Ensuring Reliable Networks TTTech

Deterministic Ethernet & Unified Networking

Never bet against Ethernet …

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About TTTech

Ensuring Reliable Networks TTTech

- **Experts in time-triggered networks and architectures for aerospace and automotive applications**
  - Premium development member - FlexRay and AUTOSAR
  - TTP and networking platforms for e.g. Boeing 787
- **Experts in deterministic Ethernet (chip IP & switch design)**
  - AFDX (ARINC664)
    - Deterministic time-sensitive streams with rate-constrained Ethernet communication
  - TTEthernet (SAE AS6802 Time-Triggered Ethernet)
    - Deterministic time-critical streams with synchronous Ethernet communication
    - Part of the core team working on Ethernet QoS Layer 2 standards at SAE (Society of Automotive Engineers)

About TTTech

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ISO 26262 Automotive

IEC 61508 Industrial

EN 13849 Off-Highway

DO 254/178 Aerospace

IEC 60601 IEC 62304 Medical

Market specific safety certification

Rising Expectations on Networks and System Integration

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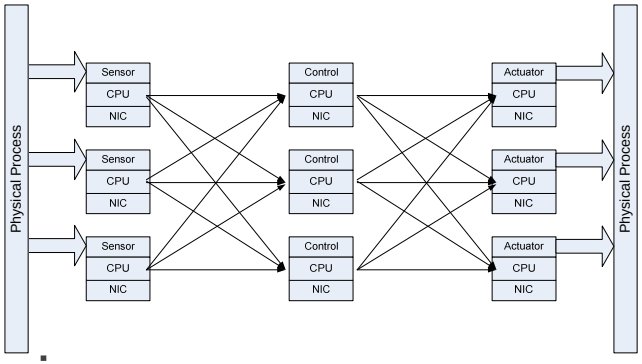
Modern society relies on integration of systems

- Internet of things, M2M, smart systems, integrated architectures, …
  - Many integrated functions
  - Drive to reduce systems costs and flexibly share common resources (cloud computing)



- Virtualization trends: many functions sharing common resources, increasingly „flat“ architectures
  - Minimize trade-offs and costs in integration of different functions
  - „The network is a distributed computer“ …
  - … or even better **„the network is a fault-tolerant hard real-time computer“**
  - …or both

Rising Expectations on Networks and System Integration

Networks gain importance in more integrated world

- Network is core technology and glue logic for different functions with different QoS requirements
- Beyond messaging, latency and jitter, the network capabilities impact:
  - Architecture and application design methodology
  - System complexity of „distributed computer“ and distributed applications
  - Integrated system lifecycle costs
- Network capabilities impact the system robustness

Ethernet Everywhere …

- Ethernet is an omni-present technology with strong cross-industry support today and guaranteed growth in the future
- Evolving, but mature technology with exceptional evolutionary capabilities

Real-time Ethernet networks today:

- Special profiles or modifications / fragmentation of markets
- Different networks for different applications

Requirements – Integrated Systems

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Our customers value both Ethernet and deterministic real-time communication:

Determinism & Robust Performance

- Predictable network behavior under different workload and faults – low latency and jitter (!)
- Latency control for (rate-limiting traffic):
  - Fast control loops and predictable comunication performance
- Jitter control for (scheduled traffic):
  - Further latency minimization (fixed latency) for time-critical streams
  - Integration of different traffic classes, synchronous & asynchonronous
  - Efficent virtualization of computing and networking resources

Requirements – Integrated Systems

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Determinism & Robust Performance

- Fault-tolerant synchronization (fault hypothesis!)
- Defined behavior, startup and recovery timing under different conditions
- Robust separation of different distributed functions
- Zero fail-over time
- Formal verification of mechanisms/algorithms

Requirements – Integrated Systems

We start with the following assumptions:

- There will be faults
- There will be malicious faults
- There will be rogue devices / non-compliant devices
- There will be integrity issues
- There will be propagation of faults and complex failure scenarios

Meaning ….

- Normal „as designed“ behavior is only a smaller portion of possible system states …
- Impact on systems – consequences?
- What happens if we add a new end station or function into the system? (scalability of safety, time-criticality …)

Ethernet as Real-Time, Deterministic & Unified Network

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How to make Ethernet not only convergence-enhanced, but completely unified networking technology?

