Practical 5G Applications in Industrial Automation

By Jody Muelaner

Wireless communications have become increasingly critical to communications for industrial automation. Now, fifth-generation (5G) cellular communication is widely heralded as the key wireless technology to advance the fourth industrial revolution — Industry 4.0 or the Industrial Internet of Things (IIoT). Some sources even suggest that 5G will be key to making consumer and other non-industrial IoT installations ubiquitous in large part because 5G facilitates the connection of staggering numbers of devices, wherever those devices happen to be located.

Figure 1: The 3rd Generation Partnership Project (3GPP) unites telecommunications standards organizations to make cellular telecommunications technologies as cross and backwards compatible as possible. (Logo source: 3GPP)

But will 5G replace the array of wireless standards currently in operation? Will 5G come to outperform WiFi, Bluetooth, and IEEE 802.15.4 in applications where these other technologies currently lead? Or is 5G simply an improved technology for the few automated applications where older cellular technologies are used? What are 5G's performance advantages … and to what extent are these already leverageable?

To understand the answers to these questions, first consider how 5G differs from other cellular and non-cellular communications. 5G — currently being rolled out for mobile-phone and industrial networks — builds on previous 2G, 3G, and 4G generations of digital cellular technology. There was never a 1G, as 2G's precursor was an analog wireless telephone technology having little in common with today's networks. With 2G came the first digital technology and encrypted phone and short message service (SMS) communications. Global System for Mobile Communications (GSM) standards define 2G circuit-switched networks allowing full-duplex voice calls. Over the years, 2G networks were further enhanced by the first General Packet Radio Service (GPRS) and then Enhanced Data Rates for GSM Evolution (EDGE). GRPS and EDGE enabled transmission of general-purpose data packets for internet connectivity with increasing data rates, which is why networks with these capabilities are sometimes called 2.5G and 2.75G technologies respectively.

3G further improved data-transfer rates — even to the point of enabling video calls. Associated standards include CDMA2000 and various forms of High-Speed Packet Access (HSPA).

Next came 4G and even greater data transfer rates through the Long Term Evolution (LTE) and WiMax standards, which utilize multiple-input and multiple-output (MIMO) transmissions.

5G evolved from 4G, with the first commercially available 5G network products released in late 2018. For historical perspective on the leadup to this development, read this 2016 Digi-Key article: How 5G Will Change the Industrial Internet of Things. Of highest interest to private and commercial users is how 5G networks must be able to support data rates of several tens of Mb/sec for tens of thousands of users. They must also be able to provide a 1 Gbit/sec connection to tens of people within a given office.

The other characteristics of 5G that are most relevant to industrial-automation applications. More specifically, 5G networks must allow hundreds of thousands of simultaneous connections with very low latency and highly reliable coverage. These features are key to the massive sensor deployment associated with IIoT and machine-control applications.

Read the related Digi-Key article: 5G Doesn't Currently Provide All That It Promises

Spectrum and Millimeter-Wave Data Communications

One caveat is that the proliferation of connected devices on mobile networks brings with it the threat of spectrum shortage. Generally, lower-frequency bands provide greater range while higher frequency bands allow a larger number of connections within a small area. Case in point: The 1G AMPS standard used the 800-MHz band while the 2G GSM initially used 1,900 MHz. Many GSM phones today support three or four different bands to allow international use … and current mobile networks operate between 700 MHz and 2.6 GHz. However, as the IoT increases the number of devices connecting to mobile networks, there's diminishing spectrum available on these existing frequency bands. This is why 5G has begun pushing into higher frequencies such as 6 GHz and even the so-called *millimeter-wave frequencies* above 24 GHz — including 28 GHz as well as 38 GHz.

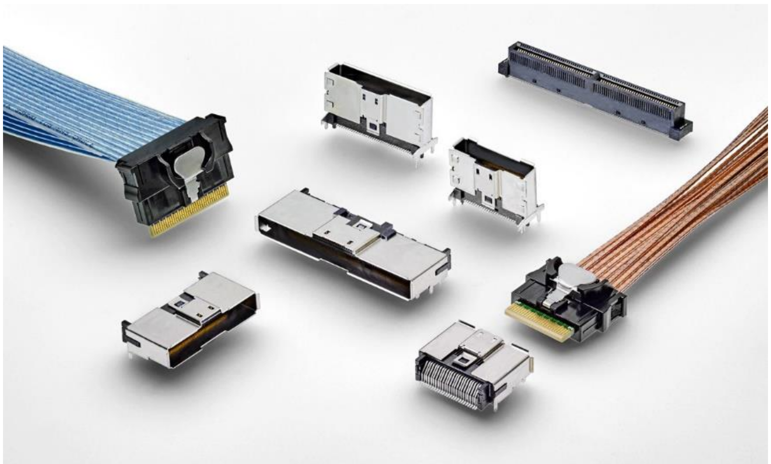

Figure 2: Sliver high-speed interconnects support 25 Gbps data rates and 5G AAS applications including data center and telecom switching and routing. (Image source: TE Connectivity)

