Ensuring Reliable Networks TTTech

TTEthernet Technology for Robust Integration of Advanced Space Systems

ADCSS 2013

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- Next Steps
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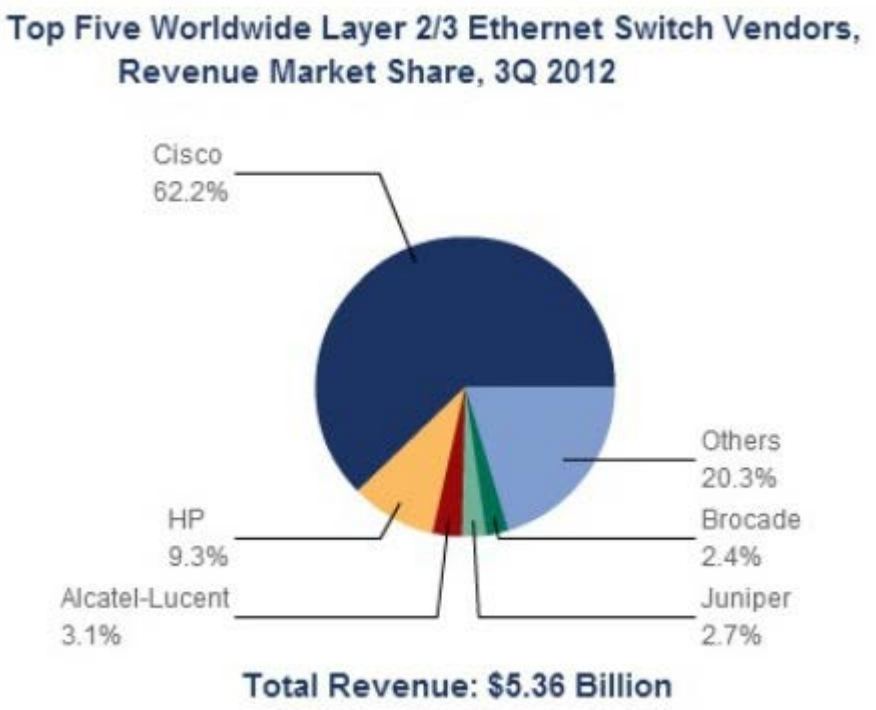
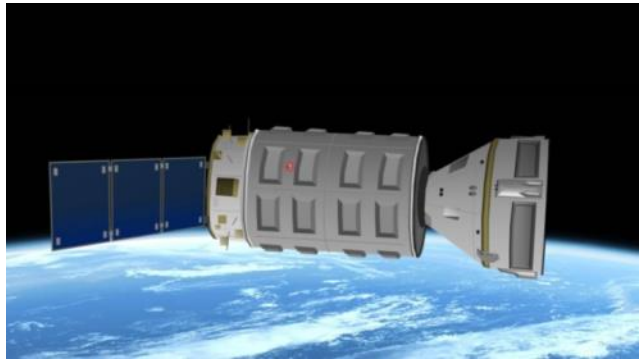
Ethernet a Worldwide Standard

- Worldwide used, cross industry with a growing market in embedded systems
- IEEE802 is an open and well defined standard
- Supports different speeds and topologies
- Well defined network stack ISO/OSI
- Low cost COTS Ethernet equipment available
- Robust physical layer with future enhancements e.g. BroadR-Reach (100Mbps with 2-wire twisted-pair)
- Standardized interface to the physical layer Engineers learn about Ethernet in schools



Space Programs Using Ethernet



Motivation for Time-Triggered Ethernet

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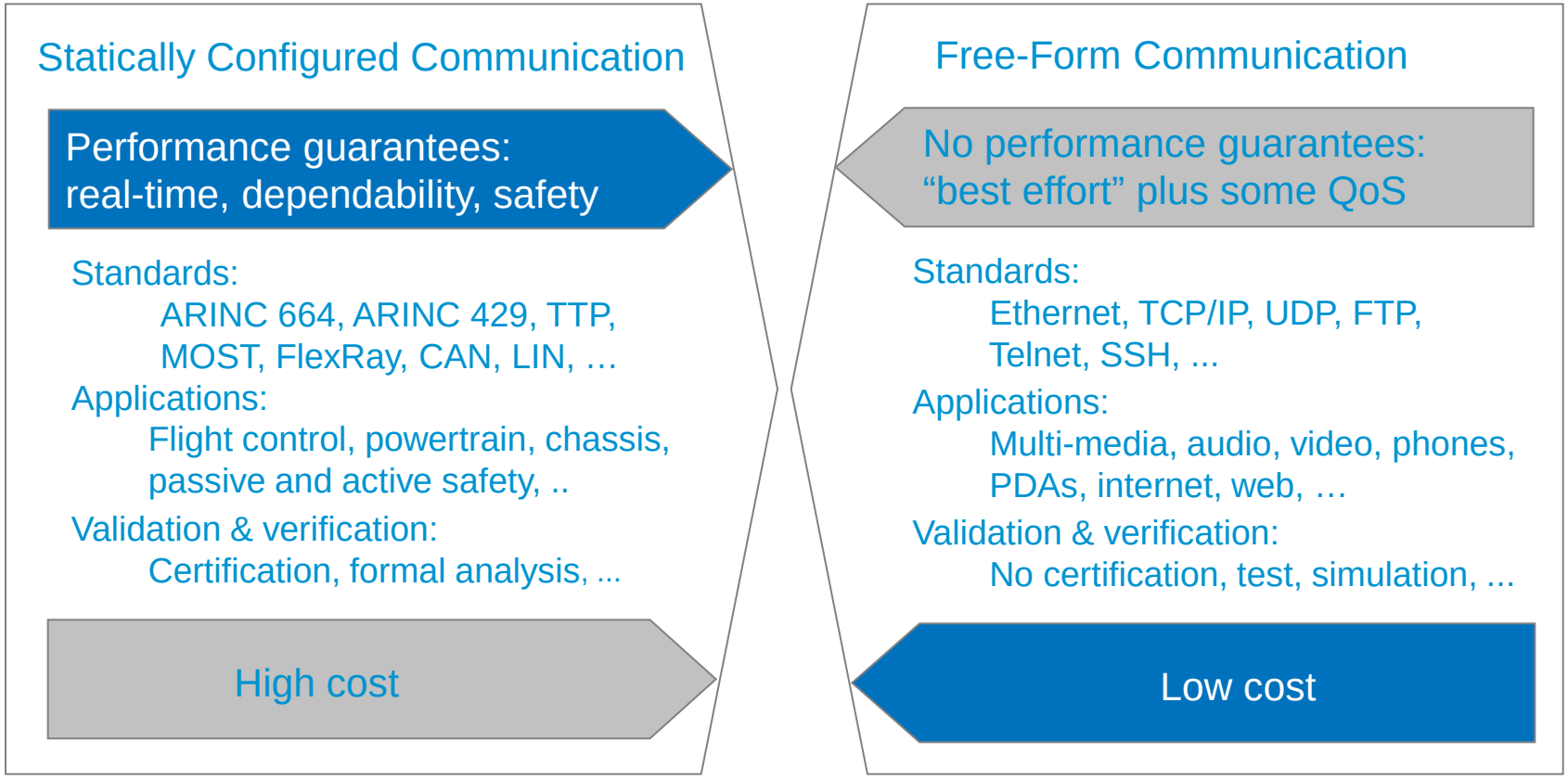


