Demystifying 5G in Industrial IOT

This paper will demystify 5G to help IIoT customers that are evaluating its domains of adoption. It discusses 5G technology's promises, how it could evolve the paradigms for use cases and services, and the impact on the way IIoT networks may integrate the technology while at the same time coexisting with other existing and new wireless technologies.

Introduction

The rapid growth and ubiquitous use of cellular technology during the past 20 years has fundamentally changed the way we live, work and connect with each other—locally, regionally and globally. The technology which began with device connectivity and mobility for voice services quickly evolved to a broad range of data services, use cases and associated business models.

As 2020 nears, we stand on the brink of a new technological phenomena: fifth-generation mobile technology, better known as 5G. Named as a key component of the Fourth Industrial Revolution by the World Economic Forum, 5G is being touted by many as the "next big thing for wireless consumers." (Source: New 5G networks aimed at cord cutters, Jefferson Graham, USA Today, Aug. 30, 2018)

And yet, while the promise of 5G is great, the technology is still young and evolving. Companies are starting to market various products and services that will run on 5G but the reality is that it's not ready for mainstream deployment. This transformation will be a multi-year journey as production deployments require stable specifications, production quality implementation and supportive ecosystems to be in place before widespread availability.

5G respresents

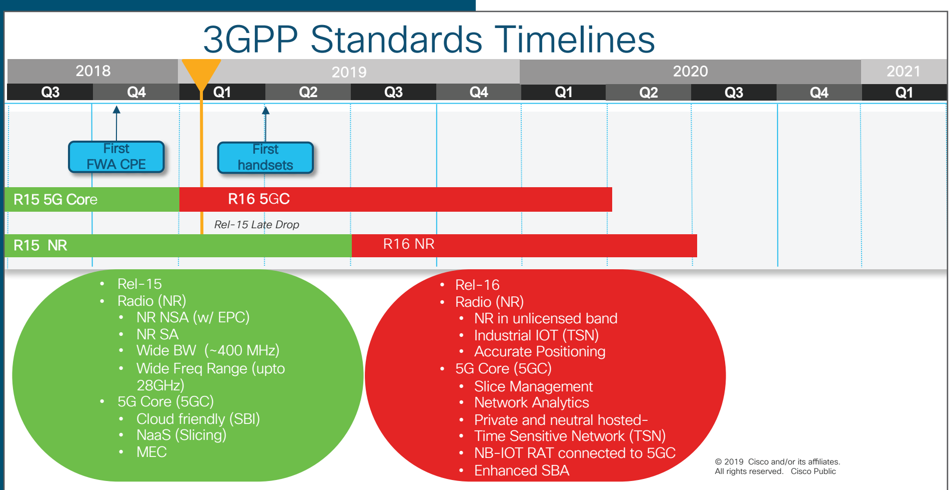
An important evolution in the scope of the industrial internet of things:

Targeting higher broadband throughput, ultra-reliable and low-latency communication, and massive scale of IoT communications

It is important for those of us in the industry to remember that our response to 5G must be integrated and comprehensive and involve all stakeholders–from private to public sectors, academia and nonprofits.

So the burning questions are not if 5G will occur - but when, where and how will it be consumed and how might it impact networking architecture aspects for industrial environments?

In fact, 5G may represent a particularly important evolution in the scope of the industrial internet of things (IIoT) since specifications were developed targeting higher broadband throughput, ultra-reliable and low-latency communication, and massive scale of IoT communications. These are the three main objectives of 5G although it is still evolving to support more advanced capabilities like precision location and support and interworking with time-sensitive networks (TSN).



What is 5G Technology?

The timeline for 5G deployment will likely be different for different businesses and industries, depending on their activities and proposed use of the technology. Yet, it is clear that the next five years will be crucial for success for many businesses--from industrials involved with standardizing and developing products to service providers planning for new business services and infrastructure upgrades (without considering the aspects of new license spectrum acquisition) to IIoT customers analyzing networks and protocols evolutions to enhance their operations, and businesses to consumers attracted by new devices and services.

