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Private 5G Mobile Networks for Industrial IoT

A Heavy Reading white paper produced for Qualcomm

Qualcomm

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5G FOR INDUSTRIAL IOT

Private mobile networks designed and deployed specifically for enterprise users provide opportunities to optimize and redefine business processes in ways that are either impractical or not possible within the limitations of wired and Wi-Fi networks. For industrial users, the ability to design mobile networks to meet the coverage, performance, and security requirements of production-critical applications is fundamental to the new wave of cyber-physical systems known as Industry 4.0.

The strategic importance of private networks is now reflected in 5G R&D. Whereas in previous generations, private networking was an add-on capability to public cellular systems, these requirements are now addressed directly in the 5G specifications. This will ensure the technology meets the needs of future private network customers, will increase their confidence in the roadmap, and will serve to accelerate the deployment of 5G networks by and for enterprises.

This Heavy Reading white paper argues that 5G technology is particularly suited to industrial users with requirements for predictable, reliable performance. It discusses how private 5G networks meet the needs of demanding industrial applications and can contribute to process automation across a range of sectors – from smart factories and warehouses, to ports, to oil & gas production, to chemical plants, to energy generation and distribution, and more. The paper investigates key issues in private 5G, including how end-user organizations can deploy and operate the technology, the integration of private local-area and wide-area public networks, and the importance of spectrum for private deployments.

The paper discusses how private 5G can be deployed across diverse licensed, shared licensed, and unlicensed spectrum bands. Specifically, it addresses the use of time synchronization in shared spectrum as a way to ensure predictable performance.

Drivers for Private 5G Networks

Private networks are designed and deployed by enterprises to optimize or enable business processes. Broadly, there are three drivers to deploy a private mobile network:

- **To guarantee coverage:** Often in locations with harsh radio frequency (RF) or operating conditions or where public network coverage is limited/nonexistent (e.g., remote areas).
- **To gain network control:** For example, to apply configurations that are not supported in a public network. Security and data privacy are also important. The ability to retain sensitive operational data on-premises is crucial to high tech industrial companies.
- **To meet a performance profile:** Specifically, a profile that will support demanding applications. 5G has a clear performance advantage over LTE and Wi-Fi in cyber-physical industrial systems.

After years of development, a robust private LTE market is emerging, with deployment activity across many sectors globally. Private LTE systems take advantage of the global LTE ecosystem, which benefits from high volume, standardized technology and well-established suppliers able to design and deploy networks. The scale economics and interoperability benefits of global 3GPP technologies also apply to sector-specific equipment, and well-developed supply chains and established best practices are now in place in many sectors. For example, devices such as sensors, automated guided vehicles (AGVs), security cameras, safety equipment, and so on are now available with integrated LTE.

Many industrial applications can be supported on LTE. However, where users have more demanding performance requirements – in terms of availability, reliability, latency, jitter, device density, throughput, etc. – 5G is better suited to their needs than LTE. 5G includes innovations in the radio domain and system architecture that make it better able to meet the requirements of high performance industrial applications. These include the following:

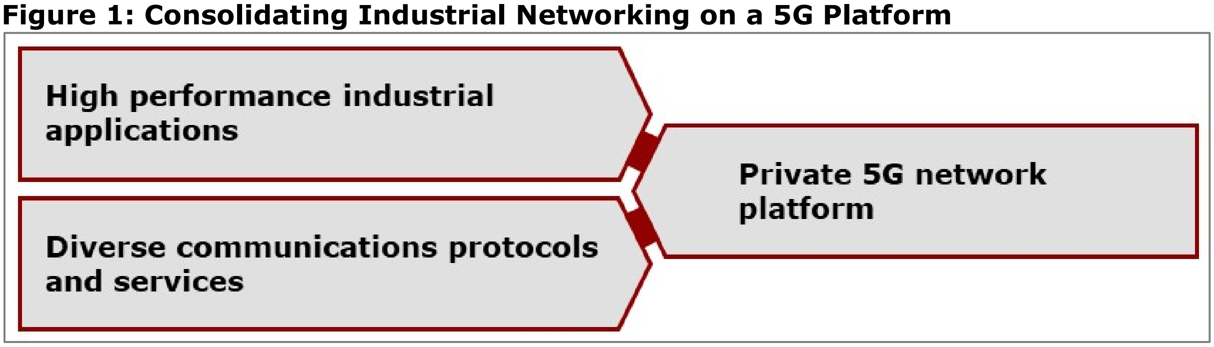
- In the radio domain, flexible numerology, Ultra-Reliable Low Latency Communications (URLLC), spatial diversity, positioning, quality of service (QoS), spectrum flexibility, etc.
- At the system level, capabilities such as network slicing, improved security, new authentication methods, edge deployment, application programming interface (API) exposure, etc.

