TECHNICAL ARTICLE



# TSN in Automation: Where Are We Currently?

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These days, anyone working in industrial communications is bound to come up against the topic of time-sensitive networking (TSN). TSN will definitely come; the only thing that still has to be clarified is when and in what form it will come. However, even today the advantages of it for industrial communications are not always clear.

## History

Ethernet was introduced to offices in the early 1980s and quickly became very popular due to its high throughput of (at that time) a sensational 10 Mbps. However, this Ethernet was not practical for real-time applications because it used a common medium known as a party line. Collisions occurring at high utilization rates caused problems in office settings.

In the next step of its development, collisions were eliminated through the introduction of switched networks. Additionally, with quality of service (QoS), Ethernet datagram prioritization was introduced.

For industrial applications, guaranteed latency is particularly important. Despite QoS, standard Ethernet as used in offices can only guarantee latencies up to a certain point, especially with high network utilization.

There are several reasons for this, with the main ones being the store-and-forward strategy commonly used in commercial multiport switches and the fact that it is impossible to reserve bandwidth.

*Store and forward* means that a switch receives a complete datagram before forwarding it. This has advantages in terms of processing in the switch, but it also brings with it potential problems that can negatively impact latency and reliability:

- When going through a switch, a datagram is delayed by an amount depending on its length. If switches are cascaded, the effect is magnified.
- Because a switch does not have an infinite storage capacity, it can reject datagrams if the network is experiencing overutilization (too much traffic); this means that datagrams—even those given higher priority—can simply be lost.
- Long datagrams can block a port for relatively long times.

Switch cascading posed a challenge in industrial environments right from the start. Apart from the star topology used in the IT field, line, ring, and tree topologies are frequently used in automation. These adapted topologies significantly reduce Ethernet installation wiring requirements and costs. Hence, in industry, 2-port switches employing a cut-through strategy are integrated into field devices. *Cut-through* means that datagrams are forwarded before being completely received.

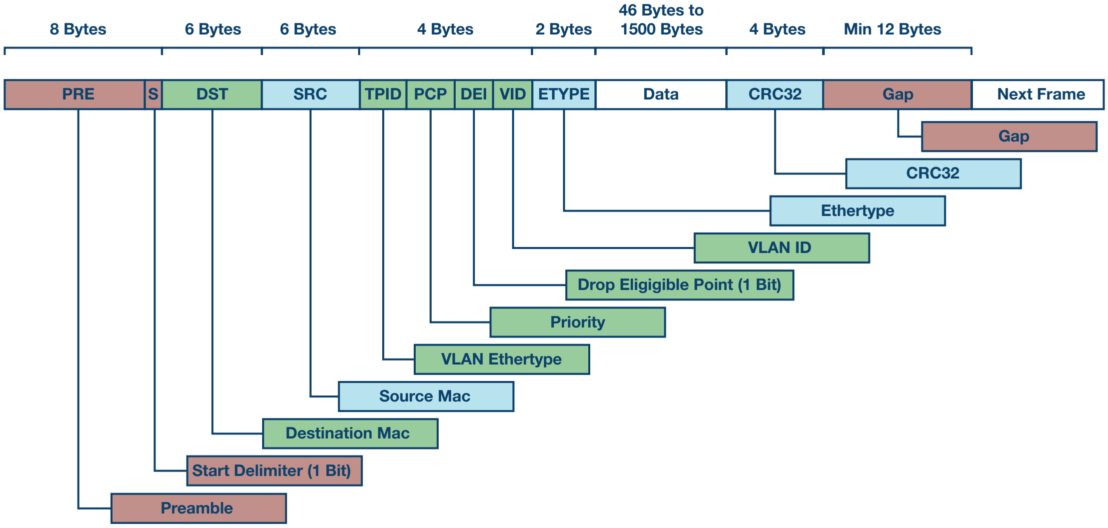


*Figure 1. Ethernet frame: Data fields relevant to TSN data flow identification are shown in green.*

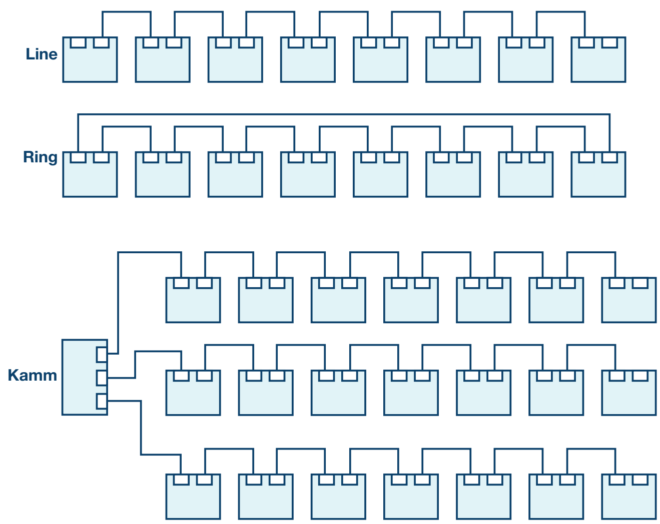


*Figure 2. Topologies.*

It must be guaranteed that there is always enough bandwidth (and buffer space) available for high priority datagrams. Standard Ethernet hasn't been able to provide that yet.

