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Bring Deterministic Data Centers to Edge Computing

The advantages of edge computing for industrial IoT (IIoT) systems have become impossible to ignore. Adding intelligence near the sensors and actuators reduces communications bandwidth, latency, and security concerns, among other benefits.

But true edge computing means more than just increasing MIPS on embedded devices. It requires end-to-end solutions capable of bringing the performance of the data center into real-time environments.

Connecting embedded devices to the Internet introduces a host of challenges, including authorization and provisioning, remote management, endpoint security, and the many complexities of data sharing across IoT and IT environments. These issues make edge computing inherently bound to enterprise platforms.

That's a problem. Most enterprise solutions are not suited to IIoT applications, leaving a gap between the requirements at the edge and the capabilities of the data center. Most notably, enterprise networks lack the determinism needed for IIoT edge computing scenarios—but this gap is being filled by the OPC Foundation's Unified Architecture (OPC UA) and the AVnu Alliance's Time-Sensitive Networking (TSN) technology.

OPC UA: A Unified Architecture for OT and IT Communications

To marry edge devices with the data center, many industrial OEMs use the OPC UA. Unlike IT-centric technologies, the OPC UA communications stack provides a service-oriented architecture (SOA) that abstracts various field-level protocols into transport-layer machine-to-machine (M2M) protocols for transmission over enterprise networks.

As shown in **Figure 1**, OPC UA enables transparent communications between the enterprise and control layers of an IIoT deployment and resolves many of the networking hurdles associated with edge computing.

Features of OPC UA that help bond enterprise systems to operational equipment include:

- **Bidirectional heartbeats**, which notify the client and server of each other's status so that interrupts can be identified quickly
- **Data buffering**, which ensures data retention in case connection is lost
- **Security, authentication, and authorization**, including a binary version of the WS-SecureConversation specification, suitable for resource-constrained devices
- **Redundancy**, which improves the reliability of data transmissions and the overall infrastructure in case of system failure

These capabilities allow OPC UA-enabled equipment to unify the edge and the cloud in industries such as factory automation, building automation, oil and gas, process control, and pharmaceuticals. But the standard does not inherently provide mechanisms for maintaining operational determinism from the field level into the enterprise.
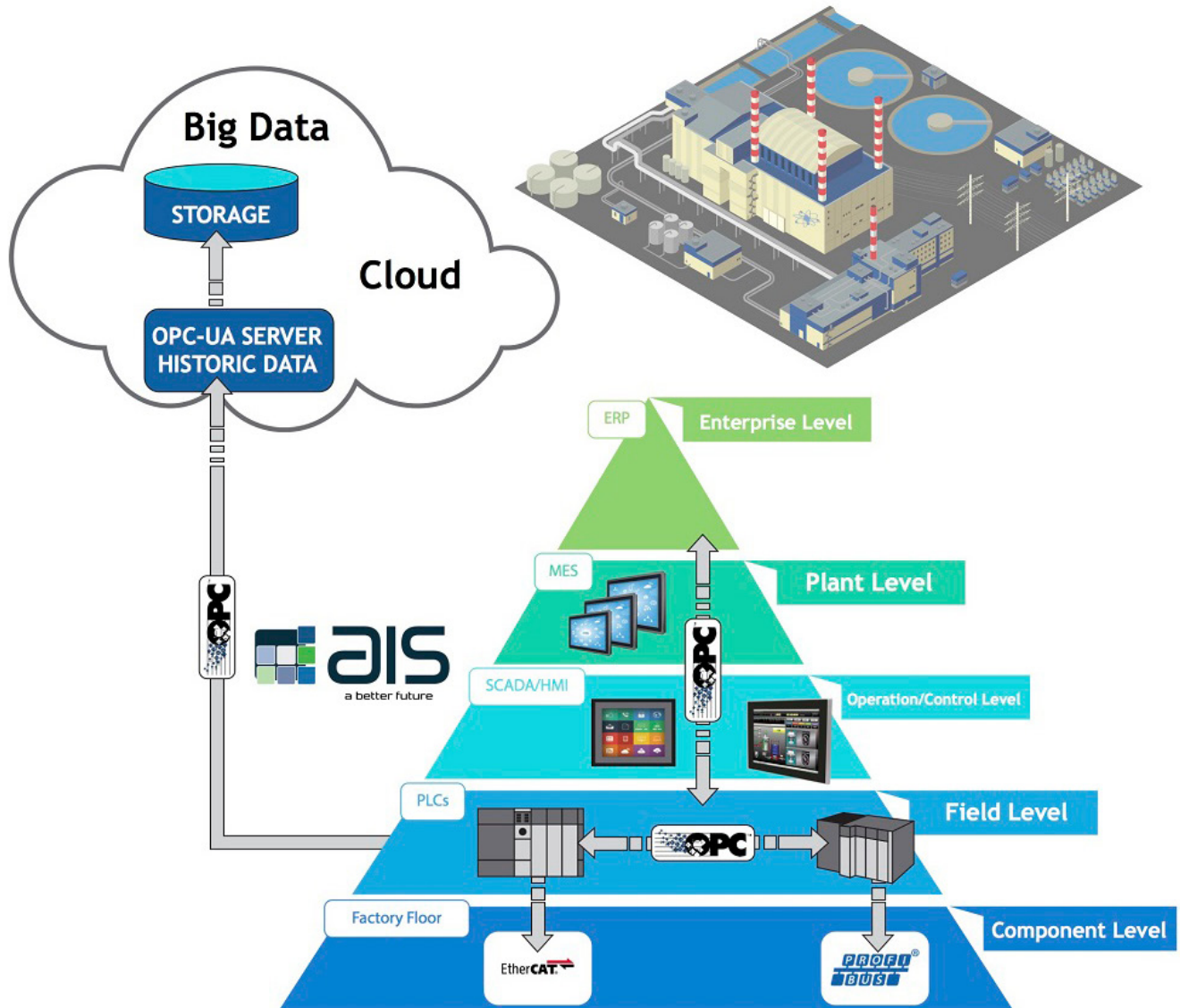
Figure 1. The OPC Unified Architecture (OPC UA) software stack enables the communications transparency and flexibility needed for industrial IoT (IIoT) edge computing. (Source: National Instruments)