For these reasons, where users have demanding applications, Heavy Reading believes 5G will be adopted in the industrial sector over other wireless technologies. Trials and commercial pilots are already underway, and adoption will scale rapidly when 3GPP Release 16 capabilities and ecosystem support are available. Given that Release 16 standards are scheduled for 1H 2020, expansion at scale will start from 2021 onwards. In the meantime, private LTE is a capable technology with a clear and committed upgrade path to 5G. Vendor solutions that will allow post-deployment upgrades to 5G and/or multi-mode LTE/5G operation are now coming to market.

5G Performance for Diverse Industrial Applications

Industrial facilities use a wide variety of fixed and mobile networking technologies within their operational technology (OT) suites. OT refers to specialized industrial equipment that use software to control and interact with devices, processes, and events. Examples include robotic production lines, sensor networks, or industrial plant equipment. In several of these cases, the performance requirements for the link between the control system and physical actuator are extremely demanding and cannot be met by LTE and Wi-Fi.

Figure 1: Consolidating Industrial Networking on a 5G Platform



Source: Heavy Reading

In industrial environments, a wide range of field bus communications technologies are used to provide reliable communications between physical production equipment on the shop floor and the control systems. Today, these communications field buses generally use quasi-proprietary industrial Ethernet wired connections to transport a variety of protocols used for communications between controllers and actuators. The diversity of protocols and the restrictions of wired connections make for a complex operating environment. 5G is, therefore, also an opportunity to consolidate industrial networking complexity. **Figure 1** above shows how performance and the consolidation of complexity are both drivers of 5G in industrial sectors.

A good example of this is seen in the cross-industry effort underway to transition diverse field buses to a common Ethernet standard known as Time-Sensitive Networking (TSN). The performance requirements of TSN links have been captured by the 3GPP standards body and incorporated into 5G specifications. **Figure 2** shows example performance requirements for robotic motion control and control-to-control uses cases. These are among the most demanding set of applications 5G is designed to support and are far beyond the capabilities of LTE or Wi-Fi. Note these high performance networks are defined for small service areas, such as seen in a factory floor, with user equipment (UE) densities greater than in macro networks. It is not expected that this performance will be supported in the wide-area public cellular network.

Figure 2: Evaluation of TSN Performance Requirements for 5G New Radio

Service Availability: Target Value	Mean Time between Failures	Message Size	Allowed End-to-End Latency	Survival Time	UE Speed	# of UEs	Service Area
99.999% to 99.99999%	~ 10 years	50 bytes	500 µs	500 µs	≤ 75 km/h	≤ 20	50 m x 10 m x 10 m
99.9999% to 99.999999%	~ 10 years	40 bytes	1 ms	1 ms	≤ 75 km/h	≤ 50	50 m x 10 m x 10 m
99.9999% to 99.999999%	~ 10 years	20 bytes	2 ms	2 ms	≤ 75 km/h	≤ 100	50 m x 10 m x 10 m

Source: 3GPP TS 22.104, Excerpted from Table 5.2-1

The 3GPP specification TS 22.104, "Service Requirements for Cyber-Physical Control Applications in Vertical Domains," identifies performance requirements for several other industrial applications and use cases. More broadly, examples of industrial applications with demanding performance requirements that can be supported on local-area private 5G networks include the following:

- **AGVs:** These are a staple wireless use case in factory and warehouse environments and can be supported, at limited densities, on Wi-Fi and LTE. 5G supports greater numbers of AGVs per service area and enables advanced applications such as video remote control for dangerous loads such as fuel and chemical tankers.
- **Extended reality headsets (a.k.a. data goggles):** This is an emerging device category that is making rapid progress. One industrial use case is remote expertise for maintenance engineers working on complex industrial equipment. There are also extensive opportunities in industrial training scenarios.

