TIME-SENSITIVE NETWORKING (TSN)

Rapidly growing networks and data volumes in the Industrial Internet of Things (IIoT) are pushing existing, often proprietary network protocols to their limits. As an open communication protocol, OPC UA enables completely continuous and transparent communication from the sensor to the cloud. By adding the real-time capability of TSN, the protocol enables IT and OT to merge into a common network and thus forms the basis for all applications in the IIoT.

The open and real-time-capable OPC UA over TSN protocol enables standards-compliant and manufacturer-independent networking of machines and systems via a unified protocol for real-time requirements in smart factories.

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AUTOMATION IN TRANSITION

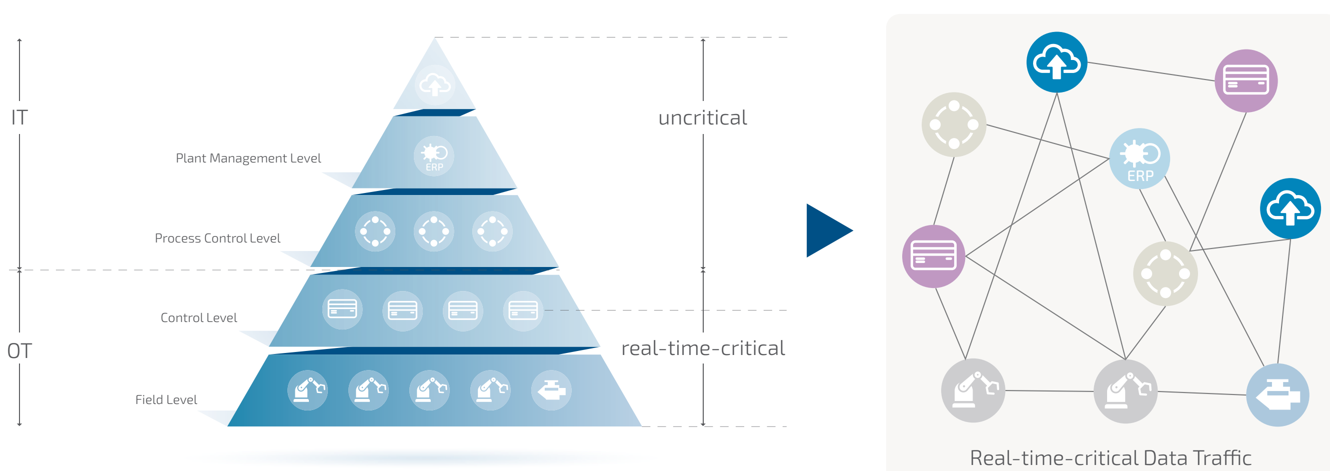
At the Hannover Messe 2011, no less than the 'fourth industrial revolution' was announced. In order to achieve the goals of Industry 4.0, production processes must adapt to changing requirements in an agile and dynamic manner. This makes it necessary for all parts of plant automation to communicate with other systems in the company on many levels.

Babylonian language confusion

The first computer networks were created to connect workstation computers in office environments. At the end of the 1980s, Ethernet became the de facto standard in this area. By the end of the 1990s, control manufacturers began to make Ethernet usable for industrial applications. However, the system developed for office environments first had to be made suitable for industrial use. Above all, some applications require determinable real-time behavior with isochronous cycle times of less than one millisecond.

Standard Ethernet does not meet these criteria, as it does not guarantee predictable time behavior under all circumstances. Therefore, for industrial applications, protocols had to be developed on top of the physical Ethernet layer to control the communication between the individual devices. Due to the different application focuses and philosophies of the developing companies, a plethora of different systems emerged under the common term Industrial Ethernet. These deviated from the Ethernet standard and were not compatible with each other. This led to frustration among component manufacturers, who had to create numerous variants for their products at great expense; and among users, who could not freely operate machines and devices of different provenance with each other.

The classic 'automation pyramid' has since become outdated and is increasingly being replaced by the flexible networking of intelligent devices in the OT area and the existing IT within the framework of Industry 4.0. This requires a manufacturer-neutral, unified and real-time-capable communication standard with high data transmission bandwidth and security.