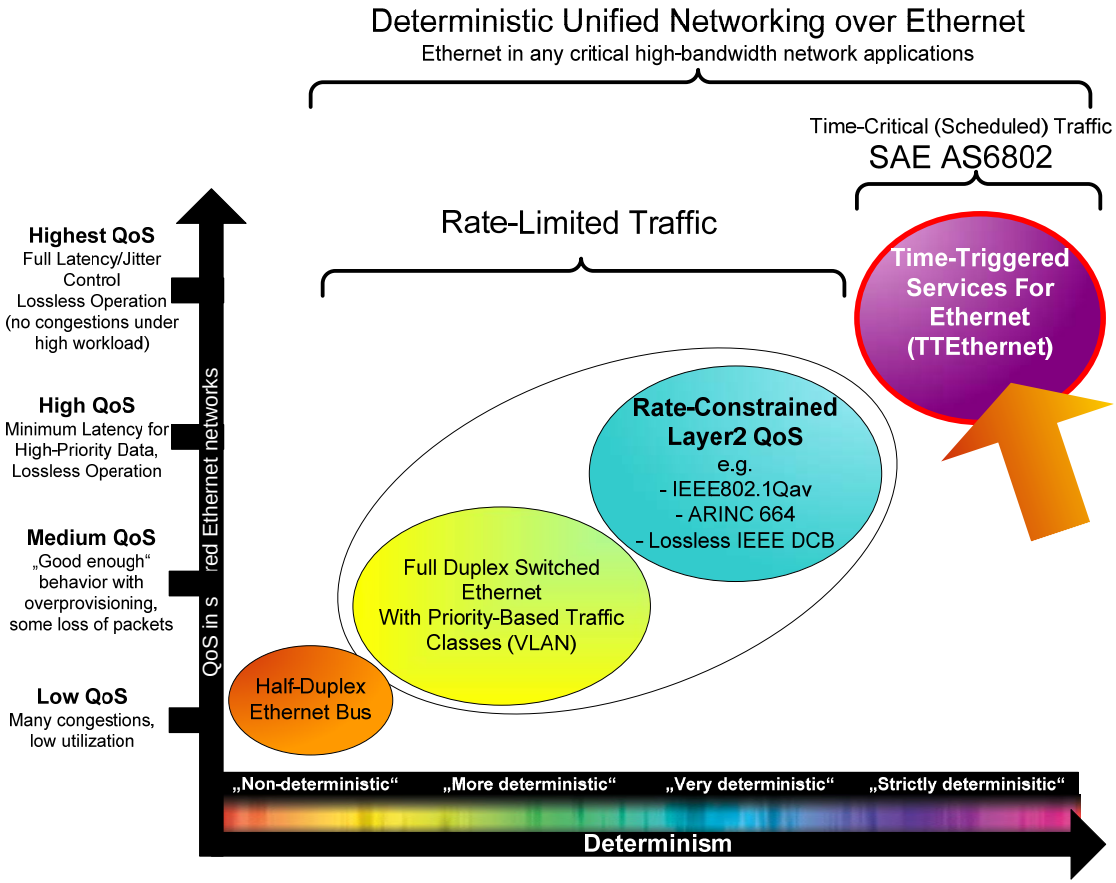
How to make Ethernet robust and viable for integration of different applications? (unified networking)

- Support for standard LAN, low-jitter and low-latency applications sharing one Ethernet network
- Time-, safety-, and mission-critical systems – stronger support at network levels
- Communication capability for both embedded and IT applications, even in a shared network

Deterministic Unified Ethernet

Complementary hard RT communication capability

- By adding scheduled hard RT streams we can reduce latency of critical streams, have lossless/congestion-free coommunication, while keeping all time-sensitive and best-effort traffic



