*Enabling the Road to TSN*

# Do I need Supporting TSN in my Equipment: Why, What and How?

## Why Time Sensitive Networking?

Since Ethernet was standardized in 1983, it has evolved both from the technical and from the application point-of-view as well. The original use for computer networks has been extended to be the de-facto Data Link protocol for field-buses in Industry (Profinet, Ethernet IP, Ethercat, Sercos III, etc.), Aerospace (AFDX), Energy (IEC 61850 over HSR/PRP), Automotive (Deterministic Ethernet) and Transportation.

Most of the applications in these critical sectors require Real-Time operation. This requirement makes it necessary to ensure the reception of specific data within a strict time interval, defined by the criticism of the process. The conventional application of Ethernet cannot ensure this deterministic operation. Therefore, during the last 30 years, the vendors of Industrial Communications solutions have implemented different protocols and enhancements for Ethernet. The result has been a plethora of non-interoperable Ethernet based alternatives.

The Industry 4.0 paradigm, based on the massive interconnection of Cyber Physical Systems combined with a Big Data analysis, has highlighted this well-known challenge of mixing Operational Technologies (OT) with Information Technologies (IT).

Therefore, a common Ethernet technology able to merge OT and IT worlds would be an outstanding forward step to really ensure interoperability and standardization. An effective development of these technologies shall offer a significant cost reduction in equipment, maintenance, seamless integration of advanced analysis services and a reduction of dependence on a single vendor.

Time Sensitive Networking (TSN) is a comprehensive proposal for an unique Ethernet based solution.

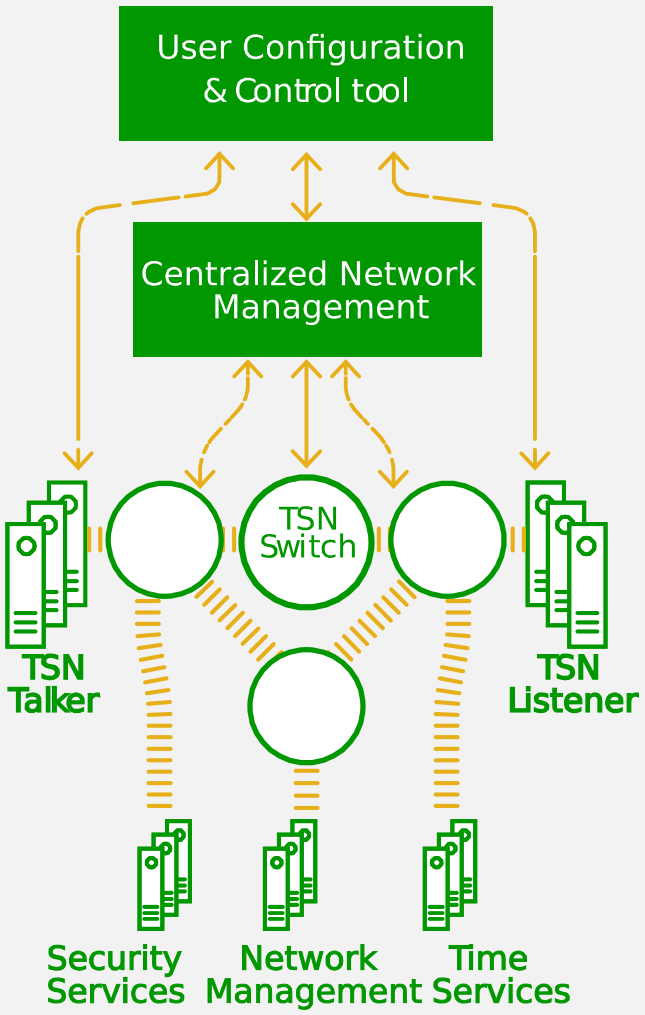
## What is Time Sensitive Networking?