Integration of functions from both worlds requires
a communication platform supporting both worlds

Complexity Example: Synchronous vs. Asynchronous

Active standby avionics system model with three components…

- **Synchronous model:** 185 reachable states (~$2x10^2$)
- **Asynchronous model & communication with no latency:** >$3x10^6$ states
- **Asynchronous model with varying communication latency:** The number of reachable states could not be calculated with 8Gb RAM…

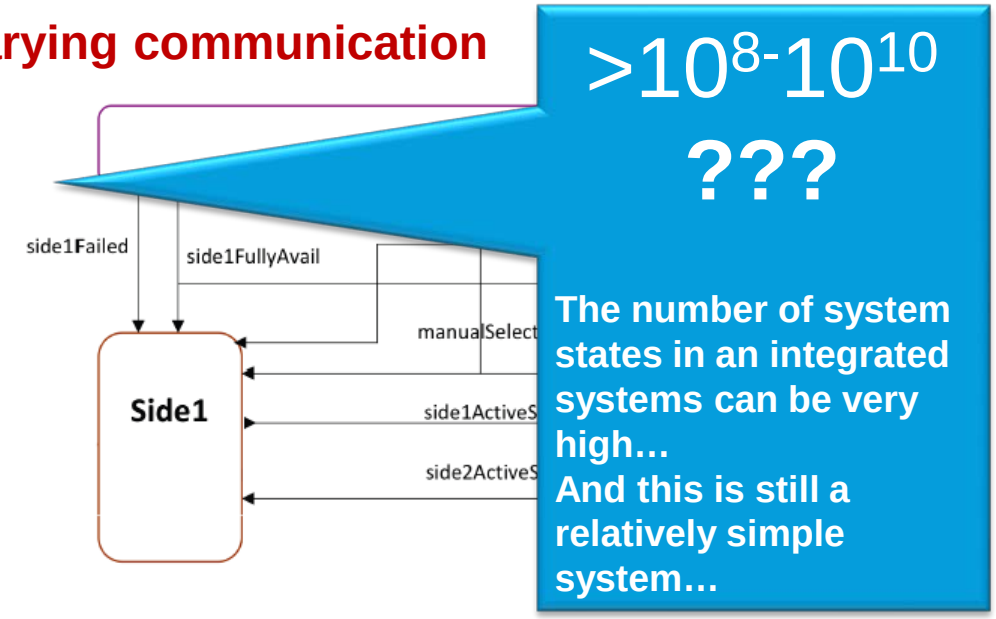
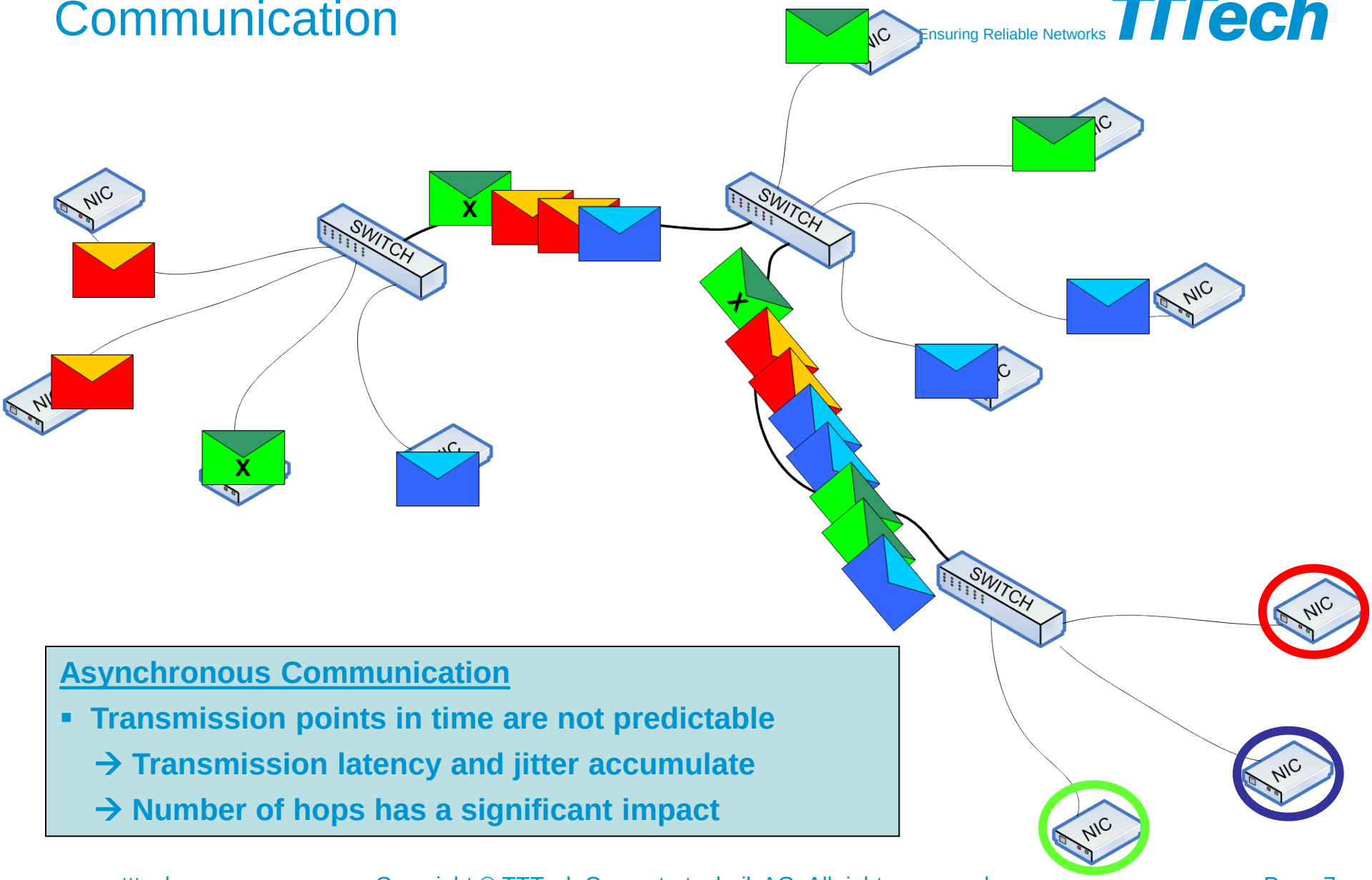


Fig. 5. The architecture of the active standby system.

https://www.ideals.illinois.edu/bitstream/handle/2142/17089/pals-formalization.pdf?sequence=2

Ethernet = Unsynchronized Communication



Asynchronous Communication

- **Transmission points in time are not predictable**
  - **→ Transmission latency and jitter accumulate**
  - **→ Number of hops has a significant impact**

TTEthernet - Big Picture

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TTEthernet = combination on the same network of

IEEE802.3

- best effort Ethernet
- no performance guarantee

ARINC664p7

- asynchronous
- jitter < 500 µs
- latency typical 1-10 ms
- TTTech AFDX licensee

SAE AS6802

- synchronous
- jitter < 1 µs
- latency < 12.5 µs/switch (1 GBit/s Ethernet)
- very tight control loops

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Distributed Fault-tolerant Synchronization

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Robust algorithm based on exchange of asynchronous IEEE 802.3 messages.

Synchronizes local clocks – system time (!)