Capabilities:
„Synchronous“ Communication

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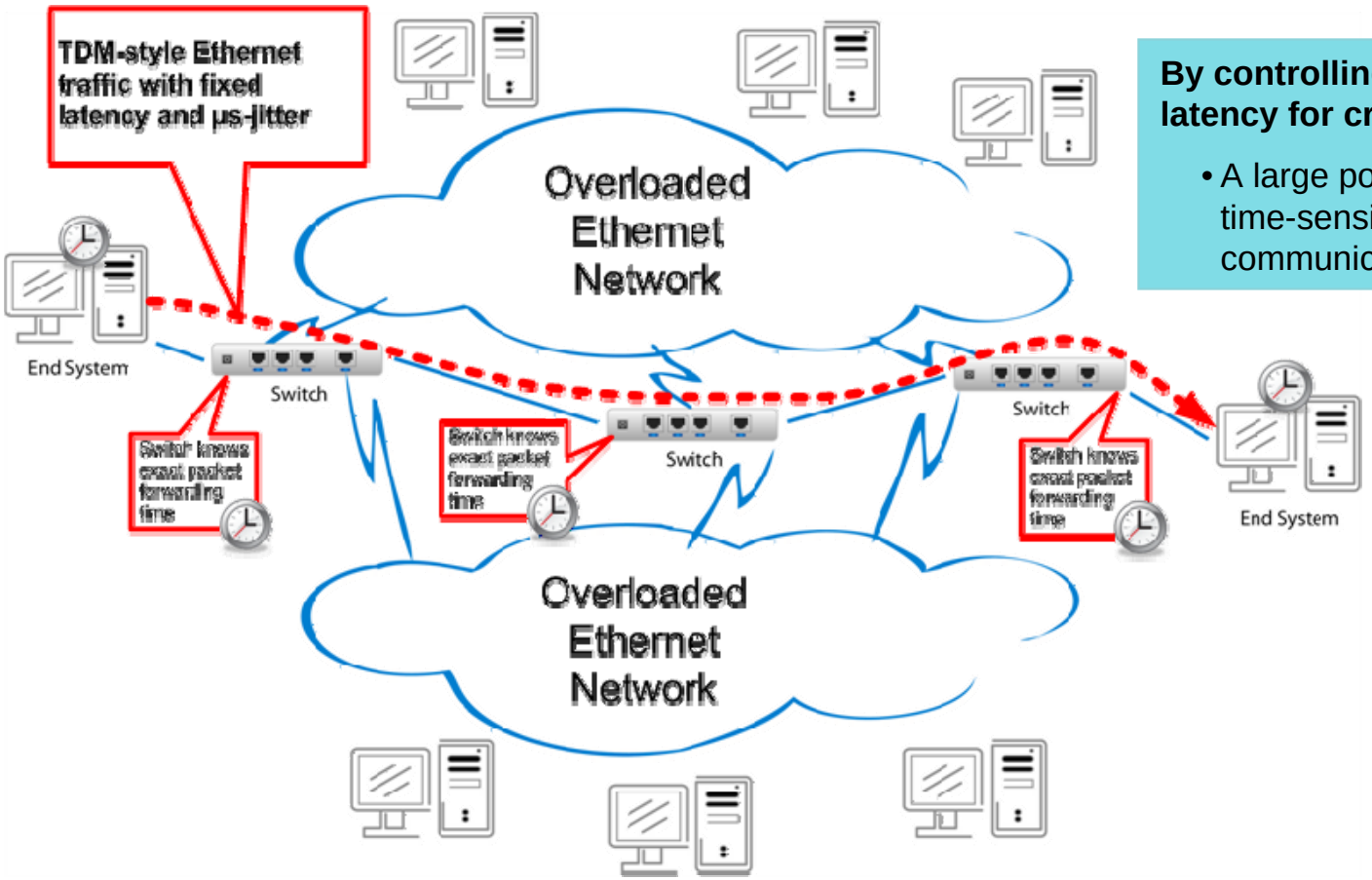
System time available on bridges and end stations

- Scheduled traffic can have fixed latency and µs-jitter
- Switch knows when the message is forwarded



By controlling jitter we also minimize latency for critical streams

- A large portion of latency in time-sensitive rate-limited communication is the jitter!