Before presenting 5G technology and its benefits, let's review the Third Generation Partnership Project (3GPP) release progress for 5G. The 3GPP releases consist of a large number of standards documents covering all aspects of the technology (access, core, security, etc.). These documents are developed by the 3GPP Technical Specification Groups and Working Groups and gathered in main releases. 3GPP Releases 15 and 16 are currently the main targets for the 5G architecture, which consists of the 5G Core and the New Generation Radio-Access Network (NG-RAN). Release 17 and above will add further enhancements that are not yet fully defined. Various standards organizations, including ITU, 3GPP and IETF, are also contributing to the 5G requirements, functionalities, interworking and specifications.

5G Vision

Today's cellular markets, which mostly focus on consumer mobility, are showing limits in terms of evolution to cope with emerging requirements, especially those related to new use cases like connected autonomous vehicles or industry 4.0. The 5G ecosystem promises a connected mobile society that will drive a socio-economic transformation by extending the internet to massive scale of machines and devices with varied access connections. This ubiquitous connectivity should fuel the economic growth of new services and can be expected to significantly impact the macroeconomics enabled by sustained growth and business models as discussed for the Fourth Industrial Revolution.

The 5G system architecture is designed to deliver more than a new radio interface using higher frequencies that offer more capacity, higher density and performance. It will also support an array of innovations, such as massive multiple-input, multiple output (MIMO), cloud RAN and network slicing. In addition, 5G architecture will support multiple access technologies with licensed and unlicensed networks as well as virtualized network modules that can be deployed and scaled in an automated and cost-effective model to serve innovations in manufacturing, automotive, transportation, utilities, public safety, media and healthcare, among other vertical industries.

Architecture Overview

5G system architecture is an end-to-end architecture – from device to application – with the following properties:

- Support of multiple access technologies, such as 5G New Radio (NR), wi-fi, cellular and low power wide area (LPWA), with inter-access mobility.
- New core functions based on the advanced virtualization/cloud native and software-defined networking (SDN) concepts with full orchestration to enable flexible deployments. Flexible deployment offers network component on a per service/customer basis (network slicing) and distribute the function further into the network (Multi-Access Edge Computing or MEC), which will be key to guarantee end-to-end Serve Level Agreements (SLAs) for application with low latency and/or secured access.
- Network capability exposure function for monitoring, provisioning and application-level influence of network policies and routing needs. The service-based architecture is defined to enable such API exposure via a common message bus.

All of these properties are key to support diverse use cases and business models that will eventually enable services providers to generate new revenues with 5G.

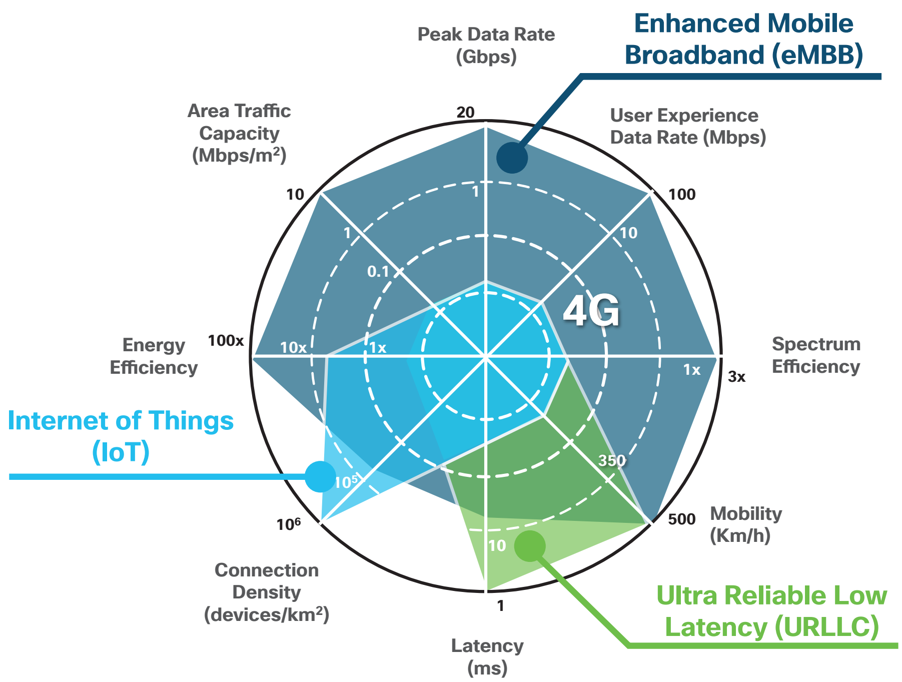
Industry stakeholders and standards organizations have identified several potential use cases for 5G, which demand very diverse requirements. Most of these can be identified within three primary categories:

Enhanced Mobile Broadband (eMBB): eMBB provides higher bandwidth and higher speeds for densely populated urban areas and event locations, such as stadiums. Broadband connectivity is expected from application services delivering augment and virtual reality, 4K/8K video streaming, smart offices and seamless cloud services on demand. The services expect 50-plus Mbps data rates everywhere. Broadband services are expected to be supported on mobile services for in-vehicle infotainment, enhanced navigation, on-board entertainment on commercial aircrafts and telematics support for safety and diagnostics.

Ultra-Reliable Low-Latency Communication (uRLLC): These use cases serve the real-time interactions for mission critical communications, such as autonomous driving, robotic control for industrial automation, drones and remote surgery medical care systems. The tactile response time is expected to be less than 1 millisecond. Public safety and emergency services supporting disaster response and location services are critical for lifeline communication and recovery.

Massive Internet of Things (mIoT): MIoT serves billions of low-cost, long range, ultra-energy efficient devices, machines and things that need connectivity from remote locations as well as cloud applications with periodic, infrequent communication. While LPWA cellular technologies were introduced with Narrow Band IoT (NB-IoT) and LTE-M in 3GPP Release 13 with further enhancements in Release 14, they are aligned to the improvements of the 5G architecture.

The figure below gives a perspective of the expected access performance for the different use cases mentioned above:



Source: ITU-R M.2038.0

5G Spectrum Landscape

5G NR brings key enhancements for radio MIMO and beamforming. It is associated with a high density of small cells that are expected to help in dense urban deployments. Radio transmissions are based on frequency bands that are either licensed to mobile service providers or unlicensed and shared. In 5G, three categories of licensed frequency bands, as shown in the figure above will be allocated to operators, enabling the respective use cases, within three primary categories, (eMBB, uRLLC and mIoT) and as discussed in Group Special Mobile Association (GSMA) 5G spectrum public position (GSMA 5G).

cm/mm-Wave (24-28GHz, 40GHz, 64GHz)

- Hotspot/Fixed Wireless Access
- Main band: 24-28 GHz
- Up to 400 Mhz channel bandwidth

1GHz to 6GHz

- Dense environment (implies Multi-RAT)
- Main band: 3.5 GHz
- Up to 100 Mhz channel bandwidth

Below 1GHz

- Wide coverage, IoT
- Main bands: 600/700 MHz

Similar to previous cellular generations, frequency bands vary between countries and operators. Country regulators have already started to allocate 5G spectrum, generally through auctions to help cope with the demand.

For industrial IoT networking products, it won't change today's requirement to get products supporting modems that comply with the local country's regulations and bands operated by the selected mobile SP.

Industrial grade modems, either 5G or LTE Cat M or NB-IoT, must become available on the market to enable IoT gateways' vendors to support 5G cellular interfaces. However, it calls for a modular IoT gateways design, such as the new Cisco IR1101 as shown in the figure above that could be upgraded to 5G.

