Ethernet and OPC UA TSN for Automation Architectures of the Future

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Category: ARC Report Abstract

For years, the industrial world developed many of its own technologies, or reluctantly accepted proven “commercial” technologies, often with

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modifications. Today’s industrial companies feel the influence of commercial information technologies (IT) stronger than ever, driven by initiatives like Industrie 4.0 and the Industrial Internet of Things (IIoT). Industrial networking is no exception. As industrial devices become more intelligent and better connected, the

amount of data they share grows exponentially. To meet these growing demands, industrial Ethernet is evolving to support automation architectures of the future.

ARC Advisory Group has been keenly observing developments in this space. Key observations to date include:

- In pursuit of achieving visions like Industrie 4.0, the amount of data generated at the machine level is growing exponentially. To meet new data communication and connectivity requirements, new network architectures will be necessary.
- OPC UA TSN is emerging as an excellent solution for real-time, vendor-neutral Ethernet communication for the industrial manufacturing sectors. This solution addresses real-time functionality and data communication requirements for both production machinery and process equipment.
- Implementation of OPC UA TSN in machine control will take time, but current familiarity with Ethernet-based networks in industrial applications will hasten acceptance. Migration strategies will play a key role.

Drivers for a New Automation Infrastructure

Analytics, Big Data, artificial intelligence, machine learning, edge computing, and distributed intelligence technologies are driving developments in the manufacturing and process industries today. To realize these, manufacturers need a new infrastructure that meets new demands for bandwidth, speed, and connectivity.

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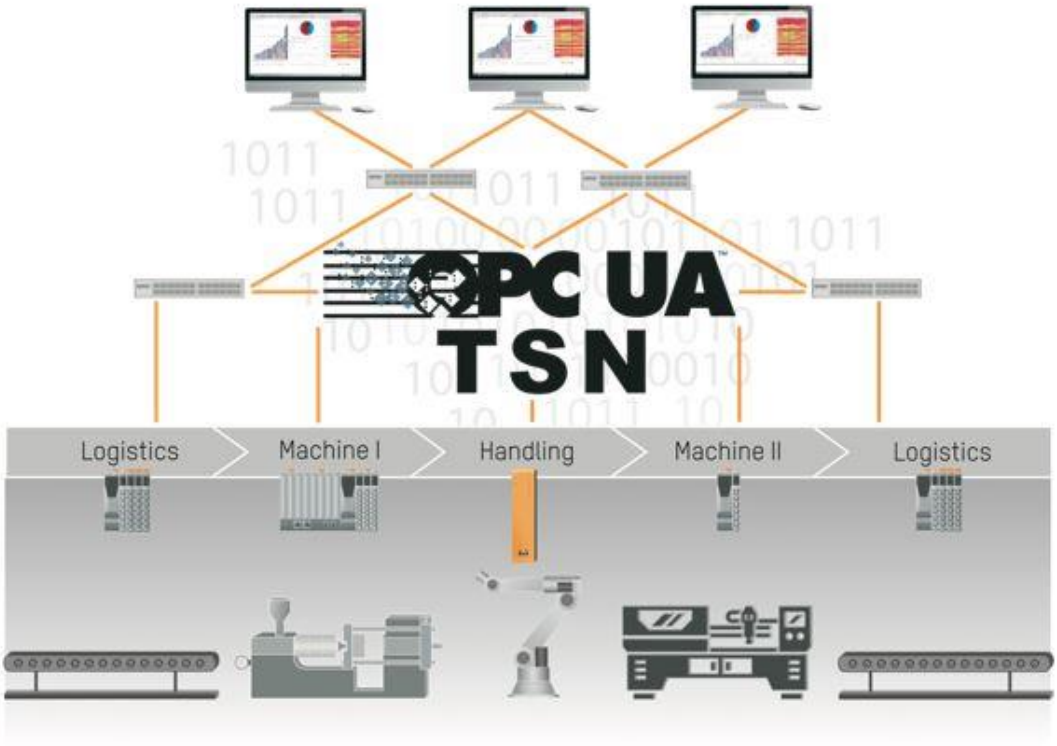
In the spirit of Industrie 4.0, machine builders are adding new smart sensors to extract data from devices and share it with other devices, systems, and applications, with the goal of adding flexibility, enhancing performance and efficiency, and improving machine uptime. Such IIoT-enabled devices in the future will send not only input and output data and diagnostic information, but also information about their own capabilities, as well as detailed information about the machine, equipment or sub-assembly of which they are a part.

Current architectures that use a combination of standard Ethernet and industrial Ethernet appear to lack both the performance and capacity required to keep up with the growing demands. Developments in industrial Ethernet thus far have focused mainly on meeting specific application requirements, such as high-speed deterministic behavior when coordinating multiple servo axes. What is needed is a “big picture” solution that replaces the current patchwork of incompatible and adapted networking solutions with a universal IT-enabled network that addresses the specific demands of users in all industries, from discrete to process.

