Questions and Answers to TSN

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1 Introduction

General

Ethernet is here to stay in industrial automation networks.
The uniform technical basis, the interoperability which goes with it and the
scalability brings a broad acceptance.
But in one application area, Ethernet could not force one’s way into: the network
communication with real time requirement.

Solution

Ethernet Time-Sensitive Networking (short: TSN) allows a time-controlled and
deterministic transfer of real time critical messages over standard hardware.
With TSN a new age in the industrial communication will be started.
In this document you find a collection of Questions and Answers on the topic of
TSN.
2 Questions and Answers

2.1 What is TSN?

Within the scope of IEEE 802.1, the standards association for Ethernet-based communication, the standard for "Time-Sensitive Networking" (TSN) is currently being defined.

TSN is made up of a series of individual standards, which mainly concern the data-link layer (Layer 2) of communication. Thus, TSN is not a complete communication protocol, but a basic technology, which can then be used by "higher value" applications.

2.2 What is the advantage of TSN over Ethernet today: Use cases?

Ethernet with TSN essentially expands the existing mechanisms of Ethernet by the topics of "Quality of Service" (e.g. bandwidth reservation), time synchronization, and low latency times and even seamless redundancy. The applications report their communication needs to the network and the network ensures the respective QoS. The respective connections then run in so-called streams, which then enjoy bandwidth protection via resource allocation in the memories of the switches.

In principle, real-time capability can be granted to any of these streams. Due to the encapsulated streams, it is also possible with TSN that several real-time capable protocols can be operated in parallel to one another in a single network. This is also called network convergence. This is fundamentally different from current Ethernet-based real-time protocols such as PROFINET, where the network only permits PROFINET as a single real-time capable protocol (in addition to TCP/IP-based traffic).
2.3 Classifying TSN in the ISO-OSI layer model

In the ISO-OSI model, TSN is limited to Layer 2 and will replace it in the future. Protocols such as PROFINET and OPC UA are located in Layers 5-7.

Figure 2-1

![ISO-OSI layer model diagram](image)

2.4 Will TSN require special Ethernet processors or will the current standard Ethernet components also function?

A "TSN-capable" hardware block is needed for TSN; the currently installed Ethernet blocks generally cannot be expanded to TSN via software. It is foreseeable, however, that the "standard Ethernet block" will be a TSN-capable Ethernet block in the future. That is the main motivating factor for Siemens to put PROFINET on TSN. All of the major block manufacturers have already begun to develop, or have at least announced that they will develop hardware blocks with TSN mechanisms. For device manufacturers, this results in many possibilities for the various hardware designs of their devices.

2.5 Will I need OPC UA and PROFINET in the future?

Yes, because the strengths of OPC UA lie in vertical communication and in the networking of machines on the control level, while PROFINET fulfills all of the requirements on the field level. Therefore, the strategy at Siemens is as follows:

Control level and higher ➔ OPC UA
Field level ➔ PROFINET
2.6 What is OPC UA?

OPC Unified Architecture (OPC UA) is the standard for exchanging data for secure, reliable, manufacturer and platform-independent industrial communication. It allows a cross-operating system exchange of data between products from various manufacturers. The strengths of OPC UA lie in its powerful, object-oriented information model, which can be remotely "browsed", as well as its service-oriented architecture (SoA) by providing many different services such as Data Access, Alarms & Conditions, Methods, Historian, etc. OPC A is therefore much more than "just" a protocol and is thus ideal for the exchange of data between applications from a wide variety of manufacturers in automation technology. OPC was defined for vertical communication, not for IO communication.

2.7 What is the difference between OPC and OPC UA?

The original OPC was based on the Microsoft Windows mechanism OLE (Object Linking and Embedding) with DCOM. OPC UA (Unified Architecture) was developed to be independent of Windows and is based on standard Ethernet mechanisms.

2.8 OPC UA: What is the difference between Client/Server and Publish/Subscribe?

Client/Server communication is a kind of point-to-point communication in which a client is given access to the data of a server.