- no wall clock (external time source - e.g. GPS)

Fail-operational:

- tolerates multiple faults
- tolerates byzantine synchronization faults
- no search for best master (distributed clock!)

Provides defined worst-case synchronous startup & recovery time (in ms)

Comparison		
	IEEE1588	**SAE AS6802**
Designed for:	data acquisition & measurement applications	critical infrastructure applications (e.g. by-wire flight systems), with defined fault hypothesis
Focus on:	precise timing	robust synchronization, fault-tolerance, continuous system time under different loads and fault scenarios
Operation Principle:	Distributes external (master) clock to all networked units	Aligns local clocks to specified precision (in µs)

Time-triggered Traffic Timing

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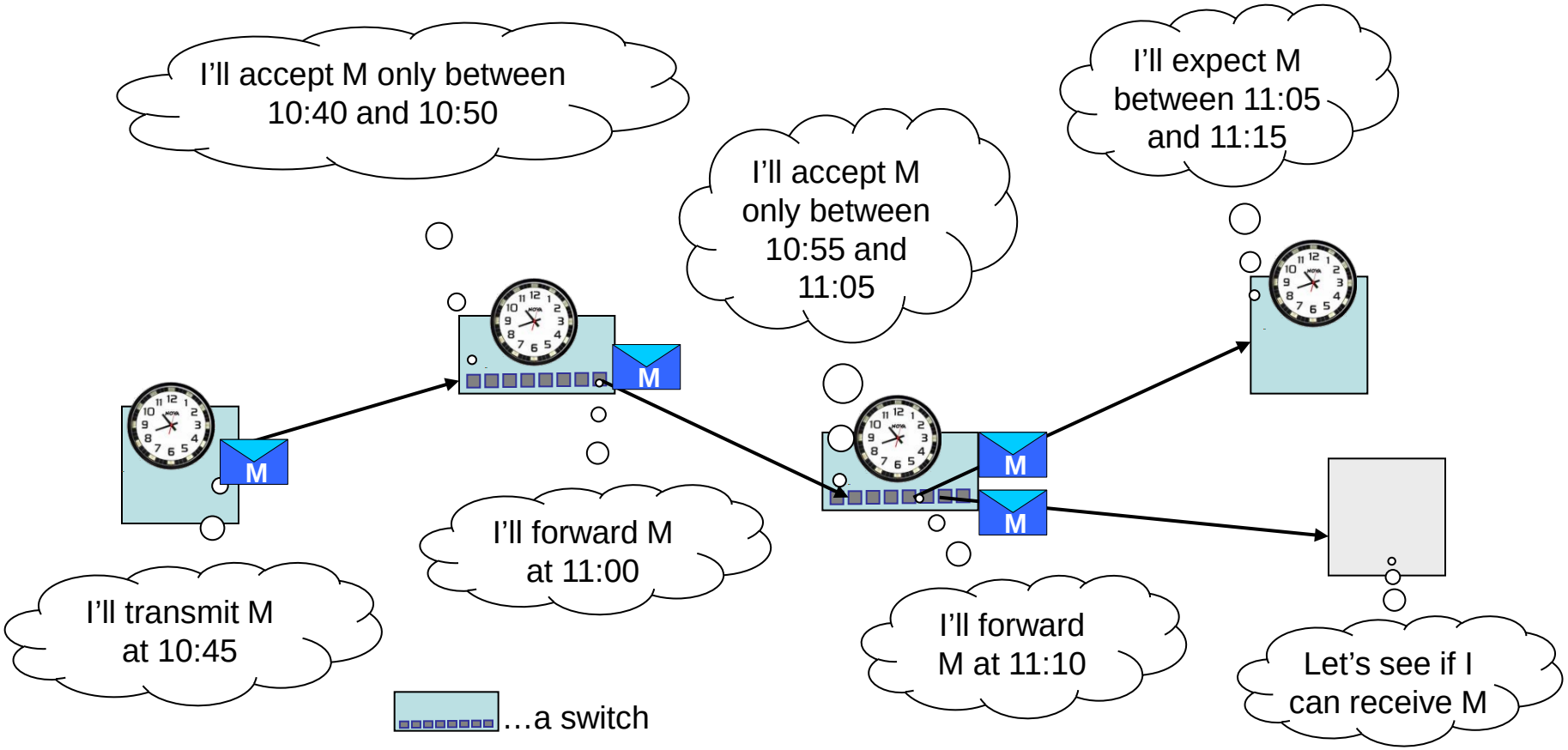
Full control of timings in the system.

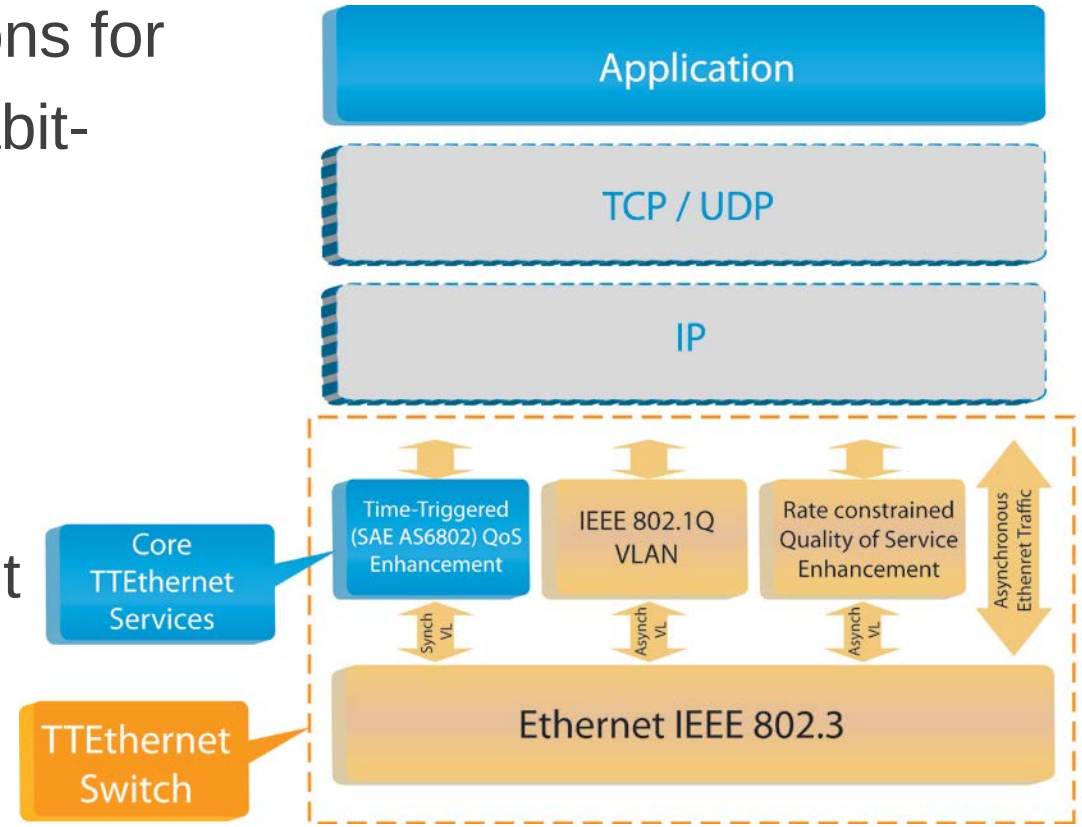
Defined latency and sub-microsecond jitter



Extensions & Standard Ethernet

Time-triggered extensions for standard switched Gigabit-Ethernet

- Startup
- Recovery
- Robust fault-tolerant distributed clock



Makes Ethernet viable for safety-critical distributed applications!