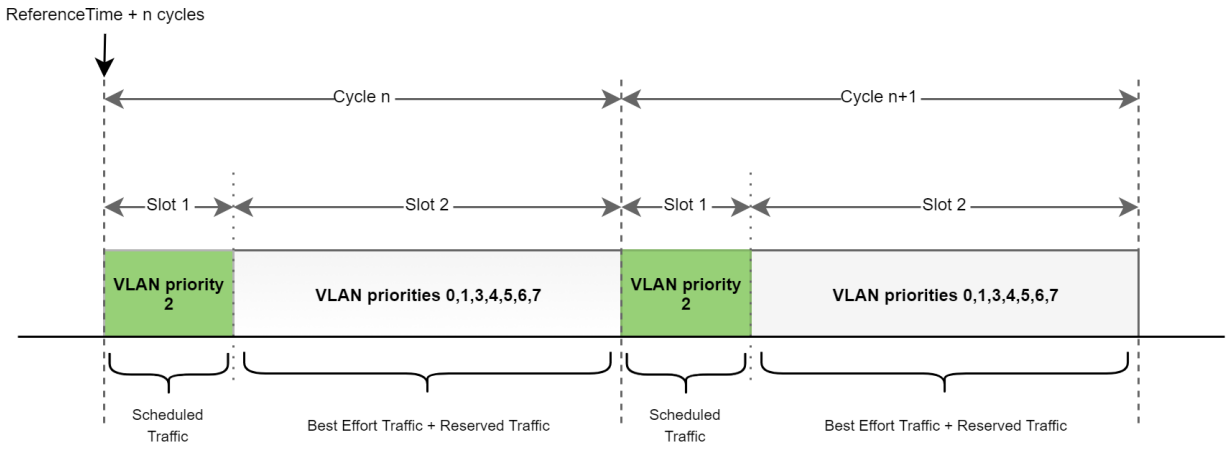
A significant success in merging critical and best effort traffic in a single media was achieved by Audio Video Bridging initiative. Indeed, some of their technical solutions were seen as valuable alternatives to other sectors.

As a result, the original AVB Working Group evolved to IEEE TSN Task Group, which is in charge of developing the standards related to TSN. These standards propose enhancements for IEEE 802.3 networks in order to define a unique Ethernet based solution for OT and IT.

The fundamental base in TSN is the Time-Aware Shaper. It is designed to separate the communication on the Ethernet network into fixed duration, periodic time cycles. These cycles are divided into time-slots according to the TSN configuration agreed between peers. The different time slots can be configured and can be assigned to one or several of the eight Ethernet priorities. The operation of the Time-Aware Shaper is defined in IEEE 802.1Qbv.

## TSN Network Topology






Taking into account this functionality, three basic traffic types are defined: Scheduled traffic, Best-effort Traffic, and Reserved Traffic. Scheduled Traffic type is appropriated for the hard real-time messages, Reserved Traffic for soft-real time ones and the Best-effort Traffic is the general Ethernet traffic that is not sensitive to any other Quality of Service metrics.

The Time Aware Shaper allows defining the number of time slots available in each cycle, their duration and which priorities can be transmitted. Thanks to this mode of operation, the Scheduled Traffic has dedicated time slots to ensure the expected deterministic behavioral. The best-effort traffic is accommodated in the remaining time-slots of each cycle of operation. An important improvement for the priorization and bandwidth use optimization in TSN is the support of Credit Based Shaper, as defined in IEEE 802.1Qav. This functionality allows the definition of the maximum fraction of the bandwidth that is available to a determined queue.

The technical challenge of providing nanosecond range synchronization accuracy among the TSN devices that compose the network is faced using IEEE 1588 synchronization protocol. Thanks to the accuracy provided by this technology, it is feasible ensuring controlled network delay and jitter implanting effective time-triggered Ethernet based solution. The specific IEEE 1588 profile for TSN is IEEE 1588ASrev.

