A protocol for Mixed-Criticality management in Switched Ethernet networks

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December 1, 2015

What's the matter ?

Mixed-Criticality (MC) in network context

A protocol to manage MC

Delay computation

Simulation results

Plan and objectives

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Context

Domains

Public transport (CAN) (Volvo, Renault, ...)
Avionics (AFDX) (Airbus)
Home automation
Defense

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Principles

Message routing and scheduling
Classifying messages by importance

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MC

Privileging messages in critical situation

- Critical for the vehicle, for the mission, for the users
- Overload context
- Assuring critical messages transmission

Why Mixed-Criticality ?

Today

1 network per group of functions (mechanical, comfort, gps tracking, ...)
Increasing of financial costs, weight, fuel and energy consumption
Example : 3/4 different antennas per public bus

Mixed-criticality

Mixing all the functions in the same network
Each function associated to a criticality level
MC management protocol to guarantee critical messages transmission

Mixed-Criticality

Related work

Mono/Multicore context
2-levels of criticality
QoS

Synchronization protocol

Ethernet IEEE-1588
PTPv2

Mixed-criticality

Problems

How to manage messages scheduling inside a embedded network ?
How to assure critical messages transmission ?

Mixed-criticality

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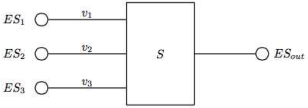
How to manage messages scheduling inside a embedded network ?
How to assure critical messages transmission ?

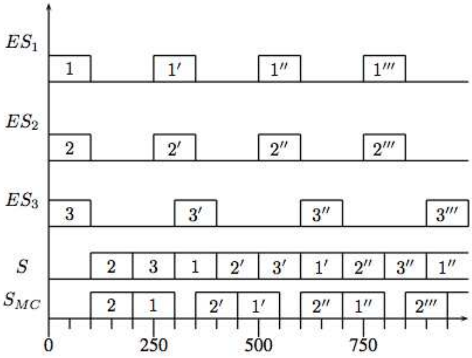
Solution

Providing MC management in embedded networks
Period-oriented or WCTT-oriented
Static-defined path

Example

Flow	T_i^{LO} (μs)	T_i^{HI} (μs)	C_i (μs)	u_i^{LO}	u_i^{HI}
v_1	500	250	100	0.2	0.4
v_2	500	250	100	0.2	0.4
v_3	300	-	100	0.33	-



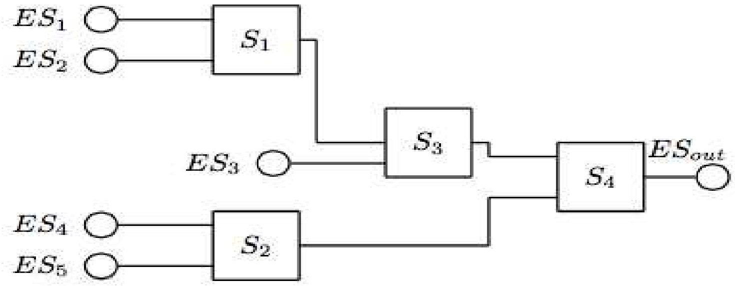


Topology

Centralized topology

Automotive Ethernet, AFDX targets
One central node to store criticality information

Example



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A two-phase protocol

First phase

Switch-criticality call
Transmitting switch order to a central node
Centralized topology

Second phase

Multicast the switch criticality order (reliable multicast)
Sending new criticality info to all nodes
Reliable (deterministic) multicast

A two-phase protocol : The call phase

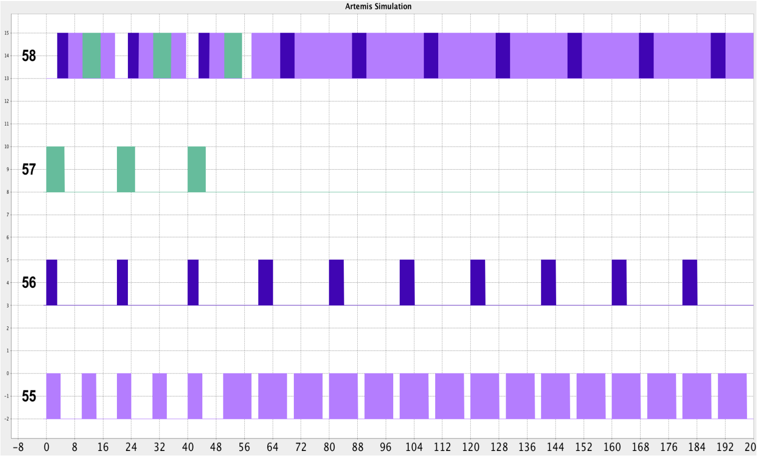
Principle

Triggering a criticality switch when :
Longer period detected Or shorter inter-arrival time detected
Fixed WCTT C_c (static known size)
Ethernet protocol