TTEthernet Traffic Partitioning

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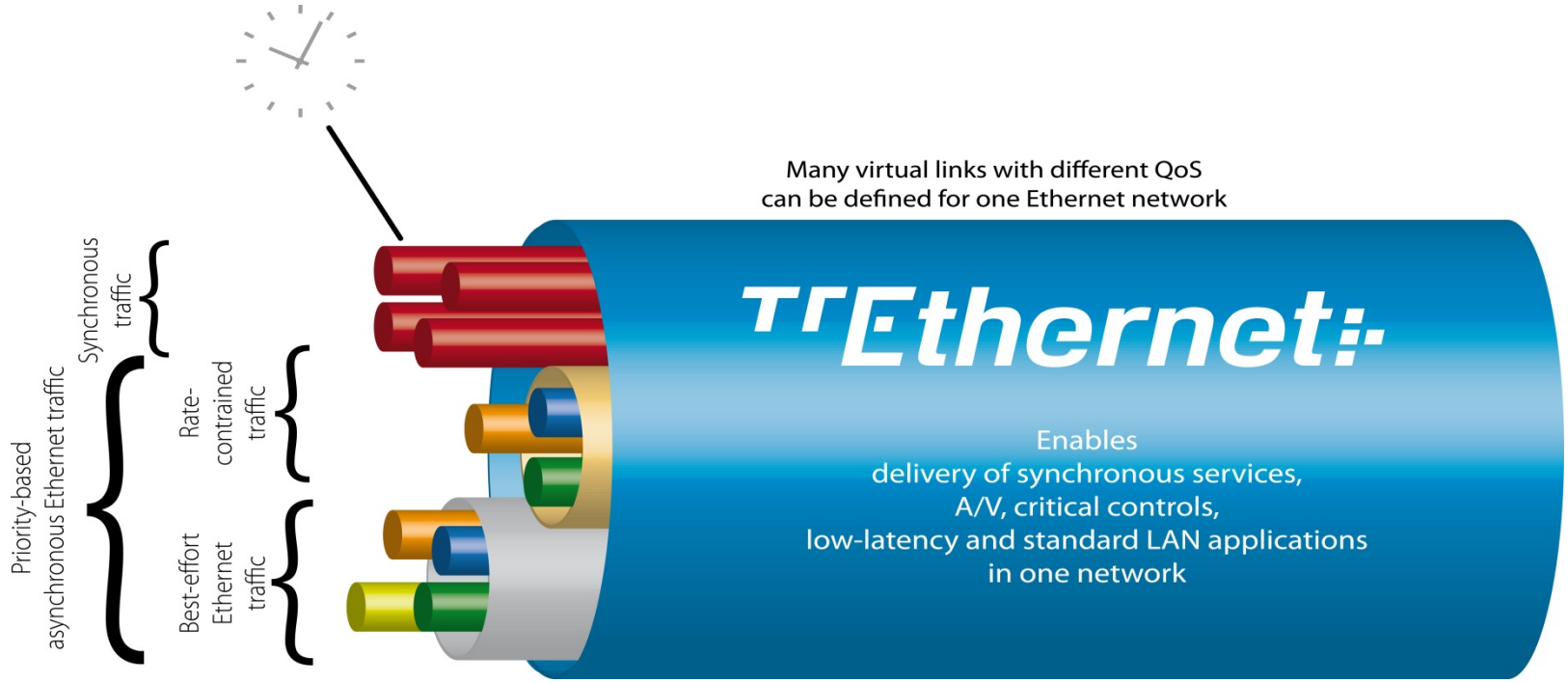
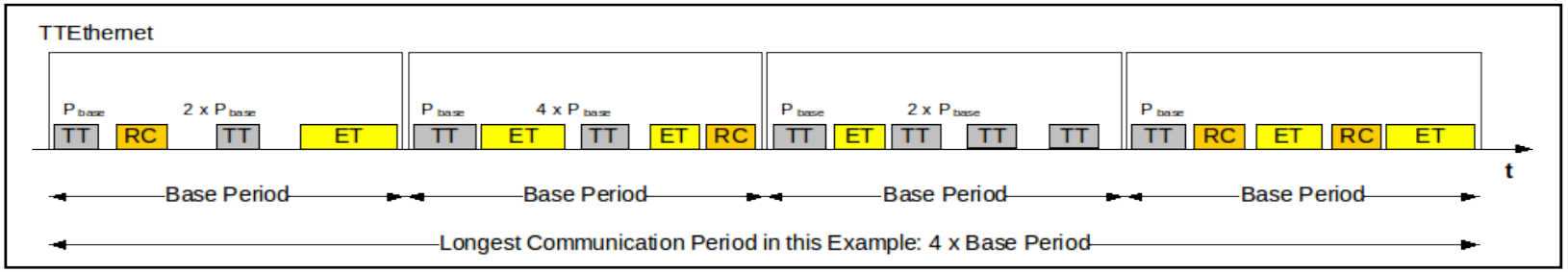
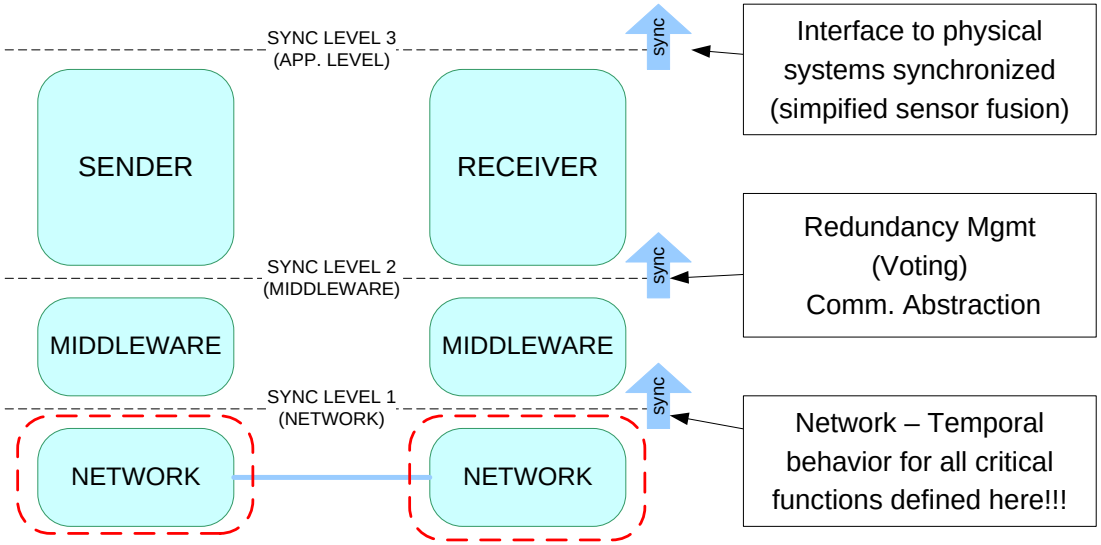




Clean Layered Model for Critical Functions

Interfaces and temporal behavior defined at network level

- Middleware contains parameter-defined communication abstraction and redundancy management (voting)
- Application can handle only functional aspects without temporal interdependencies (no busy waiting, watchdogs, semaphores, …)
  - All behavior related to progression of time, not dependent on HW or SW platform
  - Supports model-based application design (simple computation tasks)
- All sensors and actuator access synchronized to µs (using simple IO tasks)