- **Ultra-HD cameras and machine vision:** The use of imaging, in combination with machine learning, is being applied to a wide range of applications. An industrial Internet of Things (IoT) example is predicative maintenance – for example, to identify metal fatigue or manufacturing faults – to reduce failures and outages. 5G can support the large data volume generated by dense ultra-HD cameras and the low cycle times needed, in this example, for the application to recognize defects and inform the production line.
- **Electricity distribution grids:** High voltage electricity distribution grids use load control systems with very tight latency and 5x9s reliability requirements, without which continuity of supply may be compromised. They typically rely on aging wireline time-division multiplexing (TDM) networks today. 5G offers the chance to overlay this transmission system with a more modern and flexible communications system.
- **Mixed IoT:** There are myriad IoT devices used in industrial contexts. These often are not super latency sensitive or do not require very high bandwidths or extreme availability; therefore, they can be supported on LTE (e.g., narrowband-IoT [NB-IoT] and LTE-M) and Wi-Fi. However, as density increases. a 5G network may be advantageous. (In fact, NB-IoT can be considered part of the 5G system and can be deployed with New Radio [NR].)
- **Remote control of industrial plant:** Examples include mobile cranes, mobile pumps, and fixed portal cranes. These UEs are typically stationary or slow moving and may be distributed across a wide area (e.g., a shipping terminal).

PRIVATE NETWORK DEPLOYMENT MODELS

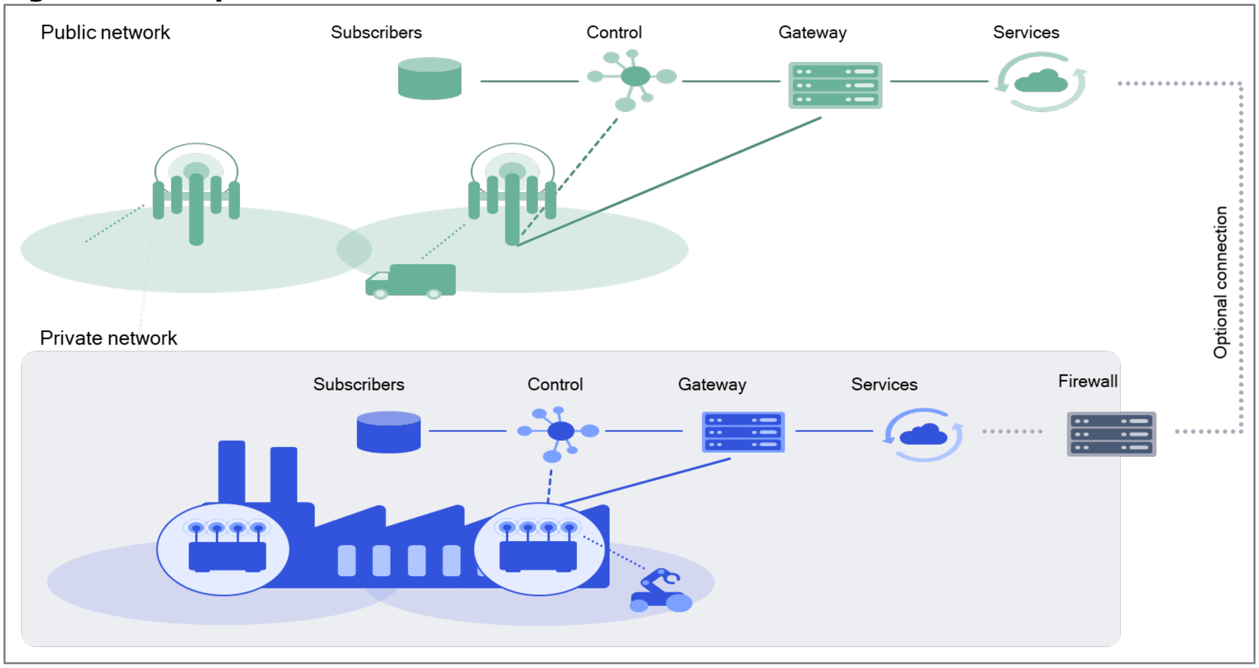
Mobile network technology is nearly always deployed and operated by a licensed public operator. Private networks are a big change to this construct, and questions remain about which party should design, deploy, operate, and own them. There are two basic forms of private 5G networks (known as non-public networks in 3GPP terminology). Heavy Reading expects both options to be adopted in the market:

- **Independent private networks without dependencies** on a licensed public operator or a wide-area network. Integration with the public network is possible, but optional.
- **Private networks deployed in conjunction with a public network**. Various levels of integration are possible.

In terms of physical deployment, the term "private network" refers to networks with radio, core, and transmission resources dedicated to the enterprise and – crucially – under the control of the enterprise. This generally means network equipment will be deployed on the customer premises, regardless of which party manages it day-to-day.

Dedicated equipment is especially important for production-critical OT because outages, service degradation, or security breaches can be economically catastrophic to the business owner and, in some cases, to safety. This private network model is shown in **Figure 3**.

Figure 3: Independent Private 5G Network

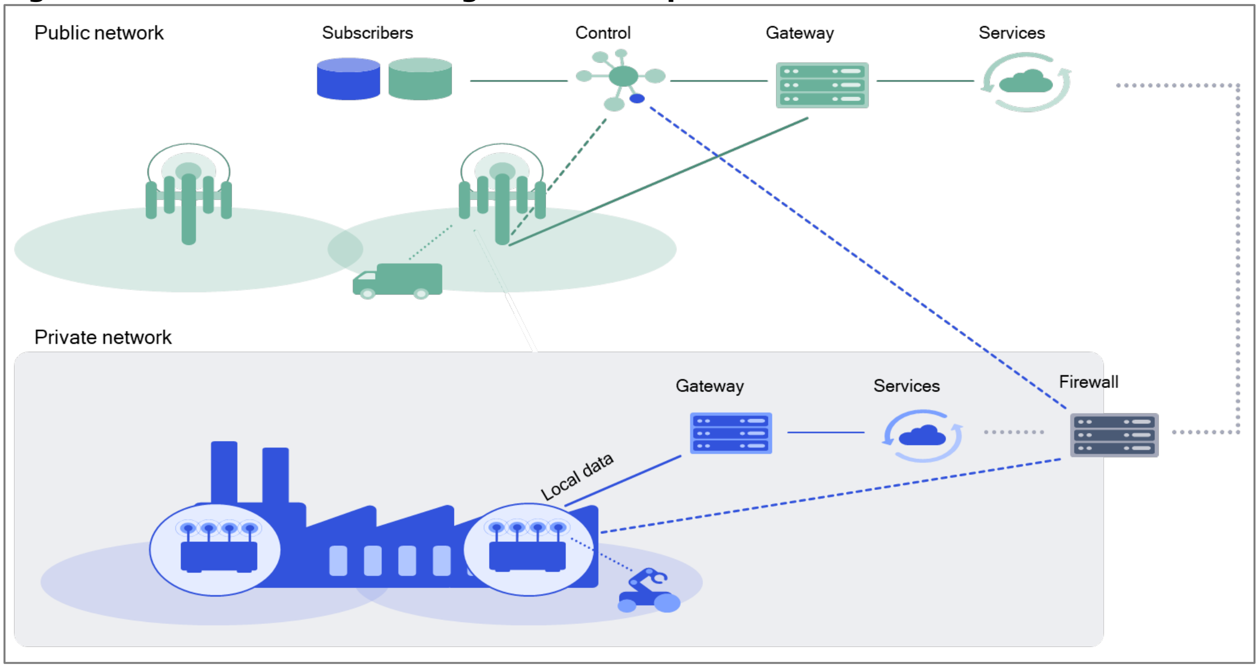


Source: Qualcomm

Another question is: Does the enterprise need integration between the private network and the public wide-area network? And if so, how should that occur? Many enterprises need external wide-area mobile coverage, and it is often desirable to connect private and public networks. Moreover, some industrial processes themselves require wide-area to local-area connectivity – for example, to track components arriving at the factory and goods leaving into the onward supply chain. The nature of this connection between private and public networks is an area that needs attention. Although solutions exist in LTE – for example, dual subscriber identification module (SIM) devices/subscriptions and roaming interfaces – there is scope for improvements that will give enterprise users finer-grained control of their data and users when they roam into the public network. The 5G system architecture better enables this integration.

