Whitepaper

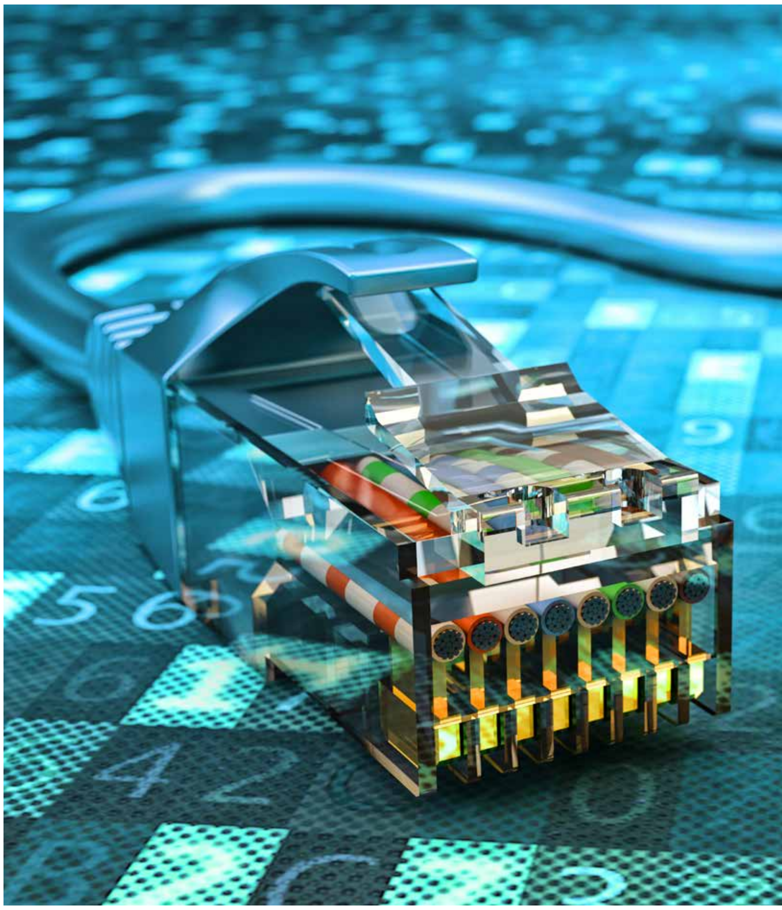
Time Sensitive Networking
TSN Ethernet Switched Endpoint Controller

Introduction

Time-Sensitive Networking (TSN) is the functional extension of IEEE 802.1 Ethernet networks that is currently being developed by the IEEE. The set of standards is intended to enable time-critical data transmission to be transmitted at the same time as non-time-critical data in a connected network. Essentially, this means implementing a standardized and convergent Ethernet network across all areas of the company - from the field level to the corporate management level. Such networks must meet the following requirements:

- Guaranteed latency times
- Low latency fluctuations (jitter)
- Guaranteed end-to-end latencies for
- the parallel transmission of (time) critical and non-critical data traffic via a convergent network
- low packet loss

This enables the shared use of an infrastructure, real-time control and monitoring across the entire network and the elimination of manufacturer dependencies with regard to real-time-capable fieldbus systems. The design, deployment and maintenance of a single infrastructure also simplifies overall networking.



Potential and fields of application of TSN

Various expectations are attached to TSN. One of these is that the costs for real-time Ethernet hardware will be significantly lower, as standard hardware components can also be used through the use of TSN and the need for gateways (protocol converters) will also be reduced. Another idea is that production planning can be made much more flexible and dynamic than is the case today. This facilitates the implementation of applications that are generally referred to as Industry 4.0 applications.

The consequence of this is that the current separation of field level and control level in a manufacturing company is dissolved and a convergent network is created in which critical data traffic can be transmitted simultaneously with non-critical data traffic without negative interactions occurring.

Figure 1 shows the simplified structure of a possible TSN network. In such a network, the stability and reliability requirements of fast motion control must be met and the control packets between drives, sensors and controller must be consistently available with a latency of < 100 µs. The movement axes of machines must be coordinated with each other, which requires a latency of < 1 µs. At the same time, camera data is transmitted, which requires a high bandwidth and can therefore cause overload problems.