Millimeter-wave communication frequencies enable much higher bandwidth and very large numbers of connections. The downside is that data transmission on these frequencies can exhibit limited range and dramatic dissipation when travelling through solid objects. In fact, millimeter-wave communications may actually exhibit less attenuation than those on other frequencies through dry air — but these communications are strongly affected by rain.

One solution to leverage the better bandwidth of these higher frequencies (but avoid range problems) is *beamforming*. With this technique, a focused communications beam is directed at a specific target and not simply broadcast in all directions. Beamforming could soon give millimeter-wave communications the range of lower frequencies more commonly used today — even while minimizing communications interference.

The 5G New Radio (NR) standard is being created to specify the radio access technology for 5G. It includes two frequency ranges. Frequency Range 1 is below 6 GHz and Frequency Range 2 is in the millimeter wave range from 24 GHz to 100 GHz.

Massive Connectivity with 5G in Automation

Increasing frequency to obtain more spectrum will be part of the solution to enable the massive connectivity needed to fully realize the promises of the IoT, such as much greater sensor density. There are, therefore, likely to be immediate improvements in the number of devices that can connect to 5G networks as they are rolled out.

Millimeter-wave 5G is capable of handling one million device connections per square kilometer but will require Narrowband Internet of Things (NB-IoT) to achieve this.

NB-IoT is a low power technology focused on indoor coverage for low cost and low power devices. Current NB-IoT connectivity falls far short of one million devices with cells currently supporting 10,000 devices. Long Term Evolution for Machines (LTE-M) is another low power technology which provides higher data rate and lower latency than NB-IoT, but at greater device cost and power consumption. Another solution will be smaller cells, especially in areas of high demand.

5G Latency: Published Values and Actual Performance

5G is supposed to achieve a latency of under 1 msec … but this headline specification is not achieved most of the time. In fact, for the low power NB-IoT technology latency is around one second in normal coverage, increasing to several seconds for extended coverage. For LTE-M latency is somewhat better, around 100 msec in normal range, but still nowhere near the 1 msec required for real-time control applications.