Deterministic Unified Ethernet Capabilities

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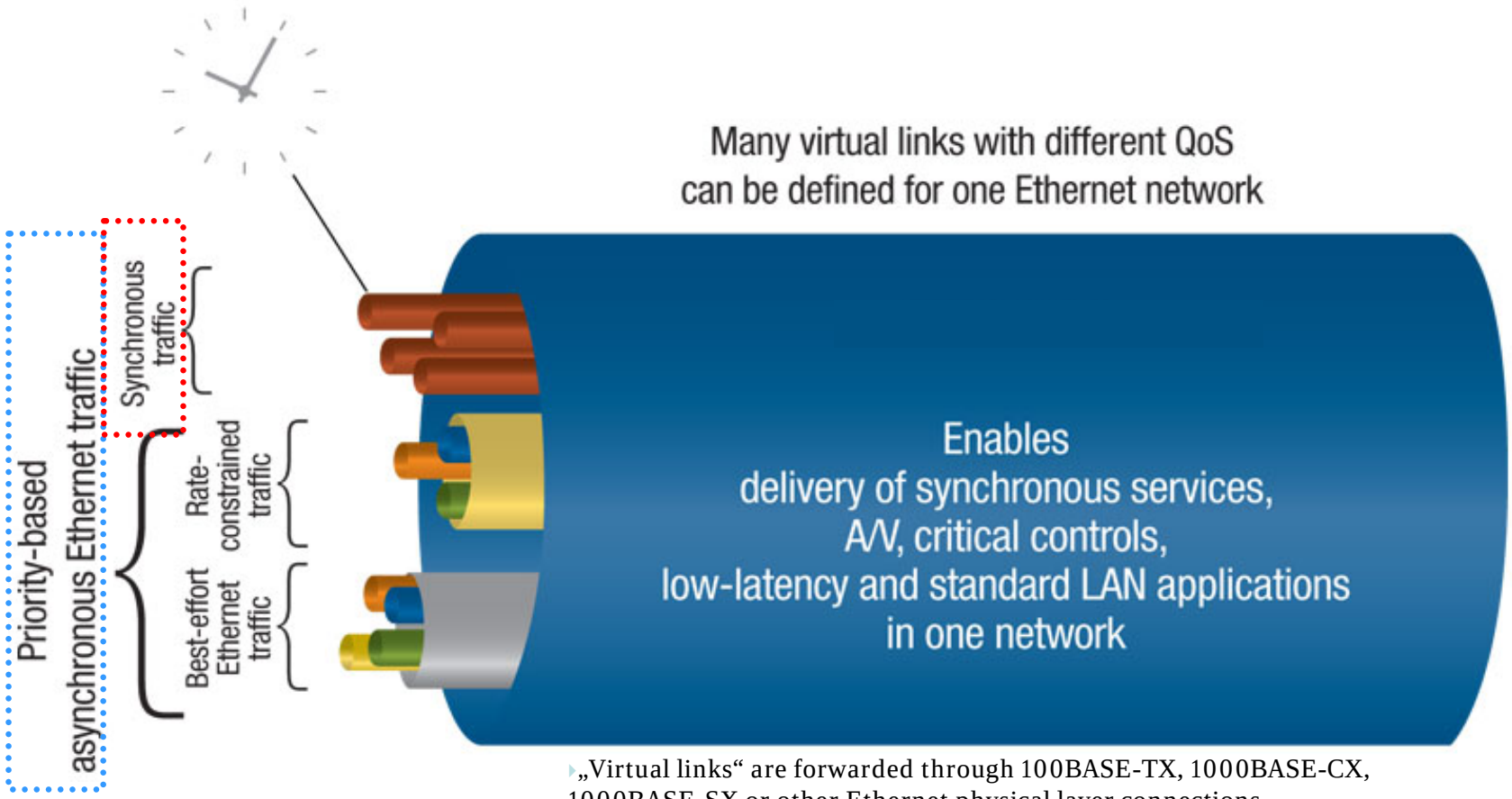
„Synchronous“ and Asynchronous Traffic



„Virtual links“ are forwarded through 100BASE-TX, 1000BASE-CX, 1000BASE-SX or other Ethernet physical layer connections