TTEthernet and SAVOIR

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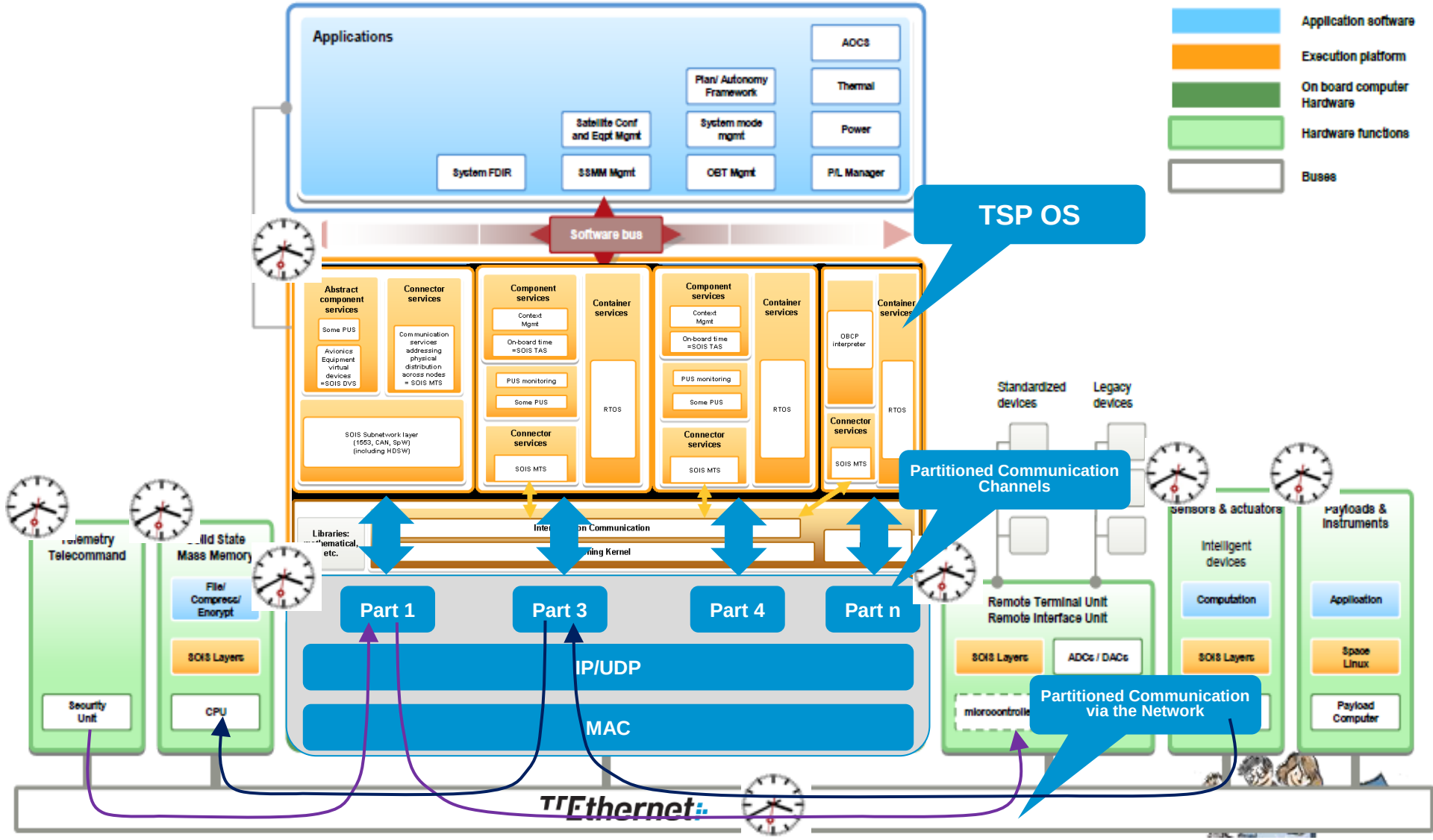
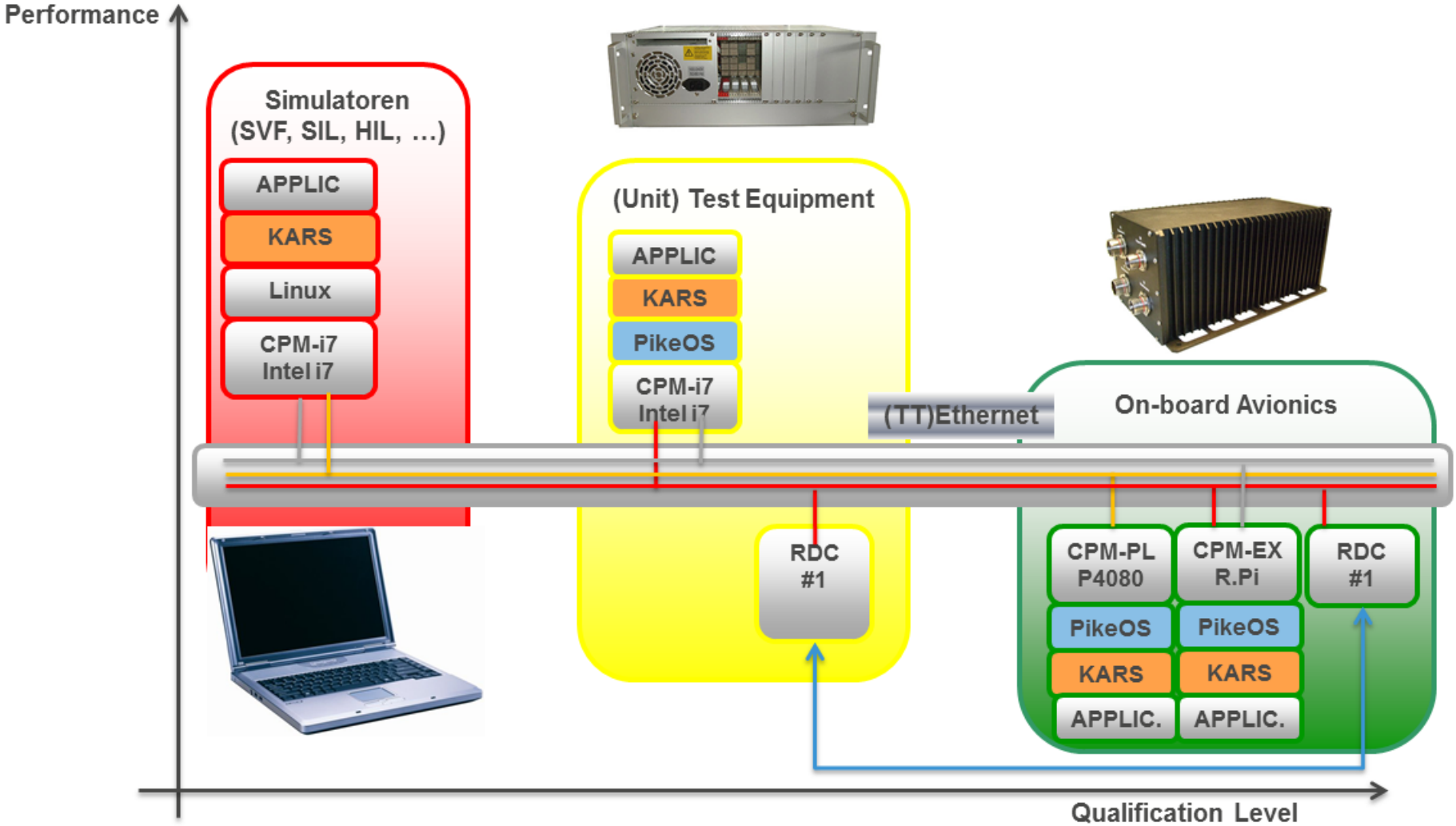