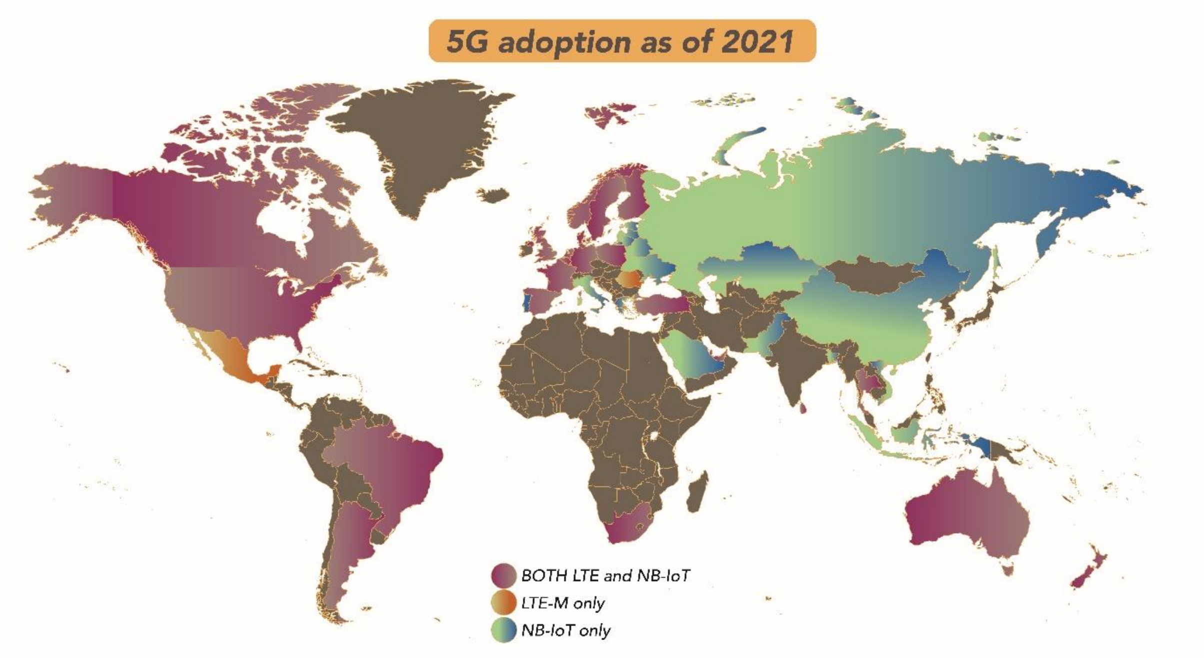

Figure 3: Various forms of 5G have seen rapid global adoption. (Image source: [Design World](#))

Achieving a latency below 1 msec with a centralized network is impossible, as the round trip can take 50 to 100 msec. The solution to this is to execute processing within the cell … though that necessitates servers at the cell level. This is a simplification, because as connected devices move between cells — as in autonomous vehicles — continuity of control and coordination must be maintained. That in turn demands a combination of distributed and centralized control within the network. Small cells can also help reduce latency.

Another method used in 5G to reduce latency is called *network slicing*. Here, the network bandwidth is divided into lanes that are individually manageable so that some are reserved for low-latency transmissions by keeping the traffic on those lanes lower. Industrial control applications which require this capability can therefore use these reserved lanes.

Current 5G networks are achieving a latency of under 30 msec, but the 1 msec required for real-time control is a way off.

Other 5G benefits: Low energy and high reliability

The use of smaller cells will naturally reduce energy consumption but will be somewhat offset by the larger number of devices. Smarter energy management will also play a role in reducing energy use in the 5G network. NB-IoT will enable a battery life exceeding 10 years for many devices, with a range of 10 km.

More reliable coverage is yet another 5G benefit. 5G is being rolled out rapidly. NB-IoT and LTE-M networks are already available across much of the globe. The availability of low latency reserved lanes is somewhat less clear at this stage.

Alternative Non-Cellular Wireless Connectivity

5G cellular technologies are not the only way to wirelessly connect industrial devices. Alternatives include WiFi, Bluetooth and IEEE 802.15.4-based technologies.

WiFi latency is typically 20 to 40 msec and has some issues with connection stability — meaning that it is not generally used for control and industrial automation applications. However, it's currently used for condition monitoring of machines, motion sensors, and barcode scanners. IEEE 802.11ah (WiFi HaLow) operates around 900 MHz for ranges to 1 km with very low power consumption. This makes it competitive with IoT-specific 5G technologies, although it cannot match the low latency and high sensor density.

Bluetooth Low Energy (Bluetooth LE) provides low-cost and low power connectivity, with limited speed and range, but it's focused on consumer devices. IEEE 802.15.4 based technologies also emphasize low-cost and low-power over speed and range, with just 250 kbit/sec and a range of just 10 meters. However, because mesh network topologies are supported, networks can be extended beyond 10 m provided that no device is more than 10 meters from one other device in the network. Many low cost IoT devices use technologies such as 6LoWPAN, WirelessHART and ZigBee. The most industrially focused of these, WirelessHART is supported by a wide range of industrial organizations including ABB, Siemens, the Fieldbus Foundation and Profibus.

Conclusion

5G must be considered as a family of technologies. Impressive performance claims — including very high bandwidth, massive sensor density, and super-fast latency — aren't simultaneously possible with any single technology. That means the most important industrial automation 5G implementations won't simply appear as 5G mobile network services become ubiquitous. The high sensor density of automated installations will require IoT-specific technologies such as NB-IoT and LTE-M. The good news is that such technologies are already being introduced and seeing increased availability throughout the developed world — as well as the developing world. Engineers can expect steady 5G network capability gains in coming years.

Using 5G for control applications requiring very low latency is still somewhat further away. Low-power technologies such as NB-IoT and LTE-M 5G (and especially IoT-specific adaptations) will play a significant role in realizing Industry 4.0 and making machines smarter, factories more flexible, and processes less wasteful. Of course, 5G will continue to compete with noncellular WiFi, Bluetooth, and IEEE 802.15.4-based technologies. Ultimately, all this will spur higher automation productivity.

In short, 5G and other forms of secure and flexible wireless connectivity will enable the sensor density required for big data analytics to fully characterize production processes, optimize maintenance programs, coordinate material flows, and enable autonomous robot collaborations.