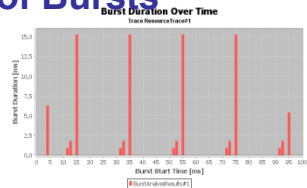


Load per Link

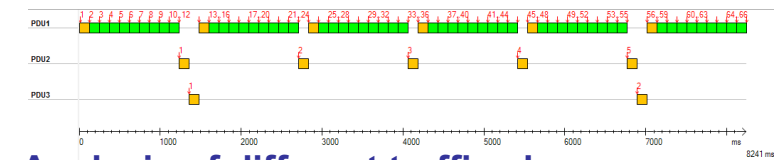
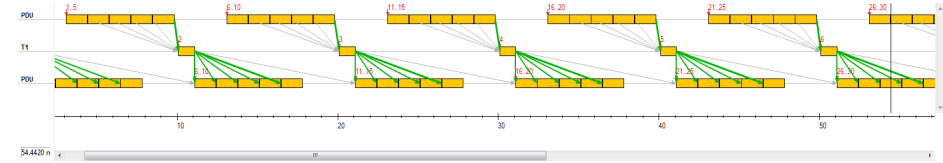


Topology Visualization

Visualization of Bursts

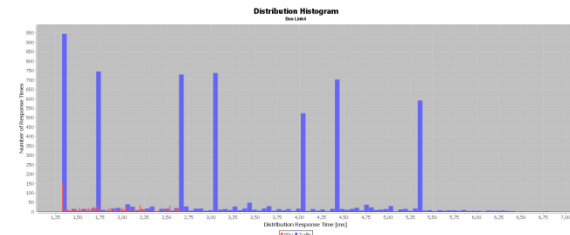
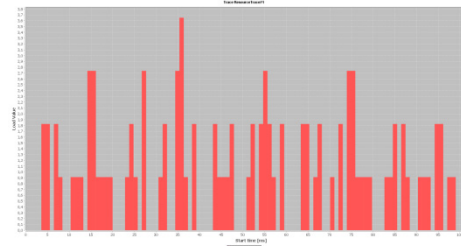


Analysis of Data Paths



Analysis of different traffic classes

Buffer Load over Time



Statistical Results of Packet Transmission Times

Thank You!



SYMITA VISION