OMAC4S - One Concept – Different Applications



“System of Systems” Fusion

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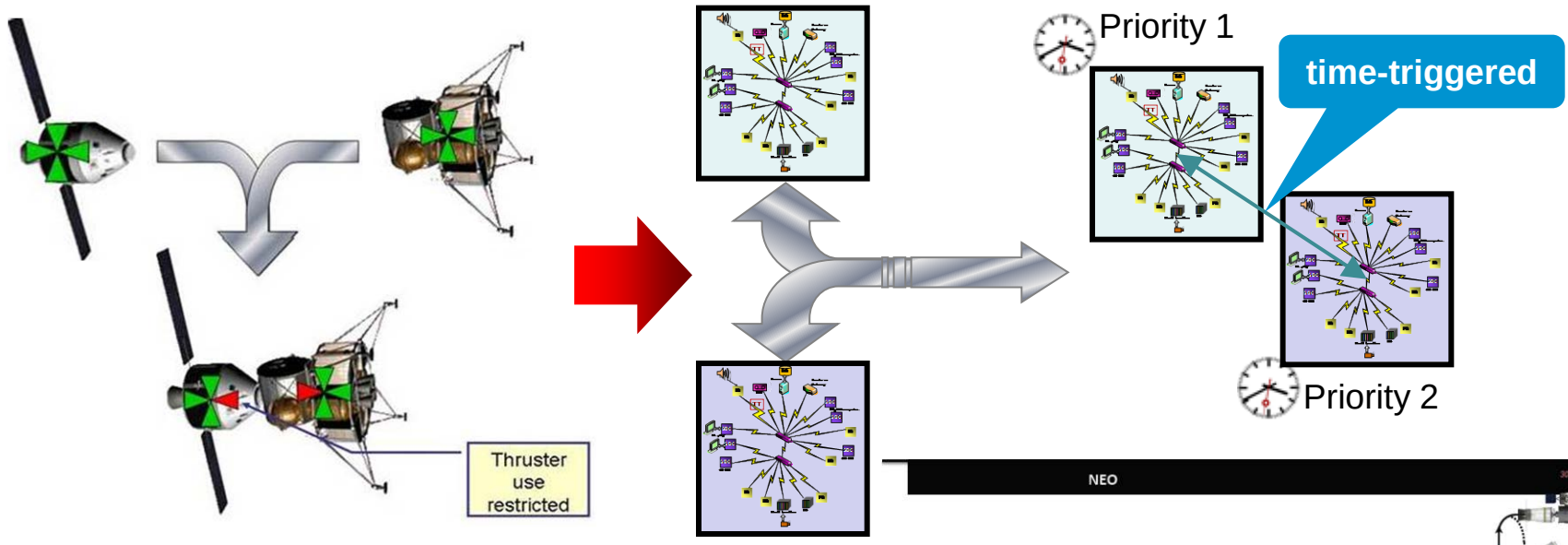

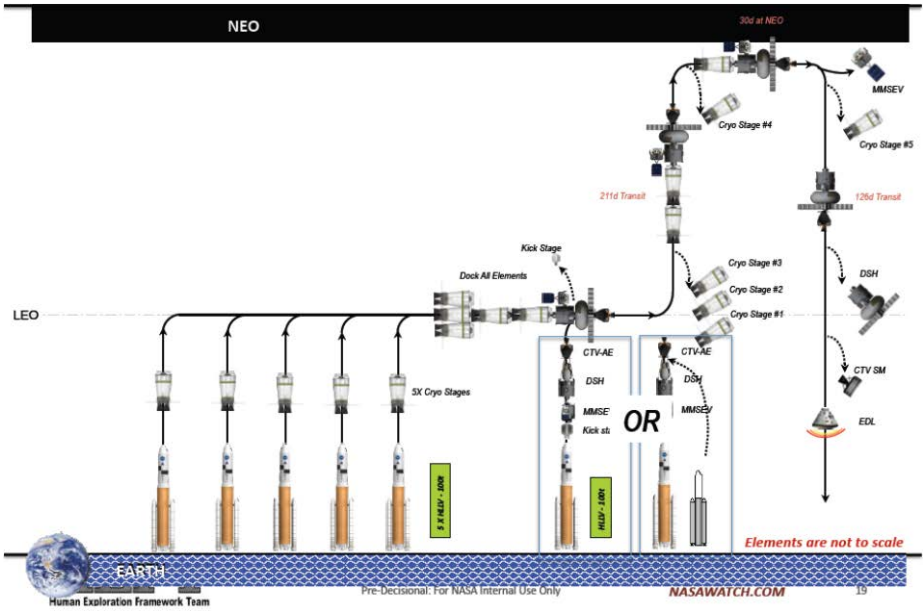

SoS architecture with TTEthernet supports reconfiguration

Several separate vehicles or elements fuse into a new combined network configuration

TTEthernet COTS Products

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Rugged Hardware

- TTESwitch 3U VPX Rugged
- TTEPMC Card Rugged

Development Equipment

Switches

- TTEDev Switch 1 Gbit/s 12 Ports
- TTEDev Switch 100 Mbit/s A664
- TTESwitch 1 Gbit/s Lab 24 Ports

E/S

- TTEPMC Card, TTEPCI Card
- TTEXMC Card, TTEPCIe Card

Test and Simulation Equipment

- TTEMonitoring Switch 1 Gbit/s 12+1 Ports
- TTEEnd System A664 Dev & Test

Development Systems

- TTEDev System 1 Gbit/s v2.0
- TTEDev System 1 Gbit/s for VxWorks 653

Configuration & Verification Tooling

- TTEBuild
- TTELoad
- TTEView
- TTEVerify (certification RTCA DO 178B)

Embedded Software

- TTEDriver and TTEAPI Library
- TTECOM Layer ARINC 653
- TTESync Library

Space (IP) Product Roadmap

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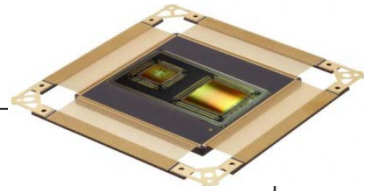


TTEthernet Space IP Variants
- For rad-tolerant/hard FPGA

"Pluto" Space IP
- 2x 10/100 Mbps (small footprint IP)

PT SR

Looking for Funding

***Third Party* Combined End System ASIC**
- Rad-hard SoC
- Leon CPU
- 2x 10/100/1000 Mbps End System
- Other Interfaces e.g. SpaceFibre, Serial, ...

