5G and TSN: Working Together to Drive Automation Innovation

WHITE PAPER

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Smart manufacturing is in full swing, ready to hit critical mass—but most industrial plants have work to do to prepare for this transformation.

According to a recent Deloitte report:

- 86% of manufacturers believe that smart-manufacturing initiatives will drive industry competitiveness in the next five years.
- 83% of manufacturers think that smart-manufacturing initiatives will change the way products are made.
- Only 30% of manufacturers have smart-factory initiatives underway.
- Only 5% of manufacturers have a full-on smart manufacturing plant in operation.

To self-monitor and improve production in real time, industrial environments will have no choice but to build emerging technologies like artificial intelligence (AI), automated guided vehicles (AGVs) and augmented reality (AR), into their processes.

While these innovations hold much promise in terms of efficiency and automation, they also increase complexity within industrial environments and their operational networks. **Rising levels of complexity can stifle innovation, waste resources, dilute customer experiences and elevate risk.**

Why Uptime Is Critical in Industrial Automation

In any type of industrial environment—from energy, oil and gas facilities to process manufacturing plants and warehouses—just a few seconds of downtime can damage productivity, safety and revenue. Consider these three examples, which rely on uptime in order to provide value.

1. Automating Processes and Workflows

Collaborative robots (cobots) and other types of industrial robots, such as Cartesian or Delta robots, require precise control during live production. Through intelligent motion control technology, sensors and actuators manage the deterministic motion of robots.

Interconnection with sensors, other robots and networks enables data processing for robotic operations. This interconnection is especially vital for cobots, which are built to work alongside humans without barriers, guards or fences in place. Real-time communication is critical to ensure that robots and cobots can safely and quickly execute the specific functions required for their application.

A secure, low-latency connection with the cloud enables robots to gather and analyze data, as well as respond to environmental information in real time, receive instructions and maintain situational awareness.

Even a very short breakdown in communication between robots/cobots and the network can create production problems or safety issues.

2. Preventing Equipment Failure

In industrial environments, machine runtime is critical to maintain productivity and revenue. Continually collecting and analyzing real-time machine health indicators like internal operating temperature, noise level, vibration, RPM of spinning parts, etc. reduces the time and costs associated with unnecessary maintenance while making sure machines don't experience unexpected failure.

Using cloud connectivity to gather and analyze real-time data about equipment condition and operation helps operators and technicians determine what type of maintenance is needed—and when—and make predictions about future operations.

When operational abnormalities are detected, real-time alerts can be sent to the machine operator or plant manager to warn about a potential equipment issue that requires investigation and remediation. This empowers workers to optimize the performance, availability and productivity of their machines.

Without real-time capabilities, this type of predictive maintenance wouldn't be possible. Issues couldn't be recognized or addressed until they impact operations.

3. Building a Product Right the First Time

The American Society for Quality says that the average manufacturer spends between 15% and 20% of its revenue on quality-related costs.

Sensors and other devices support real-time monitoring of the manufacturing process so products can be tracked at every stage for consistency, quality and compliance. This enables fast identification of production errors and irregularities so they can be corrected immediately to reduce waste and rework.

Without the ability to track and correct processes in real time, workers may not realize for hours—or longer—that there's a production problem. Sometimes, issues aren't discovered until a customer complains about receiving a poor-quality product.

5G and TSN Integration to Support Industry 4.0

To enable automation and real-time applications that drive efficiency across industrial environments—like the three we just mentioned on pages 2 and 3—more manufacturers are beginning to explore the integration of 5G and TSN (time-sensitive networking).

Let's learn a little bit more about what this means.

What is 5G?

Defined by global organization 3GPP, 5G is cellular technology that offers significantly higher bandwidth compared to previous standards, along with reduced latency and improved security mechanisms.

5G can support mobile automation and the fast-roaming wireless needed in industrial environments to ensure connectivity with very low latency and high reliability.

What is TSN?