The controllers and the Human Machine Interface (HMI) are also connected via standard Ethernet, and the same network bus can be used to integrate the machine into the overall manufacturing process, where they communicate directly with neighboring machines. This connection also enables integration into the plant's overall MES system and remote connection to the machine manufacturer's maintenance and service systems.

Without TSN enhancements, achieving these performance requirements on a shared Ethernet network requires a high level of technical expertise and can result in extremely rigid network architectures that do not allow for dynamic change in business processes and performance.

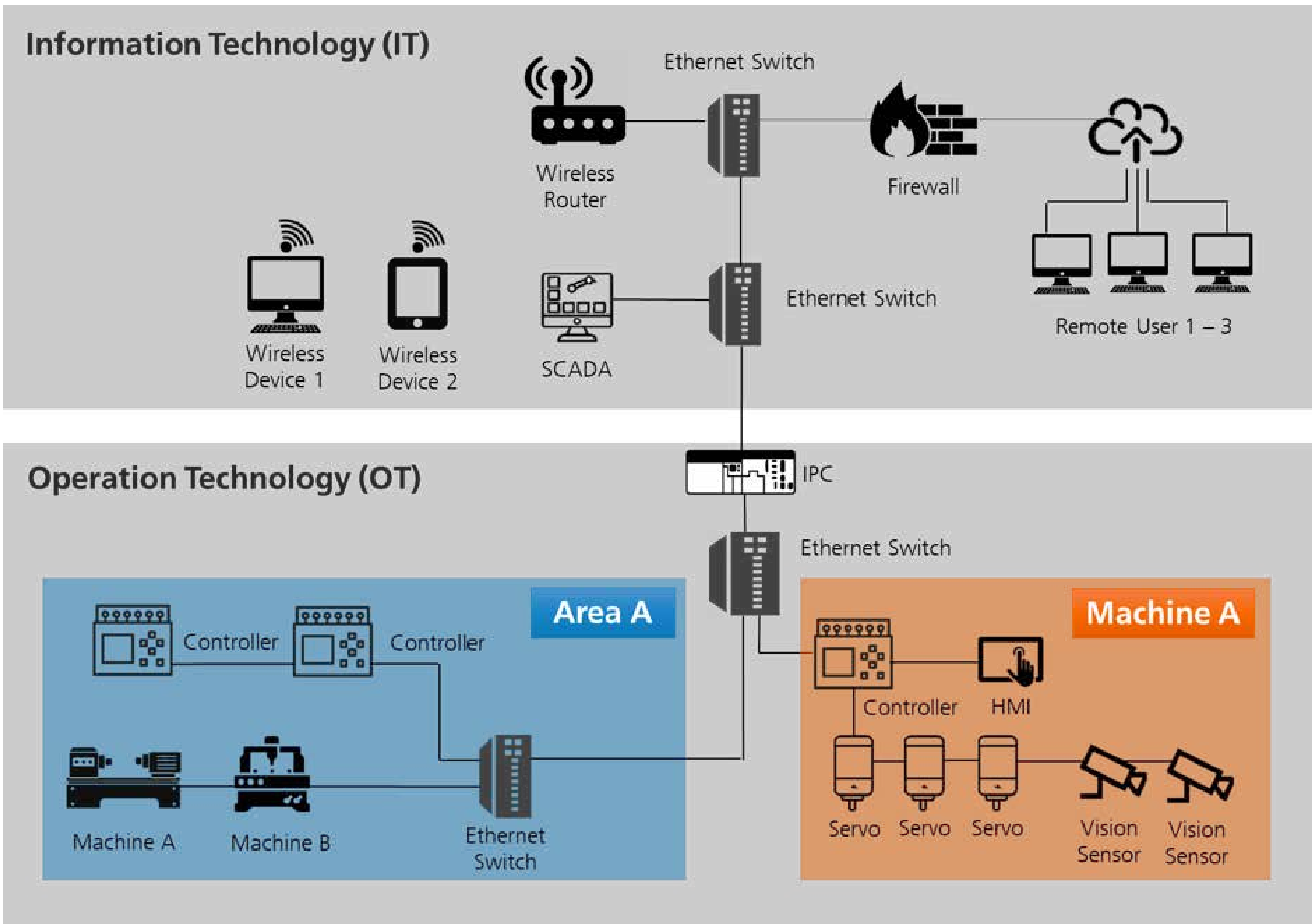


Fig. 1: Scheme of a TSN network

Daisy Chain Topology

Alongside other topologies, the daisy chain topology is also frequently used in industrial systems. The reasons for this are the savings in cabling costs. It is also a simple variant for adding further Ethernet devices to a network. An example of the use of this topology is the interlinking of servo drives in a production plant, as shown on the right.