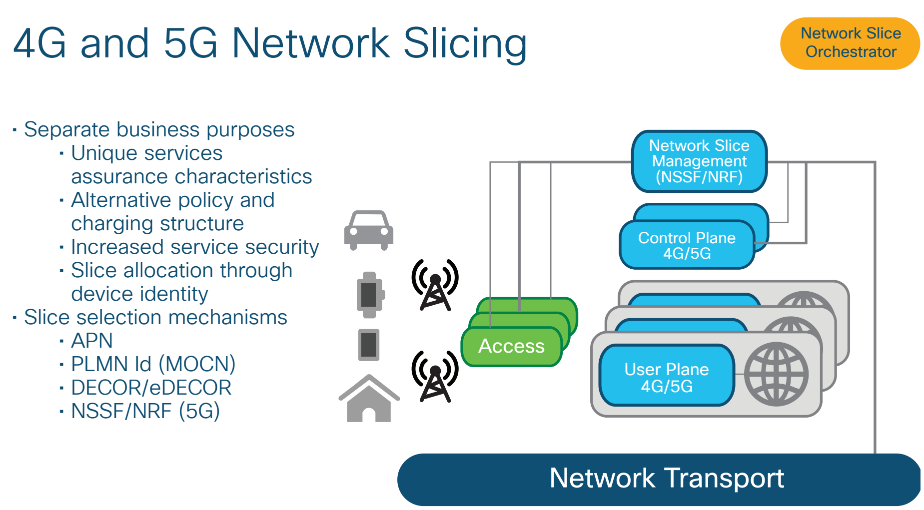
Network Slicing

One of the major benefits of the 5G network is the ability to allow business customers to define a specific requirement that can be fulfilled by the mobile operator with an agreed upon service level agreement with network slicing. A 5G slice is composed of radio resources, dedicated network functions based on software modules running in the cloud nodes, and edge nodes managed by cloud providers, operators and/or third-party vertical specific service providers.

The 3GPP standards have pre-defined three slices and provisioned each with network characteristics to support QoS, latency and throughput based on the three use case groups:

- Slice 1 is dedicated to support eMBB.
- Slice 2 is for URLLC.
- Slice 3 is for Massive IoT support allowing for operator interoperability.

A single user can be associated with multiple network slices simultaneously to support multiple applications. This provides operators and possibly enterprises to own their specific slices.



Specific frequency bands are under allocation in various countries to deal with the demand, such as:

- **US:** CBRS (3.55 GHz-3.70 GHz)
- **Germany:**
- Local (indoor) soft-reserved band 3.78 GHz-3.80 GHz
- Regional (outdoor) soft-reserved band 3.70 GHz-3.78 GHz
- **France:** Band 38 (2.6 GHz TDD) for enterprise use **
- **Australia:** 30 MHz of band 3 (1.8 GHz) for enterprise and community networks in rural areas
- **UK/Netherlands:** DECT guard band, 3 MHz of Band 3 (1.8 GHz) for private GSM
- **Japan:** sXGP Band 39 private LBT-LTE in 1.9 GHz (uses carrier sense to avoid legacy PHS)

*3GPP release 16 introduces the possibility to support 5G NR in unlicensed bands

** Under discussion

IoT and 5G in the Enterprises

Industrial IoT networking covers a wide range of use cases--from extended enterprises to vertical markets and services--with different requirements that are generally well specified by industrial architecture and specifications.

While there are many versions of industrial networking protocols, they run on a variation of access technologies, wired and wireless (as long as the access technologies meet their requirements). Considering the three main promises of 5G, within three primary categories, (eMBB, uRLLC and mIoT), this opens the discussion when evaluating new generations of technologies that will be adopted in the enterprises. This section discusses some that are specific to enterprise 5G topics, knowing it is always challenging to find one technology that fits all requirements.

In 5G IoT for Enterprise, the service level agreement (SLA) and automation tools that will bridge the SP and Enterprise domains are keys to successful deployment. This is an area where solutions are still to be offered.