TSN is a set of standards defined in IEEE 802.1 and IEEE 802.3 to introduce mechanisms for Quality of Service (QoS), reliability and configuration. As an evolution of Ethernet, TSN makes Ethernet **deterministic** (ensuring that data is delivered on time with defined levels of latency). It also allows different types of traffic to share the same network.

As you can guess from its name, the concept of "time" is what TSN is all about. Through protocols for timing, time synchronization and data traffic control and prioritization, TSN helps mission-critical information move from one point to another within a specific amount of time.

Bringing 5G and TSN Together

While TSN supports wired connectivity, 5G supports mobile and cloud connectivity. Through 5G-TSN integration, **5G can bring the real-time capabilities of TSN to wireless networks for industrial communication.**

Bringing 5G and TSN together is a critical step toward establishing more fully connected and productive industrial environments by supporting these types of communications:

- Controller-to-controller
- Controller-to-device
- Device-to-compute

Unifying 5G and TSN enables visibility into plant operations so employees can pinpoint opportunities for improvement and make better decisions.

The Industry Moves Closer to TSN Over 5G

3GPP has made significant strides toward integrating 5G systems with TSN to support industrial communication; 5G does have the capabilities required to work with TSN in industrial automation applications.

Release 16 (5G Phase 2), for example, introduces 5G enablers to support TSN. But currently, 5G lags when it comes to bringing the real-time capabilities of TSN to wireless networks. Meanwhile, the margin for error in manufacturing environments continues to shrink.

Today, three major challenges prevent 5G-TSN from making its way to industrial-automation applications. Let's take a closer look at these obstacles.

1. Data Communication Across OSI Layers

While industrial communication operates through Ethernet protocols within Layer 2 of the OSI model, IP-based communication is found in Layer 3.

For industrial networks, both kinds of addressing—Layer 2 and Layer 3—are equally important. Typically, industrial protocols use Layer 2 addressing for communication between PLCs and sensors or actuators. SCADA and monitoring applications use Layer 3 addressing.

To enable the forwarding of Layer 2 and Layer 3 communication through a 5G network, 3GPP developed two types of protocol data units (PDUs) and user plane functions (UPFs): Ethernet and IP. Simplified, the user equipment decides, based on packet headers, whether the 5G system should handle the packet as a switch communication (for Ethernet) or a router communication (for IP).

But today's industrial 5G core systems don't support this differentiation in communication. They only support IP communication. Consider a traditional switch. This device "learns" where the Layer 2 addresses are. When the switch receives data packets, it knows where to put them. The 5G system behaves like a router. When it receives Layer 2 communication, it doesn't know what to do with it, so it tosses the information aside instead of passing it along like it should. **Available 5G systems can't currently support data communication across layers.**

2. Lack of Time Synchronization

To automate workflows, ensure quality and prevent equipment failure, industrial networks or network segments require synchronization to support successful operation control loops. For example, a control loop enables a PLC to control a wireless robotic arm, or multiple sensors to report their data to the cloud, with time-synchronization enabling a consistent sequence of events.

Time protocols, such as PTP (precision time protocol), are required to manage a control loop or sequence of events. But neither IEEE 1588 (PTP) nor IEEE 802.1AS are currently supported in available 5G systems.

To integrate 5G systems into industrial automation applications, 3GPP offers possibilities to implement time synchronization (e.g., through SIB9 messages). **Although they're defined in the standards, these features haven't trickled down into products for industrial networks yet.**

3. Quality of Service Capabilities

In a traditional Ethernet LAN, all device data is treated similarly. In industrial and control networks, QoS is needed to:

- Control and manage traffic
- Ensure proper performance of mission-critical applications
- Minimize interference like latency, packet loss and jitter

Differentiation of traffic types guarantees data delivery and service.