COMMUNICATION NEEDS OF INDUSTRY 4.0

Fieldbus systems based on Ethernet enable the fast transmission of large amounts of data and thus very extensive information. For example, image and vibration data is meanwhile also being transmitted via the common network. Also, in today's modular system concepts, the safety-related data for personal protection are no longer transmitted on separate lines. They tunnel through the network as anonymous cross-traffic data packets using "black channel technology".

Today, computing power and memory are available in almost unlimited quantities and are no longer a decisive cost factor in mechanical and plant engineering. The computer architectures for decentralized installation in the field, including those in operating consoles and drive controllers, in the control room, the server room and in the cloud are essentially the same as in an office. This has broken down the former rigid division into control computers and "dumb" peripherals; even sensors and actuators with rather narrowly defined tasks are often equipped with their own processors.

CROSS-MANUFACTURER COMMUNICATION

A number of - often industry-specific - protocols have been developed with the goal of enabling cross-manufacturer communication between devices. Primarily for the exchange of information between medical devices and the overlying medical information systems in hospitals, the IEEE 11073 Service-oriented Device Connectivity (SDC) family of standards defines a communication protocol based on the paradigm of service-oriented architecture (SOA).

In the field of industrial automation, an industrial communication protocol has existed since 2006 in the form of Open Platform Communication Unified Architecture (OPC UA) according to IEC 62541, with which machine data can be described semantically in a machine-readable manner. OPC UA owes its high popularity and rapid spread, in addition to genuine manufacturer independence and inherent security, to an integrated introduction mechanism. This allows new and previously unknown devices to be brought into the network later without having to take them into account from the outset in the programming or configuration. This makes production plants future-proof, because it considerably reduces the effort for partial modernization. It is also an essential prerequisite for assembling production machines for Plug & Produce as easily as for office equipment with Plug & Play.

Overcoming previous compatibility deficiencies

However, OPC UA does not exhibit deterministic time behavior, so it is not suitable for the transmission of real-time data within synchronized plant sections. For data exchange between controllers, the OPC Foundation therefore introduced the fast communication model Publisher-Subscriber (Pub/Sub). The OPC UA Pub/Sub standard enables devices to make information available to all other communication participants in the network without first establishing a bidirectional communication path with the recipients. A publisher sends data for distribution to subscribers in the network. Already this continuous transmission, without waiting for replies from the recipients between individual messages, brings a considerable acceleration.

However, the ability for deterministic, hard real-time behavior only arises through a uniform time basis, as the IEEE (Institute of Electrical and Electronics Engineers) has defined it in the Ethernet standard Time Sensitive Networking (TSN). Ultimately, only the combination of OPC UA PubSub with TSN communication technology makes realizing real-time-capable applications in the industrial environment on the basis of generally available standards possible.

At the SPS IPC Drives 2018 trade fair in Nuremberg, the OPC Foundation presented 'OPC UA including TSN down to field level' as a universal, real-time communication platform. It thus laid the foundation for overcoming the previous compatibility deficiencies with a single, globally uniform standard.

WHAT CAN TSN DO?

TSN is an extension of the Ethernet standard with standardized real-time mechanisms. In combination with Gigabit switches, it allows deterministic data exchange. A whole bundle of standards regulates the transmission behavior of data packets in various ways (see table on page 6). With a multitude of improvements to the original IEEE 802.3 standard, TSN makes Ethernet real-time capable. For this purpose, it has three core capabilities whose interaction enables real-time communication using standard Ethernet components:

Time synchronisation

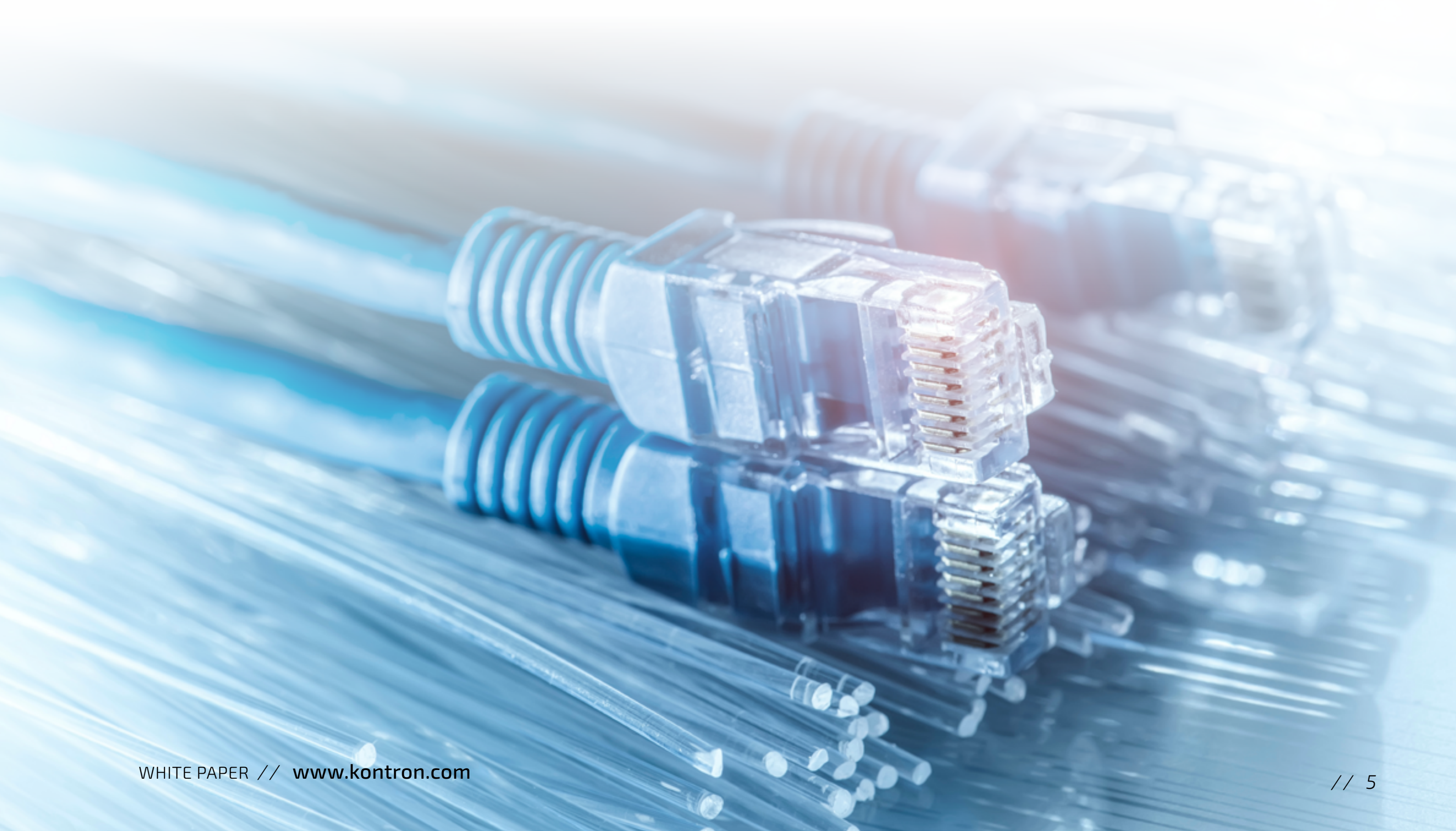
The basic prerequisite for the use of TSN in industrial real-time communication is time synchronization according to 802.1AS-2020. This TSN substandard contains definitions of the Precision Time Protocol (PTP) according to IEEE 1588-2008, which ensures that all device clocks in the network are synchronized. The deviation achieved in test setups is less than 100 nanoseconds.