Such a system could, for example, be an assembly system for printed circuit boards. These machines contain a placement head that can move in three axes and rotate around the z-axis. The components are sucked in by the placement head using negative pressure and placed on the PCB. Various vision sensors are used to determine the correct position on the PCB. Servo drives also play a major role.

In the past, each individual drive was wired centrally in order to ensure the power supply and control, and the cabling effort was correspondingly high. Modern and intelligent servo drives have integrated control and regulation units and are often wired in a daisy chain topology.

The first component is connected to the higher-level controller and the other components are connected in series with their predecessors. These then form a chain that leads to serial transmission. Hybrid connectors are often used, which combine power contacts with signal contacts. The advantages lie in the savings in cabling as well as in the reduced complexity of the individual control programs.

The different functionalities have different requirements in terms of latency and determinism. To meet these application requirements, systems often use multiple bus layers. However, this leads to a situation where a system must support different Ethernet applications, each optimized for a specific application. This approach poses challenges for engineers in terms of bandwidth limitations, integration and configuration complexity, and limited remote access.

Today, Ethernet-based fieldbus systems are used for real-time communication between the drives and the higher-level controller. These ensure deterministic and real-time capable communication via an Ethernet cable, which is also frequently integrated in the hybrid connectors.

With TSN-capable devices that have a switch functionality, it is no longer necessary to use proprietary systems within a TSN network.

Fig. 2: Production plant. © Shutterstock

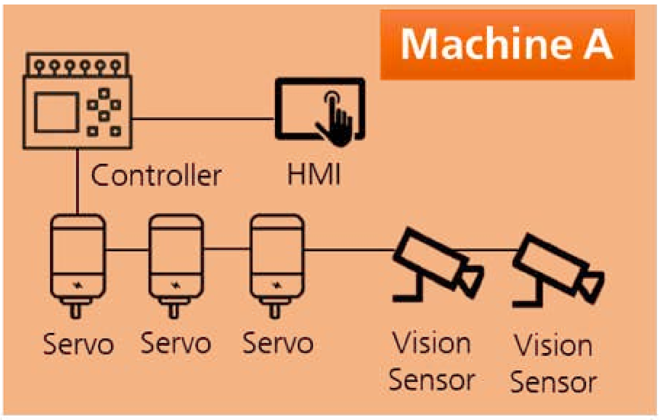


Fig. 3: Schematic representation of daisy chain topology

TSN Switched Endpoint (TSN-SE)

The TSN Ethernet IP Core TSN-SE from Fraunhofer IPMS offers switched endpoint functionality and can be integrated into TSN-capable networks. In addition to an internal CPU port, two external 10/100/1000 Mbits/s ports are available. The design implements a 1GbE switch bar with cut-through architecture. The use of the IP core in switched endpoints enables TSN-compliant point-to-point communication in a daisy chain or ring topology. The core function of these standards are implemented in hardware to ensure precision and reliability. The IP core is implemented in Intel Altera or Xilinx base.

IEEE 802.1Q Switch Funktionalities

- 2 Gigabit TSN ports and 1 standard host port
- 1024 dynamic and 1024 static MAC address table entries
- EE 802.1Q VLAN tags with up to 1024 entries
- Cut-through or store-and-forward TSN frame forwarding
- Full-duplex 10/100/1000 Ethernet ports
- PHY configuration via MDIO

TSN Funktionalities

- IEEE 802.1AS - Time and Synchronisation
- IEEE 802.1Qbv – Enhancements Scheduled Traffic

Low-Latency Ethernet MAC

- Enables high-precision synchronization in TSN networks
- Output latency: 10 Tx clock cycles
- Input latency: 6 Rx clock cycles
- 10/100/1000 Mbit/s Ethernet and MII, GMII and RGMIII PHY interfaces