Enter Time-Sensitive Networking (TSN): Determinism for IoT Architectures

TSN technology spawned from the automotive industry to deliver high-quality, real-time audio and video content over Ethernet. With Ethernet-based communications so prevalent in industrial fieldbus environments, it's no wonder TSN technology is beginning to take hold in IIoT.

Compared to the traditional IEEE 802.3 Ethernet standards, IEEE 802.1x TSN-based Ethernet networks establish nonnegotiable time boundaries that define end-to-end transmission latencies. This characteristic makes TSN communications deterministic by default, and therefore real-time.

TSN is also capable of supporting different classes of traffic and priority levels on the same network. As a result, IIoT devices that support TSN can extend enterprise connectivity technologies beyond SCADA and control systems to sensors and actuators in the field **(Figure 2)**.

As shown in the previous figure, the combination of Ethernet TSN with a technology like OPC UA delivers common IP-based connectivity from field-level edge compute systems to the cloud. But Ethernet isn't the only TSN-enabled protocol. **Figure 3** shows other existing or future industrial communications technologies that are compatible with TSN.

OPC UA and TSN Unify the Software-Defined Factory

The OPC Foundation and IEEE 802.1x working groups have been working to integrate TSN technology into the OPC UA communications stack, which has significant implications for IIoT edge computing. Rather than adding data center-like performance to embedded systems, this innovation allows industrial organizations to bring the actual data center to factory floors **(Figure 4)**.

By combining real-time, functional safety, and cloud capabilities in an on-premises edge server, automation engineers can begin to create truly software-defined