Figure 4 shows a model where the private 5G network is more tightly integrated with the public network. In this case, the radio access network (RAN), gateway, local services, and firewall are all deployed on campus but the control infrastructure (i.e., subscriber databases, policy server, IP Multimedia Subsystem [IMS], etc.) is hosted by the public operator. In principle, this makes it easier to maintain policies and subscriber profiles in the handover between the public and private networks.

Figure 4: Private Network Integrated with Operator Network



Source: Qualcomm

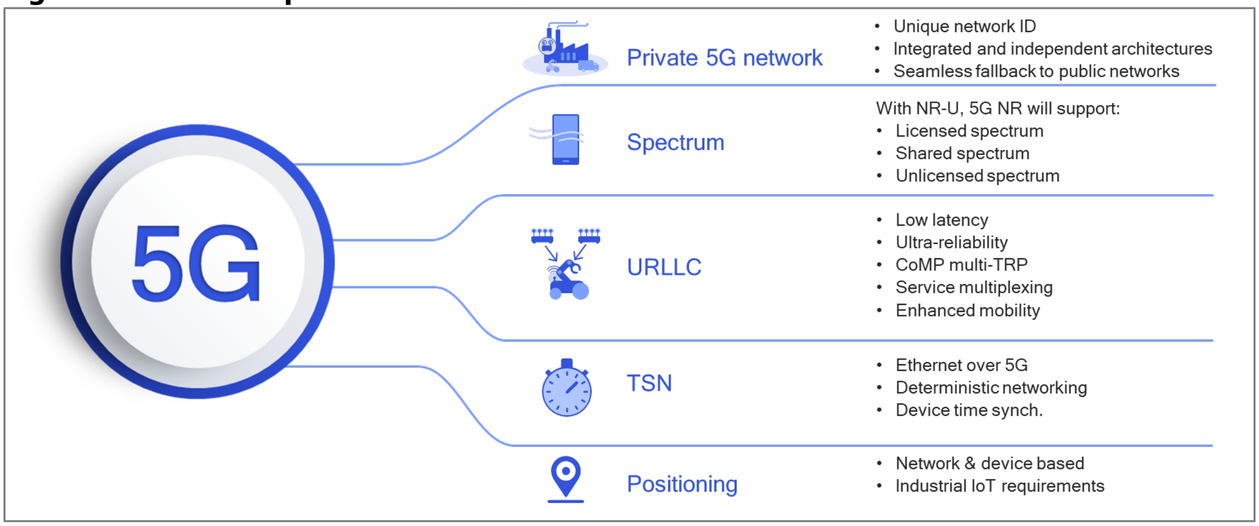
There are several variations on this integrated model. The 5G Alliance for Connected Industries and Automation (ACIA) has identified four scenarios for industrial IoT (IIoT) private networks, each of which is mapped to the service attributes of different industrial users. These models are intended to help OT companies – the organizations that will apply 5G to their business – and the technology companies that intend to make industrial IoT a part of their 5G offering. The paper is available here: *5G Non-Public Networks for Industrial Scenarios*.

In general, and especially for use cases such as smart manufacturing, Heavy Reading expects private networks deployed on-premises to be most prevalent due to latency, control, and security requirements. In sectors such as logistics and transportation where wide-area coverage is more important, then there are more opportunities for private services in shared public networks.