## One Size Fits It All: Industrial Ethernet up to Now

Because classic Ethernet did not have sufficient capabilities for bandwidth reservation, automation experts began developing their own Ethernet extensions in 2000. However, the paths they took differed greatly. Differentiation is made between the following approaches:

- Protocols using Ethernet as a transport medium for a fieldbus. These protocols claim complete control over the Ethernet medium for themselves. Classic TCP/IP communications are only possible in piggyback style via the fieldbus (EtherCAT® and POWERLINK®) or through a channel assigned by the fieldbus (Sercos). Bandwidth control is firmly in the hands of the fieldbus.
- Protocols that guarantee bandwidth reservation through a time slicing procedure on the Ethernet. PROFINET® IRT should be mentioned here. IRT enables hard deterministic real-time data transmission on the same cable on which soft real-time or background traffic is operated. A precise timing model for the transmission paths is necessary for planning of the time slices.
- Protocols based on sharing of the Ethernet cable. These protocols use QoS and are at home in factory and process automation applications. PROFINET RT and EtherNet/IP are noteworthy examples. These protocols are limited to the range of soft real time (cycle time ≥ 1 ms).

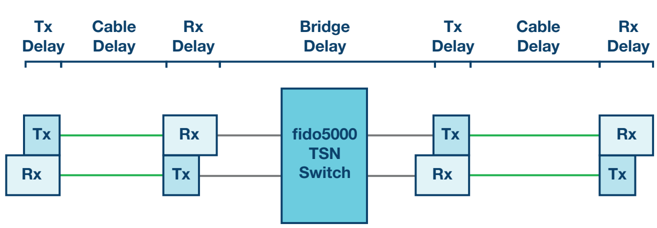


*Figure 3. Timing model: PHYs, cables, and switches contribute to delays in data transmission. This must be considered with the time slot method (PROFINET IRT and TSN time aware shaper (TAS)).*

For these standards, special hardware support and, thus, special ASICs are needed. Because PROFINET RT and EtherNet/IP® are also based on the embedded 2-port switch with cut-through, they are also not exempt here. Flexible hardware-based multiprotocol solutions such as Analog Devices' fido5000 solve the problem in an elegant manner.

## Enter TSN

With TSN, extensions for standard Ethernet in accordance with IEEE 802.1 that break free of past limitations have successfully been developed. Thus, there is now a standardized layer 2 in the ISO 7-layer model with upward compatibility to the previous Ethernet and hard real-time capability. With 802.1AS-rev, TSN also defines an interoperable, uniform method for synchronizing distributed clocks in the network. Because best effort communication always takes place with TSN, the common use of a cable is possible for hard real-time applications, as well as all other applications (web server, SSH, etc.). TSN is not dissimilar to PROFINET IRT in that regard, and it also offers comparable performance.

What's new with TSN is the need for more extensive network configuration. Centralized or decentralized configuration is possible. Both types of configuration are currently being discussed and implemented. Interoperability between the two configuration mechanisms is a future development goal.

## That's All Fine and Dandy, But What Are the Practical Advantages of TSN?

The most common answer is that with a larger market, less expensive network interfaces also appear on the market. After all, TSN will also be found in building automation and the automotive industry in the future. As a matter of fact, the market for embedded TSN solutions is expected to be significantly bigger than the current market for all industrial Ethernet solutions put together.

The greatest technical advantage of TSN over previous industrial Ethernet methods is its scalability. Unlike current industrial networks, TSN was not defined for a specific transmission rate. TSN can be used for 100 Mbps just as for 1 Gbps, 10 Mbps, or 5 Gbps.

It also enables topologies to be better optimized because now adapted data rates can be selected for various segments. Whether it's Gbps, 100 Mbps, or 10 Mbps, a unified layer 2—IEEE802.1/TSN—is used.

A uniform network infrastructure also helps personnel tasked with setting up and maintaining the network because, thanks to TSN, solutions can now be used in sectors other than automation: building, process, and factory automation and energy distribution alike.