Industrial Communication With & Without TSN

Complex Gateways And Multiple Communication Standards vs. One Network Infrastructure With TSN Over Ethernet
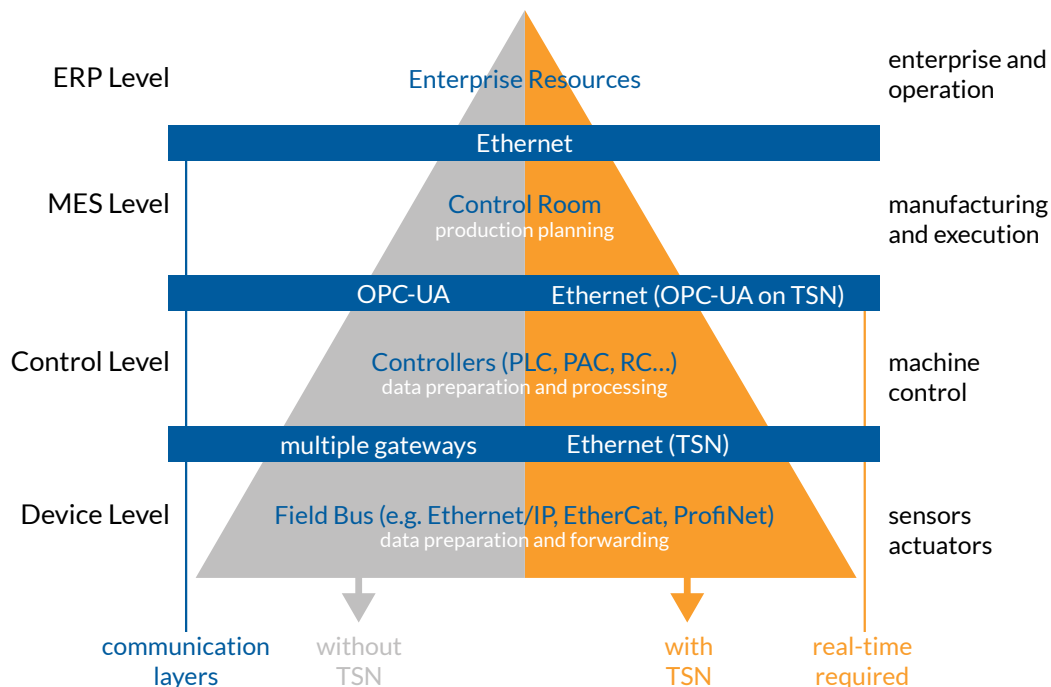

Figure 2. Industrial protocols that support the 802.1 Time-Sensitive Networking (TSN) standard can extend the determinism of operational technology (OT) systems to enterprise platforms. (Source: EBV Elektronik GmbH)
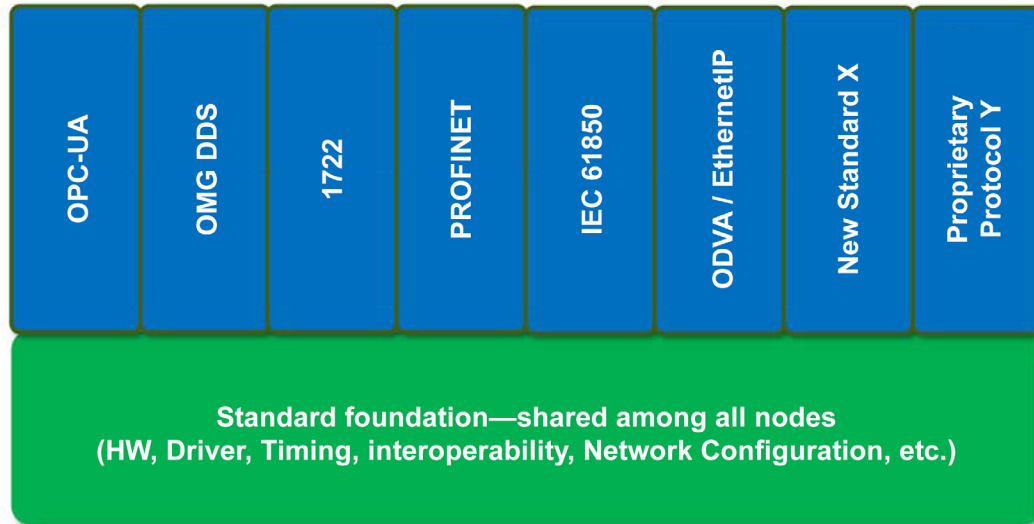
Figure 3. Time-Sensitive Networking (TSN) specifications governed by the AVnu Alliance support real-time communications over protocols such as OPC UA, PROFINET, IEC 61508, IEEE 1722, Ethernet IP, DDS, and proprietary implementations. (Source: National Instruments)
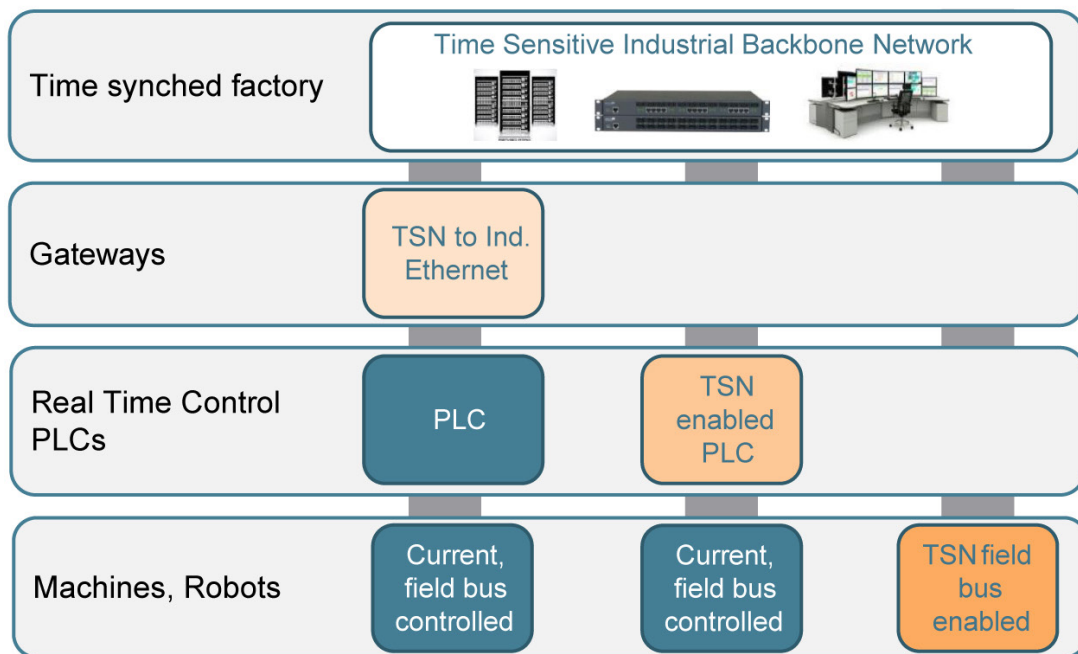