5G INNOVATION FOR INDUSTRIAL IOT

The requirements of cyber-physical systems and industrial IoT applications are fundamental to the design of 5G and have informed specifications development since the outset of work in 3GPP and technology R&D. **Figure 5** shows some of the major capabilities of the 5G system that enable private 5G networks for industrial users.

Figure 5: 5G NR Capabilities for IIoT



Source: Qualcomm

The first 5G standards release (3GPP Release 15) contains many of the critical features that will underpin the industrial IoT segment, including flexible numerology and ultra-low latency. However, while the foundational capabilities are in place, the first commercial 5G networks are being deployed for mobile broadband and do not support all the advanced features needed for cyber-physical industrial communications networks. To address this, there is an enormous amount of work underway in the next 5G specification release, known as Release 16, scheduled for functional freeze in March 2020 and ASN.1 freeze (i.e., protocols stable) in June 2020.

3GPP Initiatives Supporting Industrial IoT

The attention the global 3GPP community – which includes leading technology vendors, research organizations, and network operators – is giving to industrial IoT is extremely significant. This is a multi-year commitment that draws deeply on R&D capabilities at these organizations, and this depth of investment should generate confidence among future industrial IoT customers.

The scope of the work is also broad. **Figure 6** shows initiatives in 3GPP Release 16 that are focused on private networks for industrial IoT. These initiatives span the stack from Layer 1 enhancements to 5G NR to higher layer northbound APIs that enable third-party applications (e.g., developed by specialist OT companies) to run on private 5G networks.

Figure 6: Summary of 3GPP Initiatives Supporting Private 5G Networks for IIoT

Initiative	Summary Description
5G LAN	• Integration of Ethernet-based local-area networks (LANs) with 5G • Study on requirements for R16 complete (TR 22.821)
CAV	• Communications for automation in verticals • Study on requirements for R16 complete (TR 22.804)
CyberCav	• Identifies requirements for cyber-physical control in vertical domains • Includes support for LAN-type services specific to industrial use cases • Formal requirements for R16 completed (TS 22.104)
Vertical LAN Enhancements to 5G Systems	• Architectural enhancements for 5G system support of vertical LAN services • Support for TSN, time synchronization, and QoS • Focused on non-public networks, with roaming to public networks considered • Service exposure via APIs for third-party functions • Study for R16 completed (TR 23.734)
NR IIoT	• Radio aspects for IIoT • Examples include factory automation, transport industry, and power distribution • Includes Layer2/3 optimization, TSN, synchronization, QoS, header compression, etc. • Study for R16 completed (TR 38.825)
NR Mobility Enhancements	• To achieve handover performance with 0 ms interruption and high reliability • Applied to both inter-/intra-frequency handover • Also beneficial to high speed train and aerial use cases where handover is challenging • Solution to be documented in multiple specifications (e.g., TS 38.300 and TS 38.331)
NR URLLC	• NR enhancements to URLLC and IIoT • Addresses the requirements for eURLLC with Layer 1 enhancements • Targets higher reliability (6x9s), higher availability (percentage of UEs able to connect at desired performance), and shorter latency in the order of 0.5 ms to 1 ms • Study for R16 completed (TR 38.824)
NR MIMO	• Various enhancements for NR MIMO • Includes multi-TRP transmission for improved reliability and robustness • Includes multi-TRP techniques for URLLC (important for IIoT) • Solution to be documented in multiple specifications (e.g., TS 38.213)

Initiative	Summary Description
NR-Unlicensed	• Technical report complete December 2018 (TR 38.889) • Study NR-based operation in unlicensed spectrum below 7 GHz • Considers NR-based LAA cell(s) connected to LTE or NR-licensed anchor cell • Also covers NR-based network operating standalone in unlicensed spectrum, connected to a 5G core network (e.g., for private network deployments)
Non-Public Network	• Radio aspects of non-public networks • Work for R16 to start in August 2019
Non-Public Network Management	• Proposed study on non-public network management • Identify use cases and requirements for non-public networks management • Make recommendations for normative work
SEAL	• Service enabler architecture layer for verticals (TS 23.434) • Complements Common API Framework (CAPIF) for third-party applications • Application-enabling services (e.g., group management, location management, network resource management); can be reused across vertical applications