5G Private and Unlicensed Industrial IoT Networks

Mobile operators need a lot of spectrum to deliver their 5G services, and there are proposals to build 5G private networks in the enterprises, based on unlicensed spectrum for private radio.*

It's also worth mentioning the MuLTEFire initiative that intends to enable cellular-based technology that will operate in a standalone function in the unlicensed 5 GHz band, similar to "Wi-Fi-Like simplicity deployment". In the recent MuLTEFire 1.1 specifications (December 2018), a roadmap to future solutions based on 5G NR was added. Dependent of the world region and preferred specifications, this diversity faces the simplicity of IEEE 802.11ax or Wi-Fi 6, which becomes available for production in 2019. In the context of ultra-reliable low-latency communication (uRLLC), this indicates that Industry 4.0 can already run over Time Sensitive Network (TSN) as available for Ethernet [Cisco_TSN]. This is why the multi-access technologies aspect of 5G and how SLA and tools will handle them is fundamental.

5G and LPWA

In Releases 13 and 14, 3GPP added the support of LPWAN devices through the LTE Cat. M and NB-IoT specifications. While LTE Cat. M can be deployed on existing infrastructures with minimum changes, NB-IoT is a different radio access technology (RAT) type that is supported on the LTE spectrum using the guard band or as a standalone dedicated band. Dependent of the equipment vendors, someneed to upgrade the eNodeB software but some require additional hardware for new baseband. The LTE packet core can support NB-IoT for all IP-based devices. For a non-IP, there is a new path leveraging the SCEF Service Capability Exposure Function (SCEF) functionality.

NB-IoT adoption and ecosystem is still in its infancy, status can be monitored from this website location. https://www.gsma.com/iot/mobile-iot-commercial-launches/

LTE Cat. M and NB-IoT are integrated in the 5G specifications, first to guarantee the interoperability with existing deployment, then to benefit from the 5G bands. In the meantime, services providers and enterprises considering LPWA use cases have largely started to adopt unlicensed LPWA technology, such as LoRaWAN specified by the LoRa Alliance. With lower device's cost and power consumption, unlicensed LPWA today represents more than 100 public networks, 100-plus deployed countries and more than 80 million connected devices (source: LoRa Alliance San Diego meeting, February 2019).

5G and IoT Innovations

As noted in the introduction, 5G is one of the components of the Fourth industrial revolution. It will help drive innovations in various industry domains, such as the following:

Vehicle to Everything (V2X)

Innovations in the connected vehicles with the vision of autonomous transport systems requires an infrastructure that can provide high throughput for in-car infotainment and ultra-reliable and low-latency services for assisted driving. In addition to existing IEEE 802.11p and dedicated short-range communications (DSRC) technology, 5G promises to deliver the reliable, real-time communication at high speed on a distributed architecture needed to support transmission between vehicles, network and transport infrastructure.

Vehicle to Everything communication enables data exchanges between vehicles, infrastructure, pedestrians and applications running on the edge and cloud. V2X can be used in multiple ways to enhance road safety by using the following techniques:

- **Vehicle Platooning:** Enables vehicles travelling together to dynamically form a group. For example: trucks haul loads great distances with long driver hours spent on roads. V2X will allow trucks to form a convoy with truck-to-truck communications and one lead truck. All the trucks in the platoon receive periodic data from the leading truck in order to carry on platoon operations. This allows the drivers to take rests, and it can also form an aerodynamic formation which saves fuel consumption.
- **Intent-based Driving:** Vehicles driving in proximity can share information with other vehicles for activities such as lane change, sudden stops, etc., to avoid collisions, improve traffic safety and efficiency. Similarly, traffic information can be collected from roadside units, temporary road work blocking units and pedestrians for the vehicles to obtain a holistic view of the driving environment, making it increasingly autonomous.
- **Edge and Cloud Integration:** Applications need to use network resources available at the edge for CDN caching content for improved Quality of Experience (QoE) and cloud-hosted, back-end system integration to provide vehicle-to-network application services over the licensed cellular spectrum.