Figure 4. The combination of OPC UA and TSN technologies enables industrial automation companies to bring cloud technologies into deterministic environments. (Source: Kontron)

factories. With deterministic, low-latency connections to nearby data center intelligence, controllers, sensors, and actuators become part of a localized performance improvement continuum. Now the collective intelligence of a factory can be leveraged to make real-time optimizations through software.

With OPC UA TSN, for example, the on-premises edge server can perform comprehensive, real-time analytics locally to accelerate decision cycles in safety- or business-critical industrial use cases. Historical data from all the nodes in a factory can also be leveraged in swift applications of predictive maintenance to preserve valuable industrial equipment. And machine learning algorithms can be updated and redeployed iteratively as new inferences are processed, making factories smarter without having to rely on the cloud.

Of course, implementing a software-defined factory also requires flexible, robust hardware with the appropriate networking capabilities. That's where companies like Kontron can play a valuable role.

Kontron brings a heritage of designing industrial-grade compute and communications platforms into smart factory environments. Today, the company offers a scalable portfolio of standards-based controllers, gateways, and multi-CPU servers based on Intel® technology that support emerging industrial networking technologies such as OPC UA and TSN.

The KBox C-102-2 TSN Starterkit, for instance, is a dual-slot industrial PC powered by a 6th generation Intel® Core™ i5 processor and a four-port 10/100/1000 Ethernet TSN network interface card (NIC). The KBox TSN Starterkit supports Linux with real-time extensions, allowing for quick deployment of an industrial TSN network.

Industrial Cloud and Connectivity Convergence for Smarter Factories

Integrating performance and functionality into edge sensors and controllers does have advantages, but not in all cases. Packing more processing power and storage into these systems can quickly breach the size, weight, power, and cost thresholds, especially in IIoT deployments comprising hundreds or thousands of sensor nodes.

Instead, bringing the data center to the edge gives automation engineers the intelligence needed to realize the IIoT while maintaining the deterministic industrial system architectures that have been proven over decades. Thanks to the real-time properties of OPC UA and TSN, this capability is now within reach.

To learn more about these technologies, watch the on-demand webinar "Edge Computing for Industrial IoT."