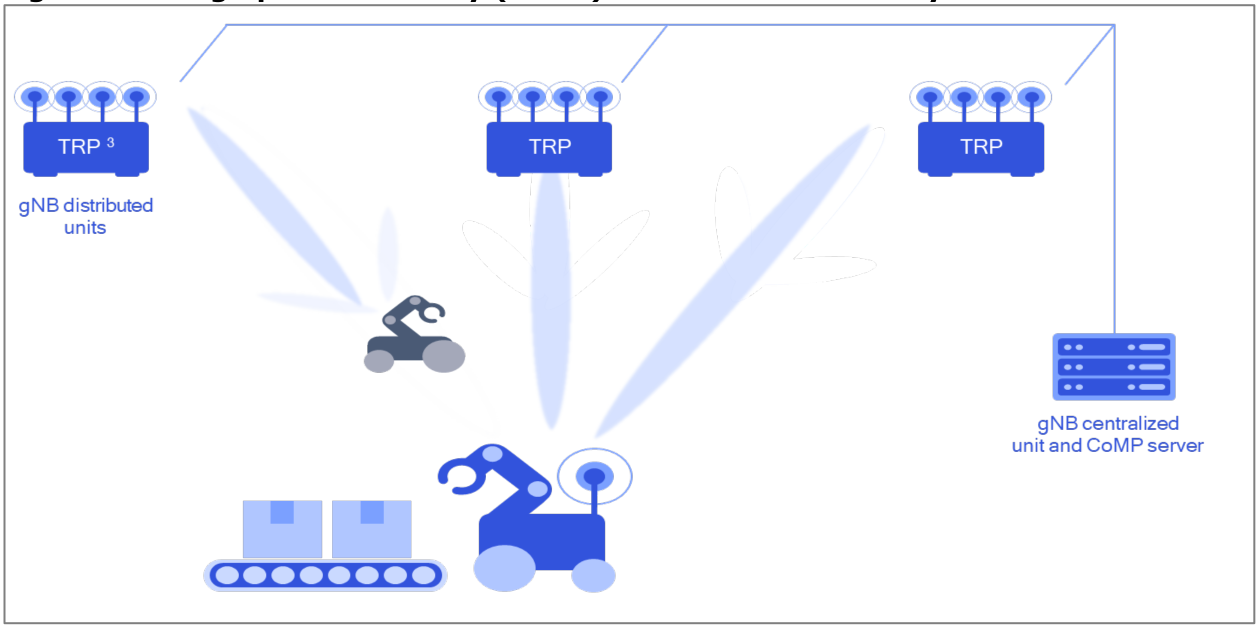
Sources: Heavy Reading, 3GPP

5G CoMP for Extreme Reliability

Certain industrial applications require 99.9999% reliability and sub-millisecond over-the-air latency, according to TS 22.104, which is challenging to deliver using classic wireless techniques. For instance, the extent to which the time and frequency domains can be used to enhance reliability is limited. The time domain is limited because the need for low latency excludes retransmission of dropped frames. The frequency domain is limited because obstructions such as metallic objects tend to affect all bands to some degree. One proposed solution is to take advantage of spatial diversity and Coordinated MultiPoint (CoMP) to enhance the reliability of 5G wireless connections.

CoMP is normally associated with increasing capacity in a wireless system. However, the same techniques can be used to achieve greater reliability. By using multiple transmission reception points (TRPs) to coordinate parallel data streams between the UE (e.g., a robot or AGV) and the network, CoMP can greatly increase the probability that packets will arrive. Using CoMP with multiple TRPs to increase reliability is shown in **Figure 7** below.