Such applications require centralized control to operate the service subscription management necessary to enable vehicles to securely create a trust group with other vehicles in order to form a platooning convoy and have trusted data exchange. In addition, V2X applications, such as road safety, traffic management, infotainment services running on the core, cloud and third-party infrastructure, need secure management to ensure critical real-time information legitimacy. Trusted vehicles can subscribe to OEM services and third-party services with dynamic API interface allowed by the network exposure functionality on the core.

This is a typical example of innovation driven by Cisco Control Center IoT platform that enables C-V2X deployments, allowing network usage management of dynamic services offered by the service providers and offering service monetization opportunities for the service providers, OEMs and infrastructure providers.

Multi-access Edge Computing (MEC)

While connectivity is foundational to the digital transformation success in IoT, vertical markets such as manufacturing, transportation and utilities are digitalizing their operations with the adoption of cloud and edge computing services to improve efficiency, optimized production cost, increase safety and maximum profits. To meet the Industry 4.0 use cases requirements of sub-milliseconds latencies, accurate location, high reliability and very high throughput, and to achieve the promise of 5G URLLC capabilities, multi-access edge computing is the way to achieve the reliable local offload and backend cloud integration for real-time data processing and content localization as shown in the figure below. Without MEC applications, URLLC requirements would be hard to achieve.

Zero touch deployment of MEC nodes and implementing services on the edge with the needs of the application security, policy and billing requirements for a managed offering are key to the successful implementation. 5G-aware MEC management platform for IoT will ensure the data stays where it is needed most and coordinate with the 5G virtualized core and the distributed user plane function (UPF), providing high-quality connectivity service experience for IIoT use cases.

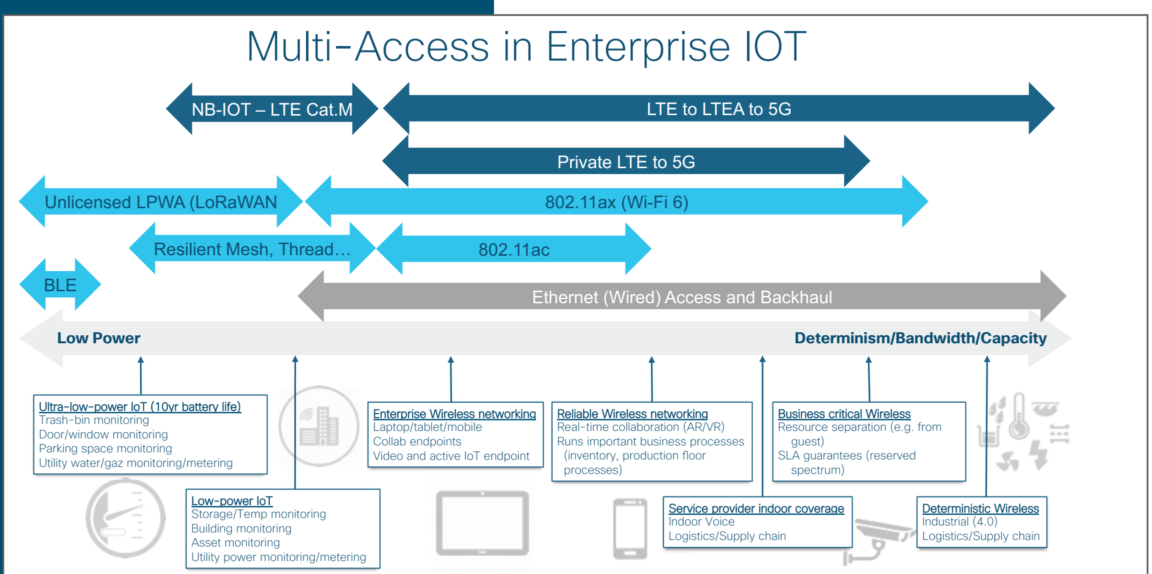
Cisco already productized the capabilities to extend data intelligence to the edge of the IoT network to extract and compute data on the manufacturing floor for accelerated decision making as available on Cisco IOx platforms, such as IC3000 Industrial Compute Gateway associated with its Field Network Director (FND) management platform. Solutions can be expanded to 5G IOT MEC requirements

What's Next?