Note:
Client/Server communication is always based on TCP/IP and can thus never be real-time capable.

With the Publish/Subscribe method, this involves "One-to-many" communication. One publisher provides data, which can then be received by any number of subscribers in the network. The PubSub communication can be fed in via various protocols (e.g. UDP), depending on performance requirements.
2.9 Which applications are implemented with OPC UA PubSub based on TSN?

OPC UA originated in vertical communication and is now becoming established in the market for M2M communication as well.
The need for real-time communication on the controller level should essentially be limited to controller/controller communication. For technical reasons, only the OPC UA PubSub method can be combined with TSN. Client/Server accesses naturally also run via the Ethernet-based network with TSN mechanisms (a so-called TSN network), but, since they are TCP/IP-based, cannot be mapped in real-time capable and bandwidth-protected streams.

2.10 Which applications are implemented with PROFINET based on TSN?

PROFINET's strengths are clearly on the field level. For the mid-term, PROFINET will be mapped to the TSN mechanisms and thus be 100% IEEE-conformant even for isochronous applications. Special ASICs such as ERTEC, Tiger etc. will then no longer be necessary.

2.11 Is TSN replacing PROFINET?

No.
Since PROFINET has relied on IEEE standards from the start, we also regard the TSN technology to be standardized in the IEEE as a sensible expansion of the Layer 2 of PROFINET.
PROFINET provides services required for automation, such as cyclic and acyclic data, alarms/diagnostics, parameterization, etc., which the IEEE mechanisms such as TSN cannot do on their own.
Thus, TSN is not a competitor of PROFINET but describes IEEE basic mechanisms, which can use communication protocols such as PROFINET or also OPC UA.
PROFINET will use the capabilities of a TSN network for itself and be able to benefit from it.

2.12 Will TSN replace PROFINET with IRT in the future?

TSN alone will never be able to replace PROFINET because TSN involves basic technology on which communication protocols can be based.
The PI is already working on using PROFINET, in addition to RT an IRT, also based on TSN.
TSN standardizes the real-time mechanisms on Layer 2, which, in the current Ethernet-based fieldbus systems such as PROFINET with IRT, have typically been resolved via special hardware. Protocols that run based on TSN will thus be able to run with hardware standardized via the IEEE in the future, even for isochronous applications.
In this way, PROFINET with TSN provides the advantages already known from PROFINET with IRT (chronological accuracy, reproducing, bandwidth reservation, diagnostics), but on the basis of standard hardware.
Of course, the RT and IRT mechanisms will remain a component of the PROFINET specification and will continue to benefit from PROFINET innovations.
By the way: PROFINET based on TSN does not just address the IRT applications (isochronous motion control applications), but also the application area addressed with RT.
2.13 How are the profiles (e.g. PROFIsafe, PROFIdrive, etc.) resolved via TSN?

Just as the Layer 7 services of PROFINET are not changed by TSN, the entire profile world of PROFINET is also not changed by TSN. In addition, failsafe M2M communication with OPC UA and PROFIsafe mechanisms is also being planned.

2.14 What is the difference between the ERTEC and a TSN-capable Ethernet block?

The ERTEC is an RT/IRT-capable ASIC for PROFINET devices developed by Siemens. It has been specially optimized for PROFINET-specific RT and IRT requirements. The ERTEC is currently installed in many Siemens products, such as the ET 200 family. There will be TSN blocks in various versions, both for controllers and for devices, and they will support the TSN mechanisms standardized by the IEEE. Intel, Marvell, Broadcom, TI, etc. will offer TSN-capable hardware blocks in the future.

2.15 What is behind IIC and LNI4.0?

Currently, there are two noteworthy test beds (scientific platform) for TSN, which are managed by 2 organizations: The IIC (Industrial Internet Consortium) and the LNI 4.0 (Labs Networks Industrie 4.0). Both have the goal to test interoperability between various TSN manufacturers at an early stage and, if need be, to influence the standardization committees using the knowledge gained. The most important representatives for the IIC TSN test bed are: Cisco, B&R, Bosch, Schneider, Belden, NI, etc. The most important representatives for the LNI 4.0 TSN test bed are Siemens, Huawei, Belden, B&R, Festo, Mitsubishi, etc. Both test beds concentrate on OPC UA based on TSN for the M2M communication.