Looking Beyond Industrial Ethernet

The industrial world waited for years to adopt Ethernet-based networking, long after Ethernet had become a defacto standard in office environments. The main reason for the delay was the fact that Ethernet didn't meet industrial requirements for deterministic behavior. To remedy this situation, several automation suppliers set out on their own and created modified versions of Ethernet. The result was about a half dozen different versions of what came to be called "industrial Ethernet." The problem was that modifications were never made with the cooperation of IEEE, so they never became part of the underlying Ethernet specifications. Instead, the various industrial Ethernets were overseen by industrial consortia made up of automation suppliers. However, this situation is about to change.



Publish-subscribe Model Allows a Server to "Publish" Data to a Network of Multiple Clients (Source: B&R)

Thanks to developments driven by the OPC Foundation, the question of real-time behavior on Ethernet is being addressed on two fronts: 1) the introduction of a publish-subscribe model for OPC Unified Architecture (OPC UA), and 2) the implementation of the IEEE 802.1 standards for time-sensitive networking (TSN) that add deterministic behavior to standard Ethernet. The result currently goes under the working name, "OPC UA TSN."

What Is OPC UA TSN?

OPC UA is a vendor-independent communication protocol developed by the OPC Foundation for industrial use. Designed initially to bridge the communications gap between devices from different vendors, OPC UA has evolved over two decades into a truly universal, open and vendor-independent communications protocol. Time-sensitive networking (TSN) is an extension of the IEEE 802.1 standards that adds deterministic behavior to Ethernet. Together,

this combination offers the first truly vendor-independent, real-time, deterministic Ethernet standard.

> OPC UA has the potential to become as ubiquitous as the IP-based technologies that connect devices around the world via the internet. When technologies like these "just work", users can focus 100 percent of their energy on the application without worrying about technical details.

With OPC UA, users can take advantage of OPC's data model and services that provide semantic interoperability. This enables clients and servers to exchange data with an agreed and shared meaning, rather than just mapping bits and bytes. In addition to the data model, rules describe how to transform every physical system into a model that can be represented in an OPC UA server.

TSN processes information on Ethernet more efficiently and therefore faster. It can schedule frames from multiple nodes so that they are received as a chain, thus maximizing available network performance. The technology uses cut-through switching where a switch starts forwarding a frame as soon as the destination address is processed, sometimes before the whole frame has been received. It also allows the use of "store and forward," a technique that stores information in an intermediate station from which it can be sent at a later time to the final destination. By supporting these functionalities, TSN addresses the requirements of a wide variety of applications, ranging from servo axes in a line topology to large-scale mesh networks.

Frequently Asked Questions

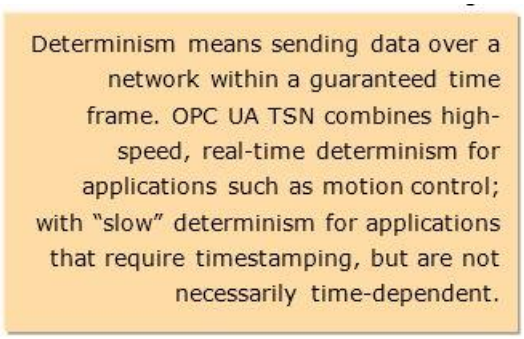
OPC UA TSN is a compelling new technology full of ramifications for industrial networking. The next section addresses typical questions from industry stakeholders.

- Will OPC UA TSN add features or just duplicate existing industrial Ethernet functionality?

  OPC UA TSN is more than just another version of industrial Ethernet. The technology addresses new challenges such as the growing number of connected industrial devices as well as the exponentially growing volume of data that will be exchanged. OPC UA TSN adds deterministic behavior, but also a number of new networking features, including time synchronization, ingress policing, seamless redundancy, frame preemption, scheduled traffic and stream reservation.

  While some versions of industrial Ethernet are restricted to speeds of up to 100 Mbps, OPC UA TSN on standard Ethernet will enable gigabit Ethernet with greater bandwidth. Also, IEEE-standard technology will make it easier to users to upgrade to higher speeds and capacities in the future as the technology is further developed.

- Acceptance of industrial Ethernet among users has been growing steadily. Is OPC UA TSN compatible with the installed base of industrial Ethernet devices?



Because it is part of the IEEE 802.1 specification, TSN can be viewed as an enhancement to existing industrial Ethernet networks if they support standard Ethernet (not all do). TSN extends the Ethernet standard, so its functionality will be available in all Ethernet components in the future. Existing components that don't support TSN can still be integrated in a TSN network, but network segments that require deterministic behavior must consist of TSN components.