Transmission

Dedicated VLAN, highest priority
PTP messages : clock accuracy (PTP-ETE)

MC management protocol



A two-phase protocol : the multicast phase

Multicast

Each node can get the switch criticality order at a different instant
Clock precision and clock synchronization (PTP - IEEE1588)
Total order : coherency in the network
At each instant, all nodes have the same criticality information (precision ϵ)

Reliability

Each single physical link is bounded
Clock accuracy ϵ
Worst-case delay computation

Switch-criticality order

All nodes switch at the same time
Last reception instant : $\max_{n \in \mathcal{N}}(d_n * (C_c + sl) + \epsilon_n)$

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The trajectory approach

Flows

Representing the network as a set of flows

Each flow v_i emits messages

$v_i = \{\mathcal{P}_i, C_i, \vec{T}_i\}$

Criticality management

One period per criticality level

$\vec{T}_i = \{T_i^{LO}, T_i^{HI}\}$

Call phase delay

Principle

Sending criticality switch call to central node
Emitting a call when a message exceeds its period or LO-WCTT
Highest priority VLAN

Delay

$$I^{n}_{delay} = F_{PTP} * \sum_{\substack{j \in hp_c \\ \mathcal{P}_c \cap \mathcal{P}_j \neq \emptyset}} \left(S^{first_{c,j}}_{max_c} - M^{first_{c,j}}_{c} + A_{c,j} \right) + \sum_{h \in \mathcal{P}_c} \delta^{h}_{c} + (|\mathcal{P}_n| - 1) * (sl + 2 * C_c)$$

Multicast phase delay

Principle

Sending the criticality level information to all nodes
Depending on the size of the network

Delay

$$M^{n}_{delay} = \quad d_n * (C_c + sl) + \epsilon_n$$

Total delay

Phases delay

$$S_{delay} = \max_{n \in \mathcal{N}} (I^n_{delay} + M^n_{delay})$$

Final expression

$$\begin{aligned} S_{delay} &= F_{PTP} * \sum_{\substack{j \in hp_c \\ \mathcal{P}_c \cap \mathcal{P}_j \neq \emptyset}} \left(S^{first_{c,j}}_{max_c} - M^{first_{c,j}}_{c} + A_{c,j} \right) \\ &+ \sum_{h \in \mathcal{P}_c} \delta^h_c \\ &+ (2 * \max_{n \in \mathcal{N}}(d_n) - 1) * (C_c + sl) + C_c(\max_{n \in \mathcal{N}}(d_n) - 1) + \epsilon \end{aligned}$$

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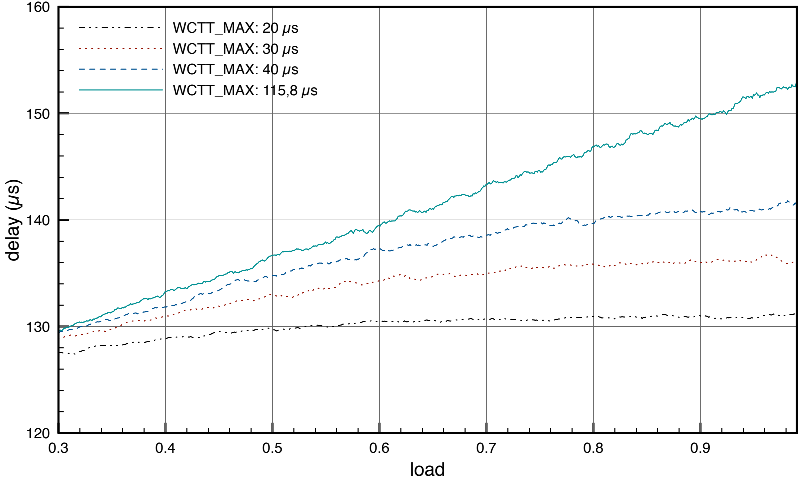
Criticality switch delay



Criticality switch delay

- Highest priority (except PTP)
- Non-preemptive effect
- Switch criticality delay stays constant
- Criticality messages transmission is guaranteed in a bounded time

Conclusion

- MC management protocol
- Reliable multicast
- Independent from the load

Perspectives

Delay computation on switch-criticality delay
Delay computation to return to low-criticality mode
Uncentralized MC management

Conclusion

Thanks

Thanks to all the authors of this presentation and publication
Thanks to our respective labs
Thank you for your attention !

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Questions ? Feel free to ask !