PT SR

NIC Space IP
- 2x 10/100/1000 Mbps MAC

PT SR

Switch Space IP
- 12x 10/100/1000 Mbps

PT

Looking for Funding

nd System ASIC
- Rad-hard ASIC
- 2x 10/100/1000Mbps End System
- 6x 10/100Mbps + 6x 10/100/1000Mbps
- Management CPU
- RGMII Interface

PT

2012 2013 2014 2015 2016 Time

AVAILABLE | UNDER DEVELOPMENT | ENVISAGED | NON-TTTECH

PT Prototype | PS Preseries | SR Series | EOL End of Life

Avionic-X Demonstrator

cnes ASTRIUM AN EADS COMPANY

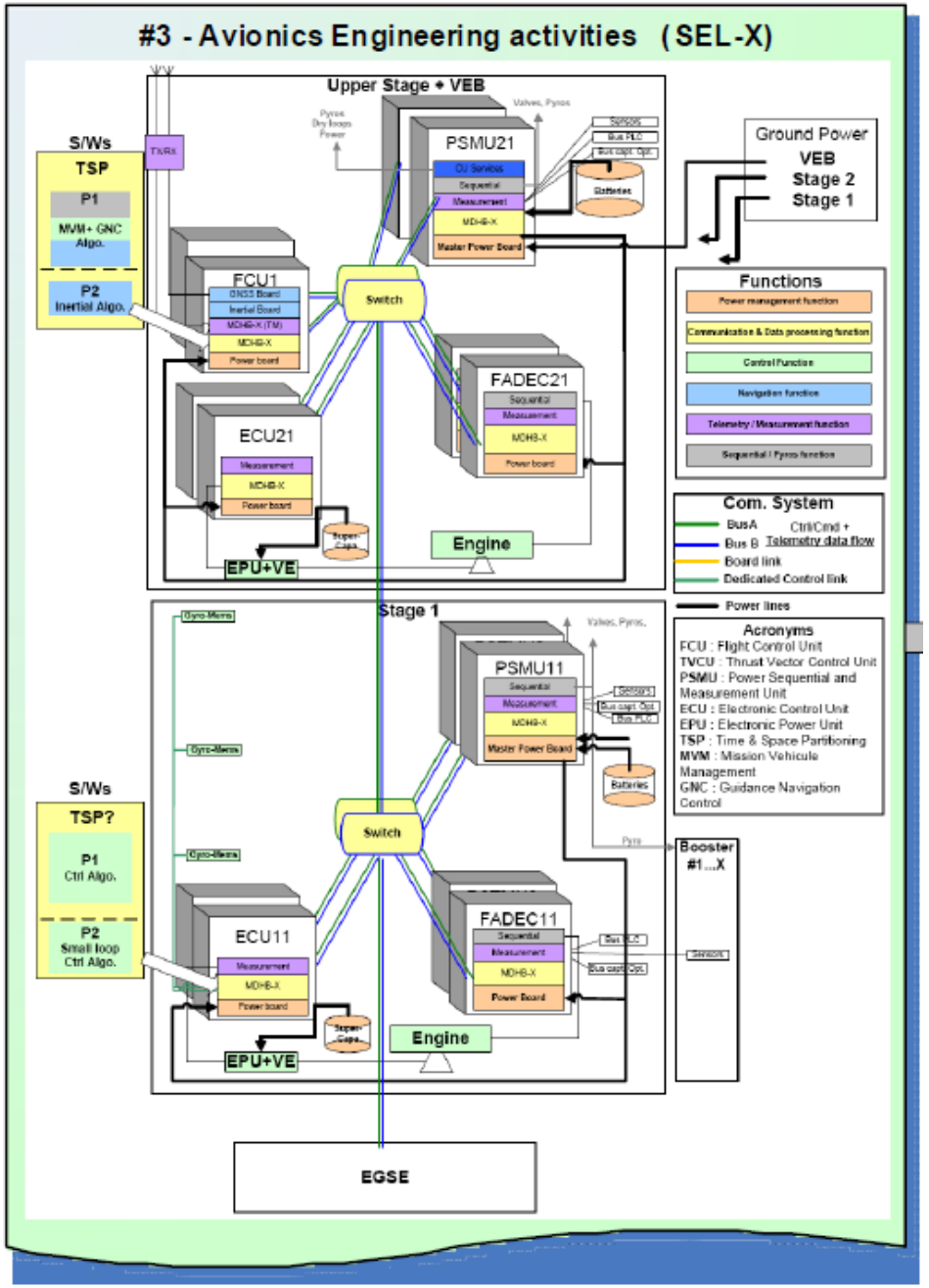
Together ahead. RUAG

TTTech provided:

- *TTEthernet Switches*
- *TTEthernet End System Cards*
- *TTEthernet ES IP Core*
- *TTE-Tools*
- *Support for the integration*

In addition as prototype

- *TTEthernet Pluto ES IP for OBC-Lite of ÅAC Microtech (proof of concept)*



Strategic ECU Programs with AUDI since 2011

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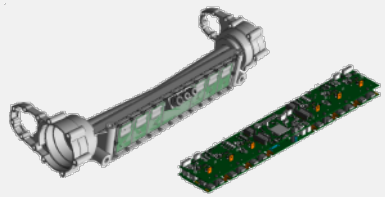
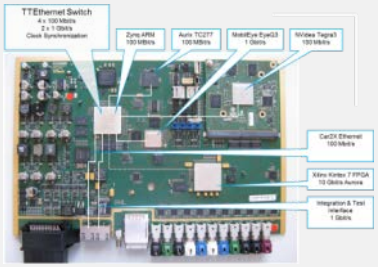
Advanced Chassis Control (integrated in front axle) and Advanced Driver Assistance Computing Platform





Automotive Ethernet Switch Chip

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NXP Semiconductors N.V. (NASDAQ: NXPI), the No. 1 supplier of semiconductors for automotive in-vehicle networking, and TTTech, are jointly developing automotive Ethernet switch solutions supporting OPEN Alliance BroadR-Reach® Ethernet PHY technology and Time-Triggered Deterministic Ethernet. The switch chip will be specifically designed for the automotive market, but will also be suitable for various demanding industrial real-time applications.

"We look forward to working closely with TTTech, as we jointly develop an innovative automotive Ethernet switch solution and believe the value proposition of TTTech's Ethernet IP together with NXP's proven technology for the connected car will lead to compelling automotive solutions for our customers.

Toni Versluijs, VP and General Manager, In-Vehicle Networking Product Line, NXP Semiconductors."

(Regional) Partnerships

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- Strong partnerships foster acceptance of technology
- Early adoption in North America
- Now focusing on Europe and Japan
- Partnership with Astrium Space Transportation for Europe
  - Support the MPCV-SM
  - European ITAR free building blocks – rad hard ASIC (by Atmel)
  - OBC-SA demonstrator for DLR (led by Astrium Satellites)

ASTRIUM AN EADS COMPANY

- …see you at our joint exhibition table!

