WHITEPAPER

TIME SENSITIVE NETWORKING AND IT'S PRACTICAL IMPLEMENTATION IN FACTORY AUTOMATION

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In 1980s, Ethernet was a popular technology connecting LANs in offices with a very high throughput about 10Mbps at that point of time. But Ethernet was not preferred for real time applications due to Collisions. Later on, switched networks were introduced to reduce collisions and provide additional Quality of Service (QoS) with the introduction of Ethernet Datagram Prioritization. But this network was unable to meet the latency requirements of real time industry environments, due to the store and forward nature and a greater number of nodes involved. The most important problem to be solved was to provide a deterministic communication in automation segment were most of the nodes operate in a time synchronized manner. This need to incorporate a real time deterministic, time bound network lead to introduction of variations in Industrial Ethernet like Fieldbus, Modbus, EtherCAT, PROFINET, Sercos and Etherner PowerLink. These protocols were applied to different ecosystems though they shared a common requirement for implementation. These protocols were mostly proprietary and the stake holders were bound to use all the components of their industrial network from the same manufacturer (Vendor dependence).

To address the problems on unstandardized protocols and to make industrial automation architectures more flexible and seamless, IEEE 802.1 working group proposed Time-Sensitive Networking (TSN) to define a standard for transmission of time sensitive data over Ethernet fulfilling the requirements of industrial applications, without vendor dependence. TSN converges the Information transfer and Operations part of the industrial network, which enables connecting both deterministic traffic and best effort traffic in a shared network. TSN enables the collaboration of different layers of industrial systems with various levels of bandwidth, QoS and time delay. TSN has been implemented in the Data Link Layer or Layer-2 of the OSI model. The Data link Layer is enhanced to deal with transmission errors, interface network layer and also regulating flow of data.

TSN Components and Common Standards

The charter of the TSN Task Group is to provide deterministic services through IEEE 802 networks, i.e., guaranteed packet transport with bounded latency, low packet delay variation, and low packet loss. The TSN TG has been evolved from the former IEEE 802.1 Audio Video Bridging (AVB) TG.

Base Standards of TSN:

IEEE Standard	Feature
802.1AS	Time Synchronization
802.1Qbv	Scheduled Traffic
802.1QC	Seamless Redundancy
802.1 Qcc	Stream Reservation Protocol
802.1Qbu	Frame Preemption
802.1 CB	Frame replication and elimination
802.1Qci	Filtering and Policing
802.1Qca	Path Control and Reservation
802.1Qch	Cyclic Queuing and Forwarding
802.1Qcr	Traffic Shaping
802.1Qcp	YANG Model for Bridging
802.1Qcw	YANG Model for Qbv, Qbu, Qci
802.1CBcv	YANG Model for CB

IEC/IEEE 60802 TSN Profile for Industrial Automation is a joint project of IEC SC65C/MT9 and IEEE 802 to define TSN profiles for industrial automation. TSN standards are upcoming and some of the standards already included as a part of TSN provides Time Synchronization, Traffic Scheduling, pre-emption, prioritization and provides a deterministic service with bounded low latency, ultra-reliability, explicit routing, Configuration and resource reservation. The system architecture of TSN is defined by IEEE 802.1Qat and IEEE802.1Qcc standards.

The components involved in a TSN may vary depending on the application and complexity of network, but the basic components include a CNC, a CUC, Bridges and End Devices. TSN can be implemented in industrial devices as a combination of the switched endpoints and switches and requires associated software.

TSN for Factory Automation

With the introduction of TSN, it is possible to create a system with multiple IOT use cases, hyper connected end devices, grids, sensors, control systems and transportation systems. TSN significantly improves the productivity of a factory in terms of quality, maintenance and monitoring. Industrial Automation applications can process the information in a time bound manner with less latency.

Motion Control applications like manufacturing and processing industries, power industry and packaging industries use PLC Controllers which require deterministic delay requirements are enhanced by TSN resulting in a higher productivity or more workload process.

In factory automation most of the processes are automated by replacing a human by a robot. Different types of robots used are fixed robots like Robotic Arms, Mobile robots like Automatic Guided Vehicles, Collaborative Robots like Pick and Place Robots. In most of the robots, we use two different channels for communication. One channel is used for real time control and another channel for high bandwidth data sharing generated due to advanced technology like Machine Vision, Artificial Intelligence and various sensors. TSN is able to provide a common channel for both these functions and handles the traffic with ease.

Power and Energy applications in production environments require exchange of large amount of timely data to control and monitor switch yard, record data and protect power equipment through continuous monitoring.

TSN enables the timely and robust communication in these environments by allowing higher layer protocols and cloud-based services for end users. TSN is known to provide a reliable, robust and broadband closed loop communication in harsh and critical environments like medical, oil and gas and power plants. TSN enables the machine to machine communication of vendor dependent machines. It is done by a network of TSN machines or end points connected through TSN switches. This makes the process of remote operation of machines easier and coordinating supervisory PLC communications possible.

TSN adds real-time capabilities to standard IEEE Ethernet and also that of the specialized industrial field buses (also called industrial Ethernet). TSN is compatible with the existing protocols and works unmodified with protocols like TCP, HTTP and PROFINET. In some systems, it may require an application programming interface and software architecture with a buffering mechanism, which is slowly evolving too. New TSN hardware and gateway functions may be introduced for Industrial Communication to bridge the existing protocols. Major Industrial Ethernet organizations are shifting to TSN technology and integrating it into existing systems and applications. TSN will be a promising technology for real time connectivity with a high transmission rate upto 5 Gbps and introduction of 5G networks.