The configuration plane of a TSN Network is one of the most active topics in the standardization (IEEE) and Industrial (IIC TSN Testbed Working Group) groups. TSN communications are based on a data streams set between a Talker and a Receiver. Based on the agreed parameters for each Stream, it is necessary to configure all the elements of the TSN network to switch the frames based on the selected parameters. This operation is performed by a Centralized Network Configuration (CNC) node. This CNC shall be able to talk to the equipment of different vendors in a standardized way. The early advances in this field are based on IEEE 802.1Qcc standard.

As it can be depicted from this introduction, TSN is not a *single* standard. Instead, it is a group of standards that are evolving at a different pace. Furthermore, many of them are still draft versions and probably, its evolution will depend on the real demand of these specific features from the market. The following list summarizes the most relevant standards involved in TSN: 802.1ASrev Timing and synchronization (currently, 802.1AS is used in most TSN implementations); 802.1Qbv Time-aware shaping; 802.1Qcc Stream Reservation Protocol Enhancements and Performance Improvements; 802.1Qci Per-stream filtering and policing; 802.1CB Redundancy; 802.1Qbu Frame pre-emption and 802.1Qch Cyclic queuing and forwarding.

## How could I introduce TSN in my equipment?

Attending the figures and information given by the Economic Analysts, The Time-Sensitive Networking (TSN) market is expected to be worth USD 606.0 Million by 2024, considering that it will get commercialized by 2019. This year, the first TSN capable end-equipment will be available in the Market, like CISCO IE-4000 or some National Instruments modules.

However, for any company that forecast introducing TSN in their equipment it is not enough having access to a third-party TSN switching equipment. It is necessary to introduce TSN technology inside the hardware and software of its own products, because they will have an active role in the network. This is a big challenge due to the diversity and complexity of the elements involved in the solution.

System-on-Chip engineering S.L. (SoC-e) is a leading technology provider for Time-aware Ethernet based solution implemented on FPGAs. Since 2010, SoC-e has licensed its IEEE 1588, HSR/PRP and GbE switch IP cores to more than 50 companies worldwide that now offer these technologies integrated in their new families of equipment. Thanks to this accumulated experience on time-aware critical systems, SoC-e has developed a comprehensive TSN solution thought to reduce the Time-to-Market and development risk to its customers.

SoC-e's TSN solution is called Multiport-TSN Switch (MTSN) IP and it has been designed to be implemented on Programmable SoCs. As an example, targeted devices are the Xilinx Zynq-7000 all programmable SoC and Zynq Ultrascale+ MPSoC. These powerful platforms offer combined hardware and software processing capabilities and they ensure upgradeability of the solution thanks to their reconfigurable nature. This last advantage is a key point for TSN implementations, taking into account that the standard is evolving, the ability to upgrade the equipment will be compulsory.

MTSN Switch IP can be implemented optimally depending on the application, from a simple 2-ports end-point to a complex multiport switch. The designer can select, among other parameters, the number of ports and memory distribution for the switch implemented in the FPGA section. This entire configuration is done graphically in Xilinx Vivado Tool.

The current release of MTSN Switch IP supports IEEE 1588 synchronization, 802.1Qbv allowing simultaneous support for scheduled traffic, credit-based shaper traffic and strict priority traffic. In order to offer the most flexible configuration schemes, MTSN supports direct configuration over its own Web Interface (see Figure) and 802.1Qcc configuration over RESTCONF/YANG.