This brings us to the next advantage, the training factor. TSN is already a topic at many universities, mostly in the research stage. However, technical and vocational colleges are already showing interest in this topic. We can fairly safely say that TSN will become basic knowledge for engineers, technicians, and skilled workers. Retraining for different fieldbuses will no longer be necessary.

## Brownfield, or What Will Happen to Today's Protocols?

In nearly all TSN-related working groups there is a recurring theme: how to safeguard the transition to TSN and the supply to existing installations, such as Brownfield applications?

On all sides, emphasis is being placed on making it possible for customers to transition to TSN easily and smoothly. It can already be said today that the existing industrial Ethernet protocols are not just going to vanish overnight. On the contrary, anyone using PROFINET, EtherNet/IP, EtherCAT, or a similarly widespread industrial Ethernet protocol today can safely assume that he or she will also be able to operate networks with these protocols—and receive support and replacement parts—in 10 years' time.

All industrial Ethernet organizations provide models that describe how existing plants can cooperate with new TSN-based devices. The interface to the existing industrial network is made by a gateway (Sercos), with a coupler (EtherCAT), or without any special hardware (PROFINET RT). Especially PROFINET and EtherNet/IP plan to make their complete protocols available right on TSN as layer 2.

This makes stepwise transition to TSN possible.

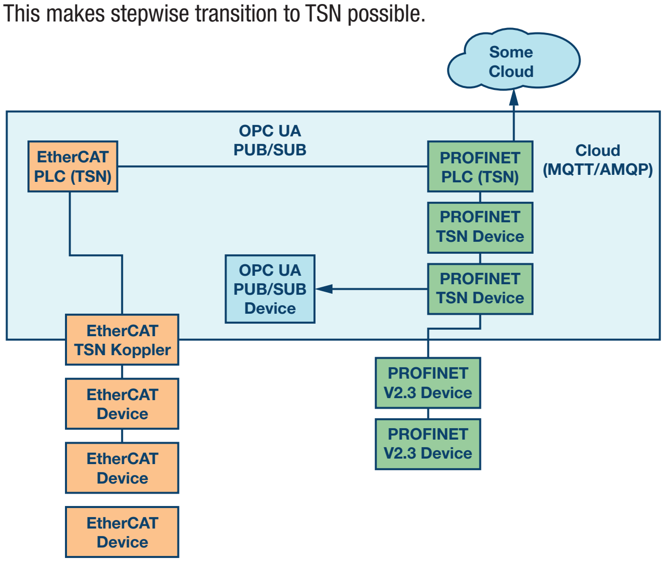


*Figure 4. Brownfield: TSN segment combined with PROFINET and EtherCAT.*

In summary, TSN will be found everywhere in new installations as well as in the form of islands or segments introduced incrementally into existing installations.

However, with TSN, there will be new players in the industrial Ethernet field. OPC UA, which, with the new transport protocol PUB/SUB, in conjunction with TSN, is already viewed as a competitor to the classic protocols. For the manufacturers of field devices, this means that the classic industrial Ethernet solutions as well as TSN and the new players will have to be supported.

## TSN and Analog Devices

Analog Devices acquired Innovasic, an industrial Ethernet leader, a little over one year ago and has now successfully integrated it. Along with Innovasic, the fido5000 series of industrial 2-port switches was incorporated into the Analog Devices portfolio. The switches in the fido5000 series support all relevant industrial Ethernet protocols and are already TSN ready.

With the fido5000, products that enable the transition to TSN and simultaneously meet today's requirements (PROFINET IRT, EtherCAT, POWERLINK, EtherNet/IP, etc.) can already be planned today. OPC UA PUB/SUB will also be possible with the fido5000. Thanks to the fido5000, TSN will become an update that can be planned for existing systems.

The fido5000 series is undergoing continuous enhancement for this. New products for Gb applications will be offered, but the 10 Mb/100 Mb products will also be continued and adapted to customer requirements.

Migration to TSN will be able to be performed reliably and efficiently thanks to the flexibility afforded by the fido5000 series.

## TSN as an Opportunity

TSN makes it possible to create a uniform basis for all industrial communications. Once TSN is introduced, layers 1, 2, and 3 of the ISO 7-layer model will be unified in industry. This will make completely new levels of scalability and performance possible.

Will communication on the upper layers also be standardized based on this? Will there be a unified OPC UA PUB/SUB? Possibly. With the fido5000 series, users are prepared for all scenarios.

## About the Author

Volker E. Goller is a systems applications engineer with Analog Devices and he has over 30 years of experience with a diverse set of industrial applications ranging from complex motion control and embedded sensors to time sensitive networking technology. A software developer by trade, Volker has developed a wide variety of communication protocols and stacks for wireless and wired applications while actively engaging in fielding new communication standards through his involvement in leading industry organizations. He can be reached at volker.goller@analog.com.

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