The Avnu Alliance Theory of Operation for TSN-enabled Industrial Systems

By Eric Gardiner, National Instruments, Avnu Alliance Industrial Segment

As awareness surrounding IoT standardization continues to grow, so does the necessity of enabling interoperability for distributed measurement and control solutions. The IEEE's Time-Sensitive Networking (TSN) task group produces a set of standards for standard Ethernet for interoperability at the network level, to create a foundation for more advanced manufacturing and product models for time synchronization and low-latency communication mechanisms where data can be shared predictably and flexibly.

Standard Ethernet has evolved to enable next-generation control systems, with the ability to operate time-sensitive systems to support diverse applications and markets including industrial. The IEEE 802.1 Time-Sensitive Networking (TSN) task group drives standards for and defines new mechanisms for creating distributed, synchronized, real-time systems using standard Ethernet technologies that will allow convergence of low latency control traffic and best effort traffic on the same network.

Avnu Alliance, the industry consortium driving open, standards-based deterministic networking, promotes interoperable use of a shared TSN-enabled network by selecting and certifying a set of underlying mechanisms to meet the market's requirements so that a common, TSN-enabled network foundation can be shared by multiple industry group or vendor applications and protocols. Avnu and its members created "Theory of Operation for TSN-enabled Systems Applied to Industrial Markets," a best practices document offering system architecture and implementation requirements for creating TSN-enabled systems and applications for two industrial applications of TSN that share a common need for distributed sensing, logic, and actuation. It describes the requirements for machine control and process automation, presents a TSN-enabled system architecture on which these applications can be built and explains the role of TSN, and describes implementation considerations for each component in the architecture.

TSN Fundamentals

Avnu's TSN architecture for industrial systems is crucial for distributed industrial control applications to facilitate event coordination and data correlation and focuses on three classes of mechanisms: time synchronization, quality of service, and network configuration. Using mechanisms defined in the IEEE 802.1AS-2011, a profile of IEEE 1588, on standard Ethernet networks, industrial controllers can establish and maintain tight time synchronization, periodically exchange synchronization information over a network, and adjust their local timing sources to match each other.

Quality of service is necessary for proper operation of time-sensitive systems, especially in the presence of same-priority or best-effort traffic, since a bridged network connecting industrial controllers with sensors and actuators must ensure that high-priority traffic can predictably meet bandwidth and latency requirements. Using mechanisms defined in IEEE 802.1Qbv, a bridged network can schedule traffic such that high priority communication is guaranteed, with the lowest possible latency, even in the presence of best-effort traffic.

TSN systems require dynamic configuration based on application requirements. Using network configuration enhancements defined in IEEE 802.1Qcc and borrowing concepts from Software Defined Networking (SDN), bridges and end stations, TSN-enabled industrial systems can be configured to take advantage of intelligence found in a centralized network controller, without adding significant cost or complexity.

Industrial Automation

In the industrial process control use case, four machine sections comprise a single machine; the end user has seven manufacturing sites around the world, each with 15 machines per site. Different OEMs each deliver a section of machinery for the process it controls, which are synchronized and coordinated to create a final product. TSN-enabled switches support concurrent or translation between multiple IEEE 1588 time synchronization profiles to provide a migration path for existing products and technologies to be included in the wider TSN value proposition.

Machine Control

Companies creating industrial machinery used for fabrication, assembly, and testing depend on free-flowing data both within the machine and between machines. To meet the stability and reliability requirements of the high-speed motion control subsystem within a modern machine, a network needs to consistently deliver the control packets between the drives/sensors and the controller with a latency of <100 μs, and the motion axes require time synchronization between the nodes of <1 μs. With TSN, machine builders can offer convergence, performance, and cost optimizations when compared to existing solutions. Without it, achieving these performance requirements with standard, shared Ethernet requires a high level of technical competence and can result in prescriptive network architectures.

For industrial markets, TSN and related standards support the ability to simplify development and deployment of distributed, synchronized control systems commonly found in a variety of industrial applications including machine control, factory automation, power generation and distribution, oil and gas exploration, etc. The real potential for IoT is a foundational common network infrastructure. With open standards, manufacturers are not reliant upon one company and their proprietary technology. Avnu Alliance defines the technical foundation and certifies for interoperability. TSN allows all vendors in the industrial space to build on top of the common foundation.

The Theory of Operations is continuously being updated by Avnu Alliance members to include additional technologies in support of a broader set of applications and markets. The full Theory of Operations document is available from Avnu Alliance by linking to http://avnu.org/knowledgebase/theory-of-operation/