- Will OPC UA TSN make existing versions of industrial Ethernet obsolete?

  The key to the future success of OPC UA TSN will be how it supports the existing installed base of industrial Ethernet. Users would be reluctant to or refuse to implement a new network if it only adds complexity to existing architectures and forces users to support multiple networks in the future. The most likely scenario is that the industrial Ethernet consortia will adapt their networks to support OPC UA TSN while preserving existing functionality and compatibility with their installed base. Industrial assets have long lifecycles, so a full transition to OPC UA TSN will take decades.

  Industrial Ethernet solutions like Powerlink, SERCOS, and EtherCAT are designed as embedded fieldbuses rather than all-purpose networks like Profinet and EtherNet/IP. While some users may continue to demand embedded fieldbuses that function at lower levels in high-speed machinery, OPC UA TSN will have high degree of performance overlap with these solutions, increasing the chance that users will adopt this technology at all levels.

- Will a new consortium be founded to oversee OPC UA TSN?

  Not likely. IEEE will oversee and monitor the Ethernet-related technologies, while the OPC Foundation will continue to develop, oversee and promote OPC UA.

- How will OPC UA TSN affect modern automation architectures?

Automation architectures will become flatter. For functional purposes, users can still think in terms of the automation pyramid. But, in the future, industrial Ethernet networks will be flat or two-layer at most. A flat network topology will eliminate the layers of the pyramid for communication and all devices will connect to just one network type. The current mix of master-slave and peer-to-peer networks will become obsolete.

- How will requirements for IIoT automation applications change in the future?

  Applying IIoT concepts such as smart devices, industry analytics, and machine learning requires a modern IT infrastructure at all levels of production, from the edge (machine level) up to the enterprise level and out to cloud-based third party applications. This infrastructure must handle not only requirements for large amounts of data, but must also ensure security down to the device level.

  A new type of infrastructure is emerging in which industry software is consolidated on open "platforms" that, like an operating system, provide the underpinnings for a common database, data sharing, and messaging services between applications and devices. Platforms will have built-in security that allows users to select desired security levels and exchange certificates and encryption keys in the background. Platforms allow application software to maintain a small footprint and to connect into an open ecosystem. Software can also be developed and deployed more quickly when this infrastructure is already in place.

  The network that connects devices in such an environment needs to be both industry- and IT-grade. In other words, networking components must meet industrial requirements for harsh environments, while being based on widely accepted IT standards to ensure future compatibility and to keep up with rapid IT developments.

  The networking solution for industry that most closely matches these requirements is IEEE-standard Ethernet with TSN using OPC UA as its communications protocol.

- What value can OPC UA TSN potentially offer end users?

  OPC UA TSN has the potential to offer industrial users value in a variety of areas. First and foremost, a single, Ethernet-based network solution will harmonize the field of a half-dozen or so supplier-influenced, industrial Ethernet protocols, thus simplifying architectures and reducing network lifecycle costs. This single, unified solution will likely offer migration paths for existing industrial Ethernet to help mitigate the risk of adopting the new technology.

At the top level, OPC UA TSN can help users achieve manufacturing KPIs such as reduced downtime, improved overall equipment effectiveness (OEE), and lower total cost of ownership. It is a key enabler to promising new technologies like predictive maintenance, data analytics, machine learning, and artificial intelligence – all of which can contribute to improving these KPIs.

Finally, at the machine level, a single networking solution will simplify maintenance, reduce training time, and probably lower the cost of industrial networks' components like switches and routers. Higher network performance will mean more machine output.

Recommendations

ARC recognizes the value of the OPC UA TSN Ethernet-based industrial networking solution described in this Insight and believes it is the right way forward for industry since it is well-positioned to support future automation applications.

Based on research and analysis, ARC makes the following recommendations:

- For automation suppliers: Enhance automation devices with OPC UA and TSN functionality now to help drive the convergence of OT and IT equipment and minimize the need for temporary solutions like gateways. In the long run, evaluate the performance and reliability of OPC UA TSN within the overall automation architecture as an alternative to today's hodgepodge of industrial Ethernet protocols.
- For machinery builders and process equipment suppliers: Encourage your automation supplier partners to provide OPC UA TSN functionality in their products. Plan both short-term and long-term strategies so that you can offer customers IIoT functionality today, and complete IIoT-based automation architectures in the future. Recognize the potential for creating new revenue streams with remote and cloud-based services enabled by IIoT architectures.
- For silicon manufacturers: Implement the OPC UA TSN in products to comply with existing solutions in the market and help ensure current and future interoperability.
- For end users: Before making future investments, discuss your OT/IT convergence requirements with your suppliers and make it clear which technologies you expect them to support in the future.