Because the 3GPP-defined features (e.g., 5QIs), to enable QoS are not yet available in 5G core systems for industrial networks, all traffic originating from one device is treated with the same priority. **This lack of QoS during 5G data transmission creates performance issues that can lead to consequences, such as application time-out.**

Exploring the 3 Levels of 5G Integration

There are different levels of 5G integration to consider in industrial automation. With each level comes more complexity but also the ability to enhance what's possible through 5G and TSN.

1. Non-Public Communication

The first level of 5G integration is a 5G network that enables **non-public (private) communication** and connectivity. This is possible in two ways:

- Through **network slicing,** where a network provider offers a network slice with certain QoS guarantees. Several "tenants" access the network, each with their own segment.
- Through **OT ownership,** where a 5G core network can be established using your own licensed frequencies.

Establishing a private communications network with 5G is often a good solution for plants that need to monitor and configure remote stations, for example. Perhaps they need to ensure that a piece of equipment is working or get status updates on performance or functionality.

Through 5G integration, devices are always accessible and visible, and **reliable connectivity** is maintained over long ranges. Typically, this deployment is used to monitor basic information through 5G as a second channel. Latency is not a consideration.

2. Seamless Sensor-to-Cloud Communication

The next level of 5G integration enables **seamless sensor-to-cloud communication** to provide guaranteed bandwidth and time synchronization over a 5G link.

Here, the focus is on **reliable service** and **low latency.** Seamless time synchronization utilizes part of URLLC (Ultra-Reliable Low-Latency Communication) criteria for time-sensitive communication, ensuring guaranteed bandwidth and Ethernet data transfer.

As mentioned earlier, industrial communication occurs through Ethernet protocols within Layer 2 of the OSI model, while IP-based communication occurs in Layer 3. This level of integration enables both types of addressing over the same 5G network.

Because seamless sensor-to-cloud integration **guarantees bandwidth**, it's ideal for situations where multiple mission-critical systems must run at once. For example: environments where turning on an IP camera for visual image capture can't interfere with the flow of predictive-maintenance data.

The support of time synchronization gives all data a relative meaning and is necessary for data analytics. Consider a long pipeline that includes five stations with flow meters. You want to know: **What is the time difference between flow-rate changes in different stations? Do these measurements align with the model of the pipeline?**

To answer these questions, you must first understand the timing (synchronization) associated with each flow meter. Because you understand when the data was captured, you can better understand what the data is telling you.

Seamless time synchronization is also a good fit for applications that lean heavily on moving process data seamlessly to the cloud for better analysis and understanding, such as predictive maintenance.

3. Deterministic Communication

The most complex—yet most potential-filled—level of 5G integration is **deterministic communication.** In these cases, the data flowing in both directions must have a guaranteed level of latency to make sure it arrives at its destination on time.

In deterministic communications, the focus is on **highly reliable service** and **ultra-low latency,** fully complying with URLLC for time-sensitive communication through time-aware shaping/time scheduling and frame preemption.

This would enable plants to operate a virtualized PLC, or a PLC with sensors and actuators that rely 100% on 5G connectivity vs. a mix of 5G and wireless connectivity. Another use case could involve a control loop that allows a PLC to wirelessly regulate a robotic arm.

What's Possible Today and Tomorrow with 5G-TSN

As of today, deterministic communication via 5G—the third integration level mentioned above—isn't possible yet. Although it's far from being commercially available, the industry is still making strong progress.

We can, however, state with good confidence that seamless sensor-to-cloud communication is evolving and will be achievable sooner rather than later.

In fact, Belden is currently developing new architectures to help manufacturing plants build the future by integrating 5G and TSN for unified wired and wireless integration. As 5G-TSN integration becomes possible, the companies that have taken steps in that direction now will be well ahead of their peers when it comes to taking advantage of opportunities it offers.

As you prepare for 5G-TSN integration to support industrial automation, we can help you drive change, not chase it. Starting your journey now will help you save time and resources while also ensuring consistency and reliability.

Learn more about Belden's industrial automation solutions.

About Belden

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