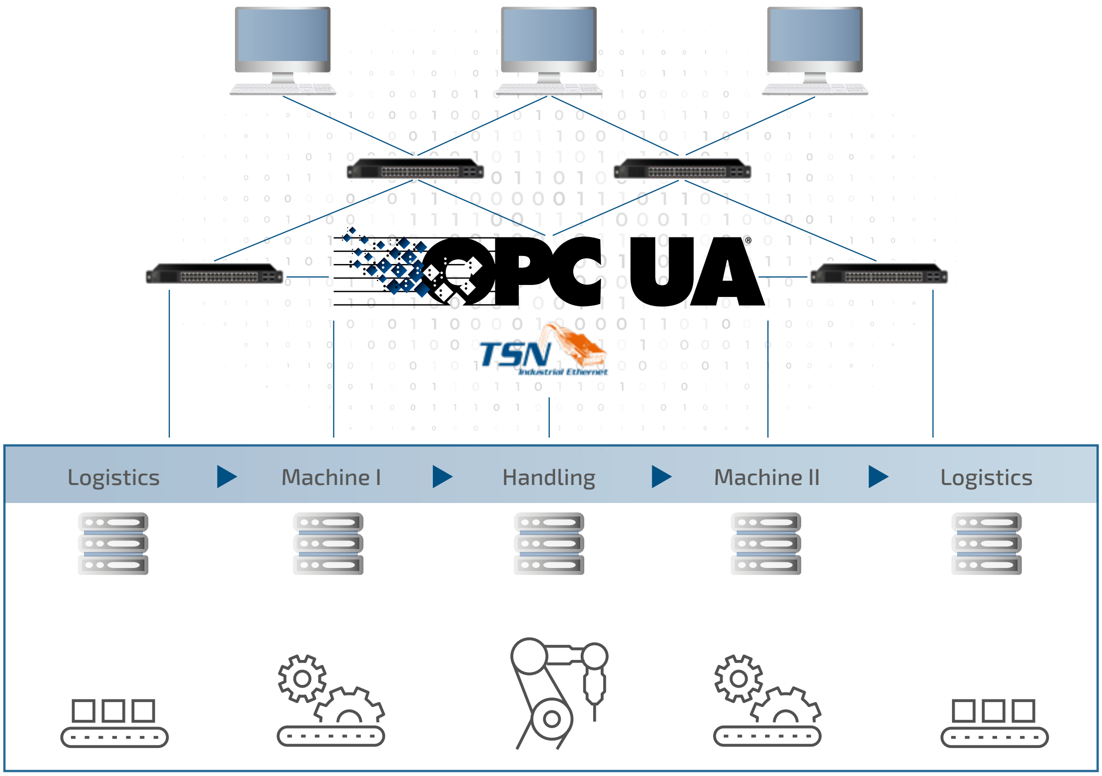
Traffic Scheduling

The second core capability of TSN is traffic scheduling, the targeted control of data packets/frames according to IEEE 802.1Qbv. A so-called time-aware scheduler ensures that time-critical data always has priority and is not slowed down by general data traffic. This ensures that even extremely time-critical synchronization processes - such as those between machine tools, tracking systems and robots - continue to function even when, for example, extensive image data is being transmitted; even in case the switches in the network are overloaded.

Dynamic configuration

The third core capability is the automated dynamic system configuration defined under IEEE 802.1Qcc. When a new device enters the network, it registers with the central network configurator (CNC). This establishes the communication relationship to the other devices with the reported requirements and configures the network accordingly.
Another standard, IEC/IEEE 60802, specifies TSN device protocols specifically for industrial automation.





// OPC UA over TSN as a manufacturer-neutral industrial communication standard enables full data continuity from the executive floor to the field level as a prerequisite for Industry 4.0.

OVERVIEW TSN STANDARDS

NORM	TITLE
IEEE 802.1AS-Rev	Timing and Synchronization for Time-Sensitive Applications
IEEE 802.1Qav	Forwarding and Queuing Enhancements for Time-Sensitive Streams
IEEE 802.1Qbu, IEEE 802.3br	Frame Preemption
IEEE 802.1Qbv	Enhancements for Scheduled Traffic
IEEE 802.1Qca	Path Control and Reservation
IEEE 802.1Qcc	Stream Reservation Protocol (SRP) Enhancements and Performance Improvements
IEEE 802.1Qci	Per-Stream Filtering and Policing
IEEE 802.1CB	Frame Replication Elimination for Reliability; Seamless Redundancy

TECHNICAL FEATURES TSN STARTER KIT

NORM	TITLE
SYSTEM	KBox C-102-2 industrial computer with PCIe-0400-TSN network card Realtime Linux + Tools
PROCESSOR	Intel® Core™ i5 processor: Quad-Core 1.9 GHz, 4 GByte RAM, 128 GByte SSD
TSN NETWORK CARD	PCIe, 4 Ethernet 10/100/1000Mbps ports
FPGA NETWORK CARD	Intel® Cyclone® V, field-upgradable
SWITCH OPERATION	Cut-Through, Store-and-Forward
SUPPORT	Linux Kernel device drivers, TSN software stacks
VERIFIED OS	Linux
RoHS COMPLIANT	yes

A NEW GLOBAL LANGUAGE

The manufacturer-independent communication solution OPC UA over TSN covers all essential applications that are currently carried out with the various Industrial Ethernet protocols. As a universal, real-time capable platform for completely universal and transparent communication from the sensor level to the cloud, it creates the prerequisites for the interoperability of all systems. This allows IT and OT networks to merge on a common, convergent communication and transport network for all applications in the IIoT.