Capabilities: Robust Partitioning for Deterministic Unified Ethernet

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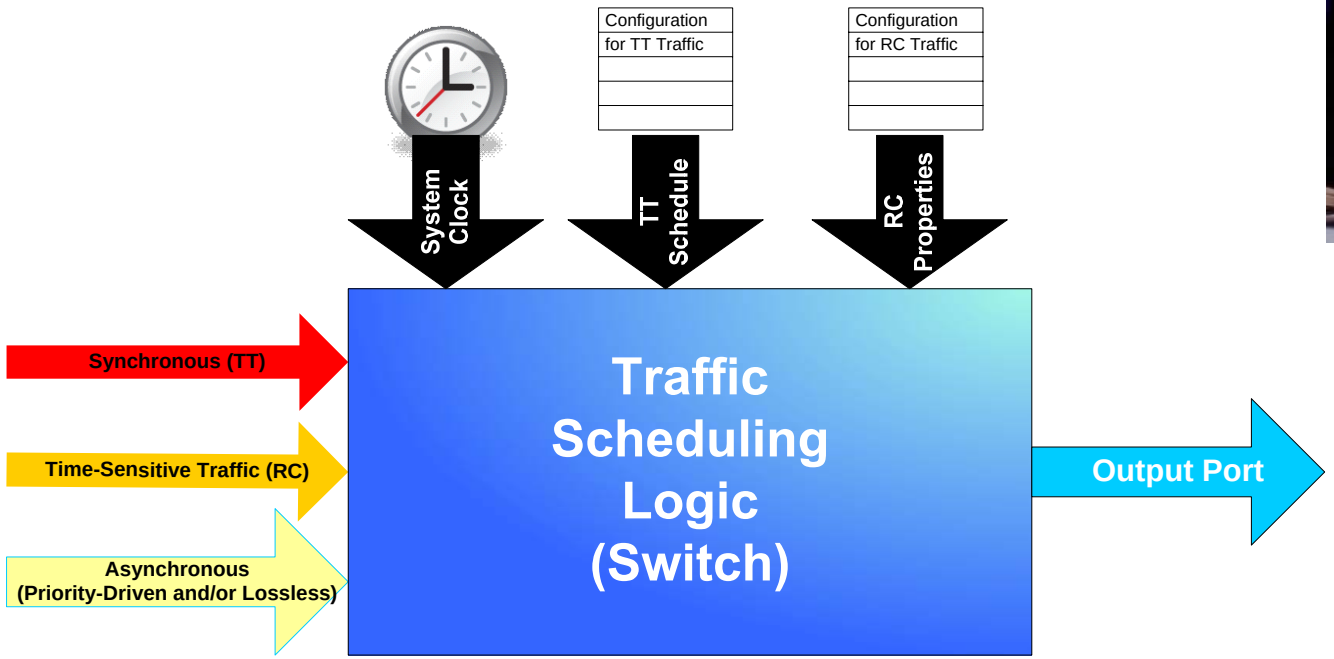
Ethernet switch can predict future collisions, plan for their resolution, and protect time-critical and time-sensitive traffic!

Mechanisms:

- Switch knows the traffic schedule for synchronous (TT) traffic
- Switch knows about properties of time-sensitive traffic and possible time-violations e.g. for AFDX / ARINC664 (e.g. rate constrained – BAG, periodicity) or 802.1Qav
- Switch knows when the best effort (asynchronous) traffic can be scheduled to prevent violation of temporal constraints for RC and TT



What is it good for?

Native synchronous communication in packet-switched Ethernet networks

- Strictly deterministic, hard RT, lossless communication
  - Congestion management per default
- Latency for critical streams is defined and fixed, unaffected by other asynchronous traffic
  - Jitter control makes the difference!
- Dynamic bandwidth release if packet not sent

What is it good for?

Impact on embedded system virtualization

- Jitter control makes the difference!
- Few powerful control units can handle Nx10 distributed functions
  - Higher processing power and bandwidth utilization
- Less critical functions do not affect time-critical functions
  - e.g. MP3 player or video download will not influence operation of critical control system

Important: Reliance on robust & continuous system time

Summary

Ethernet can handle any type of communiciation today

Deterministic Unified Ethernet is possible today in safety-critical applications:

- Example: Integration of SAE AS6802 „Time-Triggered Ethernet“ (synchronous communication, time-critical), ARINC 664/AFDX (rate constrained, time-sensitive), and best effort communication
- The system uses fault-tolerant system synchronization trusted to work in avionics, space and defense systems

IEEE 802.1 provides great platform and experience to create deterministic unified Ethernet networks capable of:

- Time-critical, time-sensitive, best effort communication …
- … for IT, embedded and critical infrastructure applications
- … and fully integrated with IEEE 802 suite of Ethernet standards

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