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(TT)Ethernet
Scalable & Power Efficient

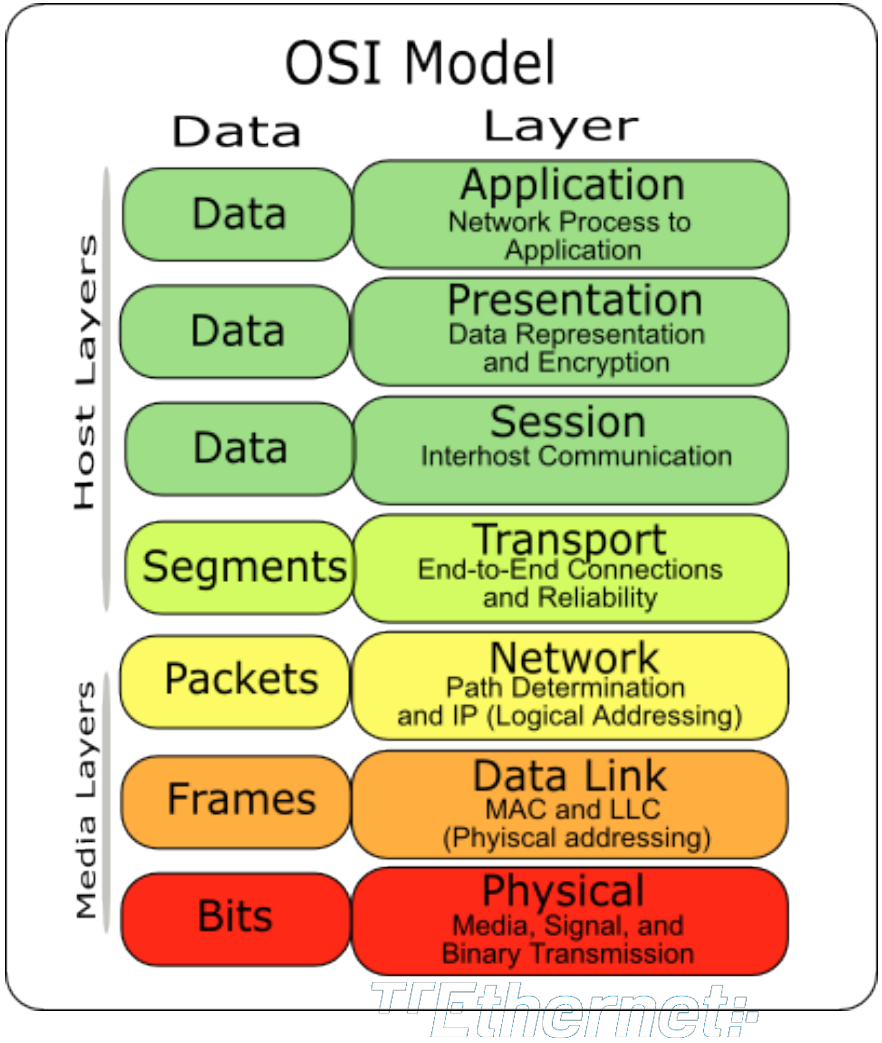
IEEE 802.3 is sclable in terms of QoS e.g.

- *MAC*
- *IP/UDP*
- *IGMP*
- *SNMP*
- *TFTP*

Physical layers which can be used

- *Copper 10/100/1000Base-T*
- *Fiber 100/1000Base-SX/FX*
- *LVDS for short distance*
- *RS485 or MIL1553 for bus architecture up to 10Mbps*

The power consumption many depends on the physical layer used!



TTEthernet Mixed Architecture

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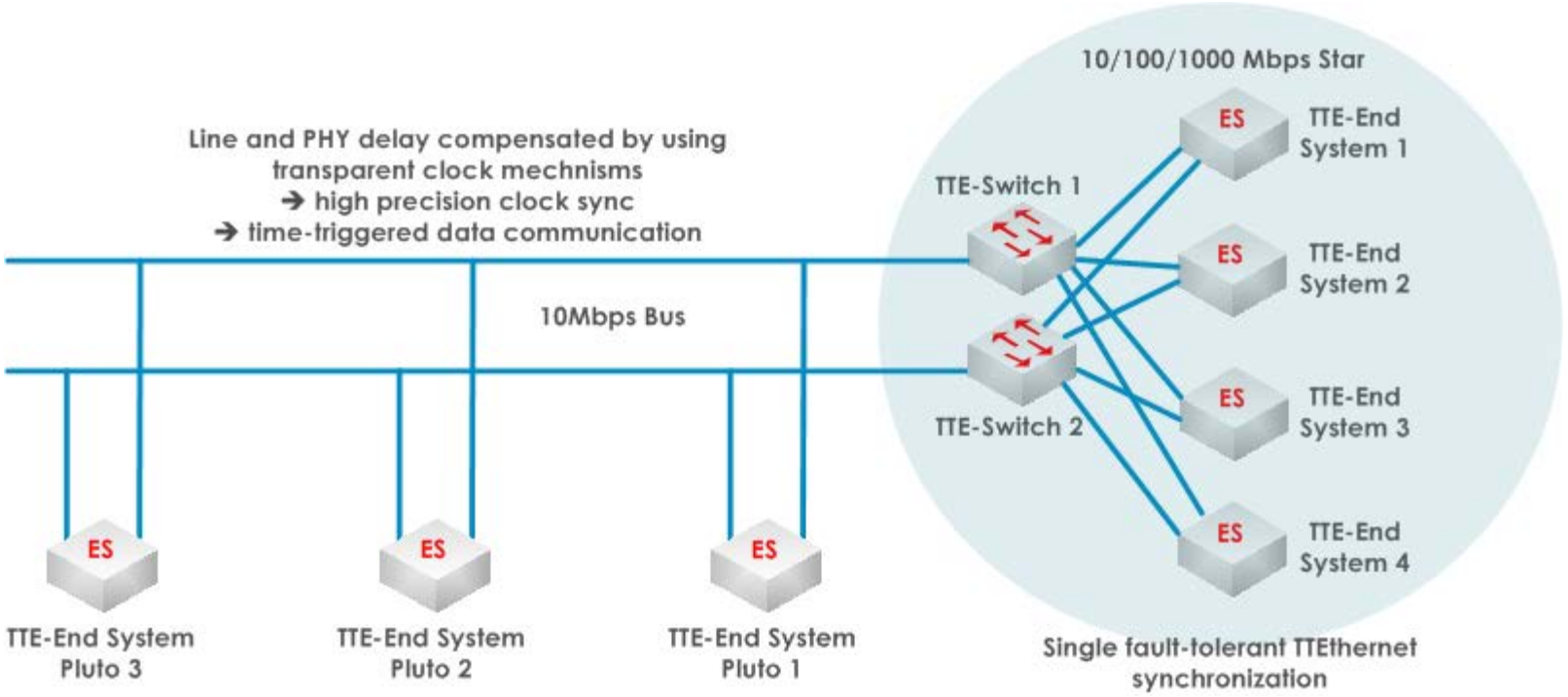
- High speed star architecture (10/100/1000Mbps) and
- Low speed bus architecture (10Mbps)
- Combined without a gateway
- Fully synchronized



RS 485 Physical Layer

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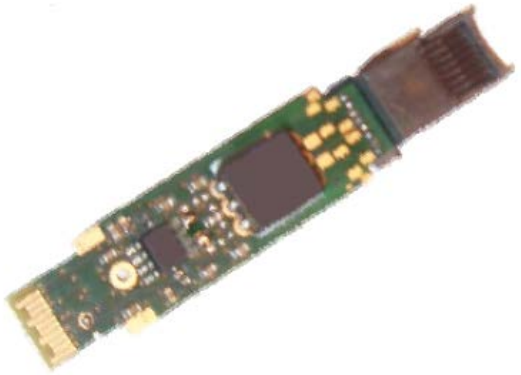
Physical Layer Features

- 10Mbps bus speed
- Up to 10 nodes
- Up to 70m
- Electrical isolation with signal transformer
- DC breakdown voltage +/- 4 kV

- Form-Factor: SFP for development



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