The technology enables Plug & Produce-capable networks with several 10,000 nodes that can be easily administered and configured. The network participants can communicate much faster than with all previous protocols. Among other things, this opens up new possibilities in the area of highly synchronous drive applications and control tasks.

Secure and open

Networking machines with cloud-based server systems requires a high level of security. OPC UA over TSN offers the possibility of securing the network across manufacturers. For the secure and trustworthy exchange of data, digital certificates according to the X.509 standard can be used with OPC UA over TSN.

Since both OPC UA and the Ethernet extension TSN are managed and further developed by independent organizations, OPC UA over TSN is a completely manufacturer-independent protocol. Its software implementations are open source and are managed and tested by the Open Source Automation Development Lab (OSADL), among others. This means that system integrators and users are no longer dependent on individual suppliers for communication. They benefit from the participation of leading independent experts in the democratized development and quality assurance activities and the associated continuous improvement processes.

UNIFIED REAL-TIME STANDARD

TSN is rapidly gaining acceptance as a unified standard for real-time data communication. The integration of TSN functionality in semiconductors from numerous manufacturers is also contributing to this. These in turn enable suppliers of PC boards and devices to equip those with this technology at no extra cost. In addition, offers such as a Starter Kit for Time Sensitive Networking, which Kontron, the German leading manufacturer of embedded computing technology (ECT) launched on the market in April 2018 as an early TSN proponent, make it easier to get started.

The Kontron TSN Starter Kit enables the easy and quick configuration and monitoring of TSN networks. With a PCI Express® card and suitable software, IPCs can be retrofitted for TSN.
The Starter Kit's KBox C-series Box PC is based on current Intel® Core™ processor technology, while the TSN-enabled PCIe® card contains an Intel® FPGA device.

Since end devices without TSN capability can also be operated over TSN networks without any problems, it can be assumed that TSN functions will in the future be available in all Ethernet switch products and that Ethernet will thus eventually support real-time capability as standard.

CONCLUSION: ADVANTAGES & BENEFITS OF TSN AT A GLANCE

TSN offers numerous advantages compared to classic Ethernet:

- Extensive independence from the physical transmission layer, therefore also applicable via certain wireless connections such as 5G
- Guaranteed latency times of real-time critical data through the entire network
- Critical and non-critical traffic can be transmitted over a convergent network
- Higher protocol layers can share a common network infrastructure
- Real-time control can also be applied outside of the OT area
- No manufacturer dependency for communication systems

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S&T Group

About Kontron – Member of the S&T Group

Kontron is a global leader in IoT/Embedded Computing Technology (ECT). As part of the S&T technology group, Kontron offers individual solutions in the areas of Internet of Things (IoT) and Industry 4.0 through a combined portfolio of hardware, software and services. With its standard and customized products based on highly reliable state-of-the-art technologies, Kontron provides secure and innovative applications for a wide variety of industries. As a result, customers benefit from accelerated time-to-market, lower total cost of ownership, extended product lifecycles and the best fully integrated applications.

For more information, please visit: www.kontron.com

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From modular components to market-ready systems, Intel and the over 1,000 global member companies of the Intel® Partner Alliance provide scalable, interoperable solutions that accelerate deployment of intelligent devices and end-to-end analytics. Close collaboration with Intel and each other enables Alliance members to innovate with the latest IoT technologies, helping developers deliver first-in-market solutions.

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GLOBAL HEADQUARTERS

Kontron Europe GmbH

Gutenbergstraße 2
85737 Ismaning, Germany
Tel.: + 49 821 4086-0
Fax: + 49 821 4086-111
info@kontron.com

www.kontron.com