2.16 What different approaches (central, distributed) are pursued by IIC and LNI4.0?

The main difference in the test beds mainly concerns the type of network configuration. The IIC is currently pursuing the central approach of the IEEE 802.1, in which each component must be individually configured via a central configuration tool.

The LNI currently pursues the distributed approach of the IEEE 802.1, in which the stream planning is distributed in the network via so-called stream reservation protocols. In particular, this approach pursues the goal of a plug&work–capable network.

For the mid-term, IIC and LNI are planning to couple the two test beds with one another to ensure interoperability between the different approaches.
2.17 What special requirements are placed on TSN with regard to security?

None. TSN has nothing to do with security at first. Both topics are to be considered independently in industrial communication.

2.18 Can a firewall be used in a TSN network?

Yes. TSN is located in Layer 2, and it is used to transfer protocols that are located on higher level layers.

2.19 Is TSN Layer 3-capable?

No. TSN is a collection of Layer 2 Ethernet services and is thus not routing-capable.

2.20 Are there special passive network components, such as a special cable, that are needed for TSN?

No, TSN and Standard Ethernet use the same bus architecture. Existing network cables can continue to be used.

2.21 Can TSN components be installed in an existing network?

TSN-capable bridges can be installed at any point in the network. However, a TSN-domain ends at a non-TSN-capable node. "TSN Traffic" can only take place via TSN-capable components.

2.22 Can today’s Ethernet components with appropriate firmware be made TSN-capable?

Ethernet components that meet certain hardware requirements (i.e. are “TSN-ready”) can be made TSN-capable via a firmware update.

2.23 What is meant by MQTT and AMQP? And what are the protocols needed for?

The terms MQTT and AMQP are frequently used in connection with Industry 4.0, digitalization, IIoT and TSN. Both MQTT (Message Queue Telemetry Transport) and AMQP (Advanced Message Queuing Protocol) are so-called transport protocols for the Cloud. Since the OPC UA information model is independent of the transport layer, these protocols can thus be used to also transport information about the OPC UA object model to the Cloud. Compared to AMQP, MQTT concentrates on slim stacks, especially for resource-saving devices. The strengths of AMQP lie in its reliability and interoperability. AMQP provides a comprehensive feature set for everything dealing with messaging, queuing, flexible routing, and security. Points are won for mechanisms, but not for performance and footprint. MQTT is currently supported by the Cloud providers IBM, QTC, SAP, GE, Amazon, Google, and Microsoft.
AMQP is currently only supported by Microsoft. Note: TSN is a Layer2 Ethernet network. AMQP and MQTT can therefore also be transferred in a TSN network, but, in their path in the direction of the Cloud (vertical communication) they may leave under certain circumstances the TSN network and use higher-level Layer 3-capable Ethernet networks.

### Glossary

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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AMQP</td>
<td>Advanced Message Queuing Protocol</td>
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<tr>
<td>IIC</td>
<td>Industrial Internet Consortium</td>
</tr>
<tr>
<td>IRT</td>
<td>Isochronous RealTime</td>
</tr>
<tr>
<td>LNI 4.0</td>
<td>Labs Network Industrie 4.0</td>
</tr>
<tr>
<td>MQTT</td>
<td>Message Queue Telemetry Transport</td>
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<tr>
<td>OPC</td>
<td>Openness Productivity Collaboration (previously: OLE for Process Control)</td>
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<tr>
<td>OPC UA</td>
<td>OPC Unified Architecture</td>
</tr>
<tr>
<td>QoS</td>
<td>Quality of Service</td>
</tr>
<tr>
<td>TAS</td>
<td>Time Aware Scheduling (802.1Qbv)</td>
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<tr>
<td>TSN</td>
<td>Time-Sensitive Networking</td>
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