Despite the progress being made in 5G deployment, there remain a number of challenges that need to be addressed before it is readily available for all customers.

Perhaps one of the top concerns is managing expectations. The promise of 5G is everywhere as companies take to the airwaves, the internet and other channels to announce the development of 5G phones and other products. But while the marketing campaigns show the exciting possibilities of 5G, they are also raising unrealistic expectations among customers.

In fact, there isn't widespread coverage of 5G right now as it's still in its early stages of deployment. 5G public services pilots are just starting while advanced features, such as network slicing, are in the development phase.



It's important to note that 5G will not replace 4G immediately. Carriers will use a combination of WAN and other networks to deliver 5G services, coexisting with other legacy architectures into the next decade. In fact, carriers are deploying 5G radio (new frequency bands) with their 4G packet core (non-standalone mode).

In addition, others are moving forward

Conclusion

As a pioneer in multi-access, routing and switching, and VPN technologies, Cisco is fully committed to working with early adopters on the 5G technology integration for enterprise IoT. Therefore, Cisco carefully reviews opportunities for proof of concepts, focusing on multi-access technologies as successful integration will represent a mix of use cases and topologies.

References
New 5G networks aimed at cord cutters, Jefferson Graham, USA Today, Aug. 30, 2018
The Fourth Industrial Revolution: what it means, how to respond
The Fourth Industrial Revolution by Klaus Schwab
Indoor 5G Networks White Paper
Wireless Infrastructure Association (WIA) Innovation Technology Council, 2/27/2018

with developing best practices in radio deployment and network design for indoor cases, such as manufacturing plants. According to Indoor 5G Networks White Paper, IoT is one of 5G's major services that will see extensive applications in warehouse management (smart logistics) and industrial manufacturing (smart factory).

The key is to unleash the power of 5G. A key part of deploying 5G coverage will be to educate the workforce. According to WIA Innovation & Technology Council, the "sea change expected from the deployment of 5G networks can only happen with a sufficiently skilled labor force trained to design, install and monitor these networks. Further, 5G deployments will require other skillsets as industries adapt their workforces to exploit changes driven by 5G adoption."

And for industries that want to not only survive but thrive in this new 5G environment, they will need to adapt to the shifting technologies. 5G represents a fundamental shift in communication network architectures, and as such, businesses will need a model that can address the diverse range of 5G use cases. Building an ecosystem, preparing the network infrastructure and establishing strategic partnerships will be key to developing successful 5G business models.

To contribute to the effort, enterprises IoT customers should review these requirements on 5G integration in their IoT deployments, particularly in the areas of:

Standards and compliances – Which ones are required by your organization? Industrial protocols are well-defined, guaranteeing interoperability and openness. Several organizations work on specifications that would require compliancy, i.e., 5G Americas, 5GAA (5G Automotive Association), 5G-ACIA (5G Alliance for Connected Industries and Automation), etc.

Spectrum – Will you pilot 5G over public services or private spectrum? If private, what is your regional frequency band allocation?

Coverage and topology – Where will the technology be deployed? Industrial environments, such as the plant floor, control loops, etc.? Understanding the environment for noise and interferences, what are the number of devices and base stations to be deployed?

Physical characteristics – How will you compare your 5G deployment with other technologies, such as Wi-Fi 6, deterministic Ethernet, LoRaWAN in regard of data rate, latency, etc.

Device type and cost – What are the typical devices you expect to connect through 5G? What is the estimated cost compared to 4G? Wi-Fi? LoRaWAN (for NB-IoT)?

Operations and manageability at scale – How large do you foresee your 5G deployment? How should it integrate with centralized automation tools, such as DNA-C, SD-WAN, Control Center and others?