FPGA Target Devices

- Intel based platforms
- Xilinx based platforms

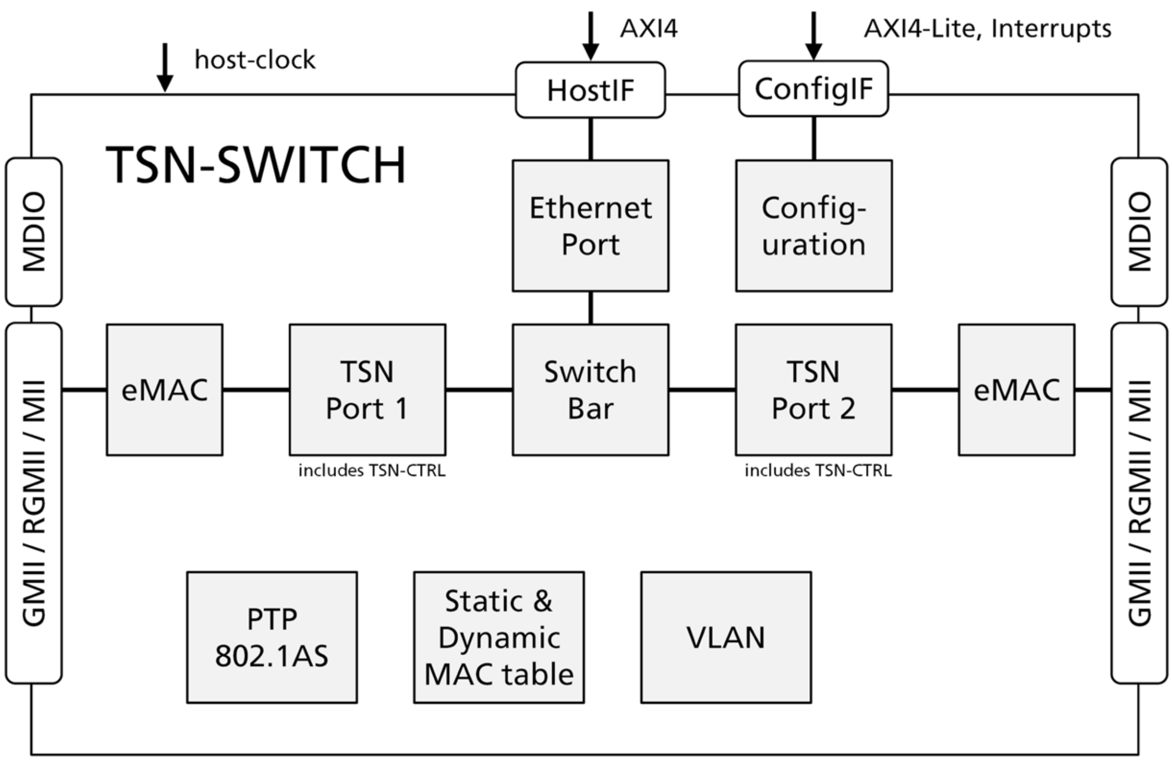


Fig. 4: Block diagram TSN-SE IP Core

ÜBER DAS FRAUNHOFER IPMS

Das Fraunhofer-Institut für Photonische Mikrosysteme IPMS steht für angewandte Forschung und Entwicklung in den Bereichen industrielle Fertigung, Medizintechnik und Verbesserung der Lebensqualität. Unsere Forschung konzentriert sich auf miniaturisierte Sensoren und Aktoren, integrierte Schaltungen, drahtlose und drahtgebundene Datenkommunikation und kundenspezifische MEMS-Systeme.

Das Fraunhofer IPMS verfügt über jahrelange Erfahrung im Entwurf und Design von IP-Cores zur automobilen Kommunikation und verfügt über eine Familie von TSN-IP-Cores. Weltweit nutzen viele Anwender die IP-Cores des Fraunhofer IPMS unter anderem in den Branchen Automotive, Aerospace und Automatisierung. Das multidisziplinäre IP-Designteam des Fraunhofer IPMS mit Fachwissen von Computerarchitekturen, Netzwerkstrukturen über RTL-Design bis hin zur Implementierung elektronischer Systeme steht auch als kompetenter Entwicklungspartner für anwendungsspezifische Anpassungen der IP-Cores sowie deren Integration in komplexe Netzwerkarchitekturen zur Verfügung.

Kontakt

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