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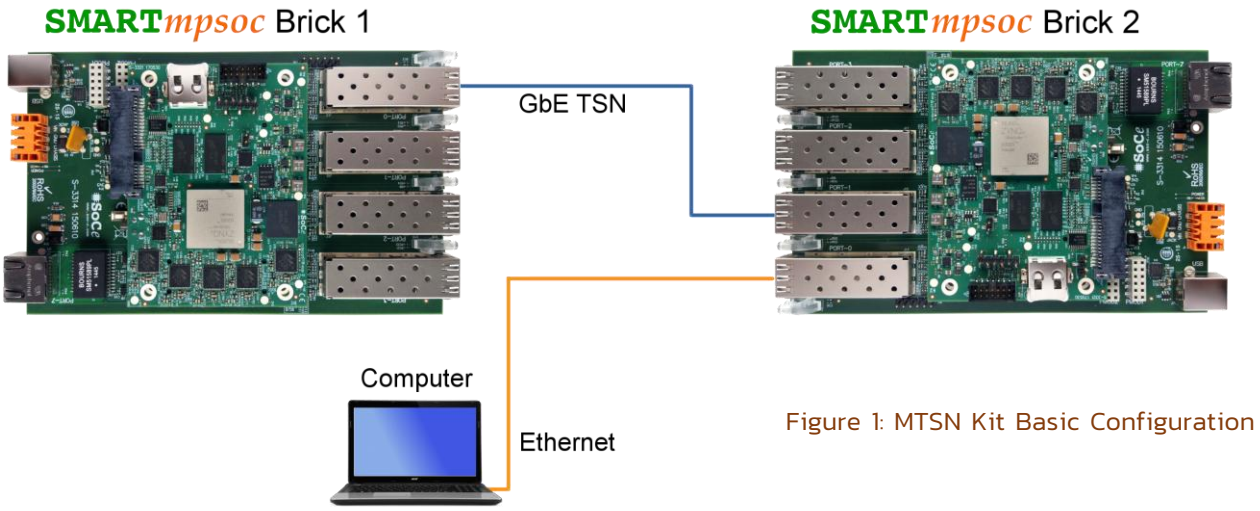



Figure 1: MTSN Kit Basic Configuration

MTSN Switch IP can be evaluated using the MTSN Kit. This kit has been designed not only to test the MTSN Switch IP, but to support an advanced hands-on TSN. There are two version of the Kit available, one based on Xilinx Zynq-7000 SoC and another based on Zynq Ultrascale+ MPSoC

Figure 1 depicts the basic interconnection of MTSN Kit: Two SMARTmpsoc or SMARTzynq Bricks boards, two interconnection cables and two power supplies. Each of the boards provides 4 external ports able to allocate copper and fiber SFP modules and an additional cooper only Ethernet service port.

The block diagram of the design implemented on MTSN Switch IP Kit (MPSoC version) is shown in Figure 2. The main elements included in this design are:

**PS Section**: Processing System section of the SoC.

**PL Section:** Programmable Logic section of the SoC.

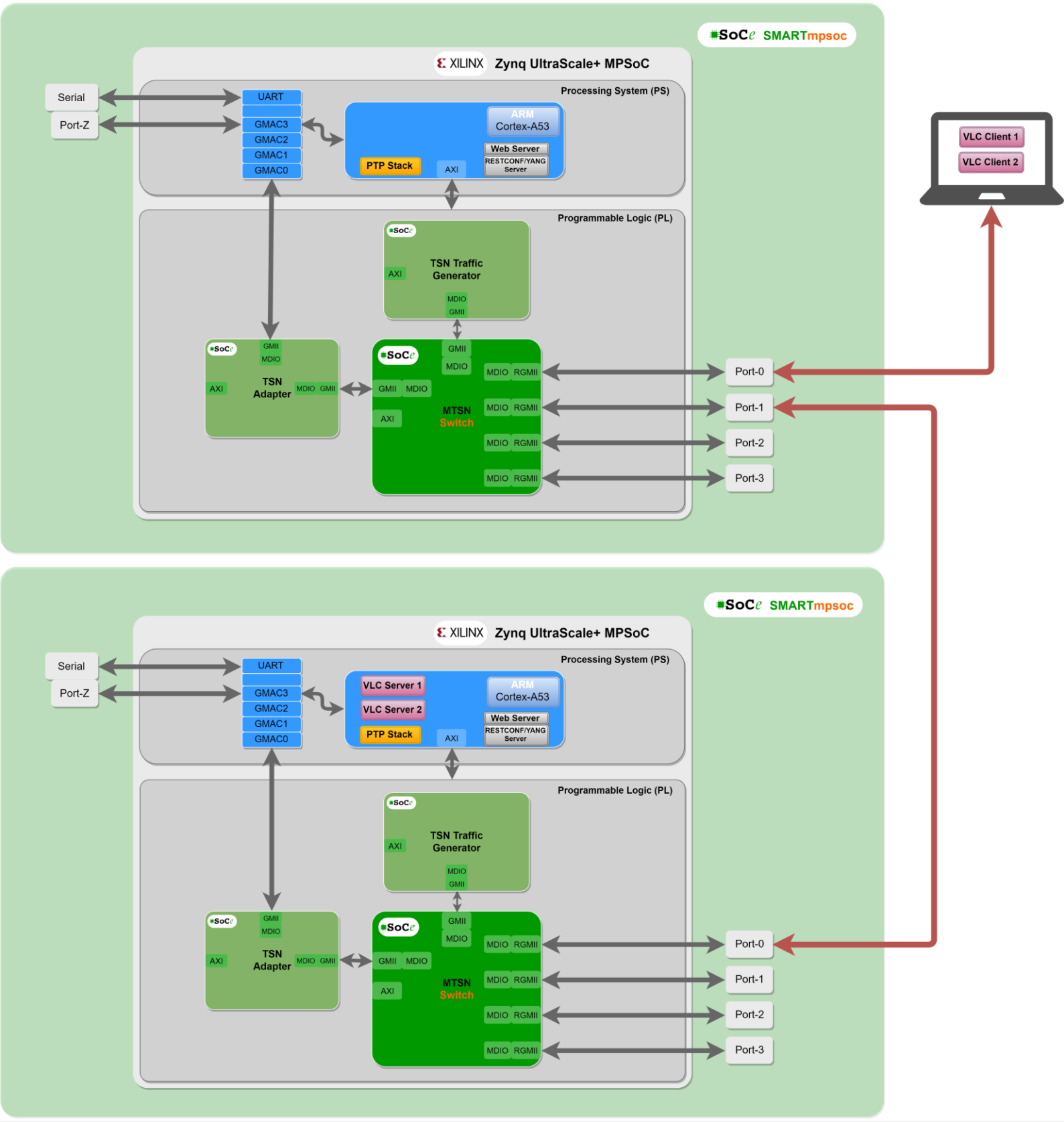
**TSN Traffic Generator:** HDL Block able to generate different class Ethernet Traffic with controlled throughput. Additionally, it integrates a Time Aware Shaper for scheduling the conventional Ethernet traffic generated by the traffic generator block.

**TSN Adapter:** HDL Block in charge of implementing the Time Aware Shaper for scheduling the conventional Ethernet traffic managed by the standard regular Ethernet MAC of the Processor Section of the SoC.

**MTSN Switch IP:** Six-ports TSN switch. These ports are distributed as two internal and four external ports

Thanks to this flexible design implemented in both boards, the user can run a full TSN set-up comprised by end-points, switches and from the application point of view, Talkers and Listeners. The guided tests explained in the Kit documentation are valid for Time and Credit shaper verification, synchronization verification, traffic generator configuration, Wireshark IO Graph operation and for visual inspection of the effect of different network configurations using a combined video streaming application.

Figure 2: MTSN Kit Block Diagram



## Conclusions

TSN offers network convergence and will enable effective implementations of Industrial Internet-of-the-Things set-ups. Several important companies are pushing the development of solutions and the development of the standards.

However, realistic TSN networks will require TSN-aware equipment from all vendors. SoC-e proposes a accessible and complete approach to all the manufactures who want to offer in their equipment TSN capabilities and decide to catch this unbroken wave.

## References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MTSN Kit: http://soc-e.com/mtsn-kit-a-comprehensive-multiport-tsn-setup/

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