Figure 7: Using Spatial Diversity (CoMP) to Increase Reliability



Source: Qualcomm

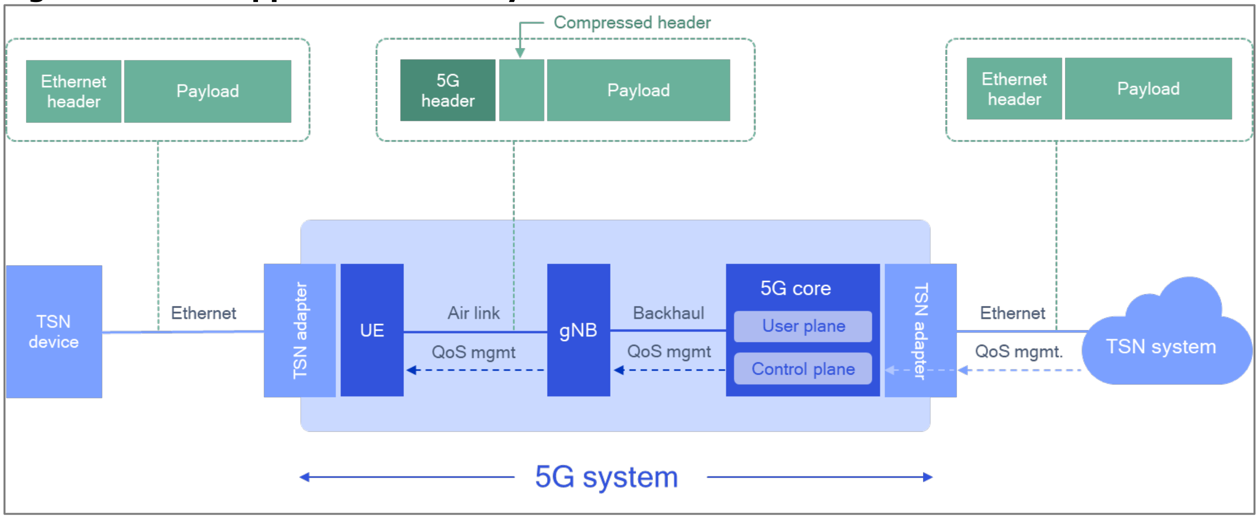
Tests have shown that 5G CoMP can overcome blocking in challenging radio environments to achieve the 99.9999% availability target (i.e., only one packet in a million is lost) set by the 3GPP. Moreover, in contained deployment environments such as factory floors, placement of multiple TRPs is eminently practical from a deployment perspective. This novel use of spatial diversity is likely to prove important, regardless of spectrum band, in industrial applications where reliability is critical. This is a breakthrough application of CoMP technology in 5G.

Time-Sensitive Networking

The ability to transport TSN over a mobile wireless network looks set to be one of the major technical achievements of 5G development. TSN is an IEEE standard designed to provide deterministic messaging on standard Ethernet networks. It is a Layer 2 technology that is centrally managed and uses coordinated scheduling to ensure deterministic performance for real-time applications. This is important to many industries – for example, aerospace, automotive, transportation, utilities, and manufacturing – and TSN is likely to become the baseline networking technology for real-time industrial networking.

Importantly, 5G Release 16 can interwork with existing wired TSN systems. As shown in **Figure 8** below, 5G defines adapters for interworking with TSN devices and systems. These adapters map TSN configurations to the 5G QoS framework to provide efficient transport of Ethernet frames via header compression. Because many industrial devices require microsecond time sync, the 5G system can also provide precise synchronization to these applications using a common 5G system time.

Figure 8: TSN Support in the 5G System



Source: Qualcomm

Accurate Positioning in 5G NR

3GPP Release 16 introduces 5G positioning, which has many applications in future networks. In the industrial market, one of the major findings from the requirements gathering process was the strong demand for indoor positioning to track assets, inventory, production equipment (such as AGVs), and so on. In many cases, GPS, Wi-Fi, and LTE are not reliable or accurate enough indoors.

5G NR has a number of characteristics that make accurate positioning possible. These include the use of multiple input, multiple output (MIMO) antenna arrays and wide bandwidths, which enable relatively accurate direction of arrival (DoA) and time of arrival (ToA) estimation, especially in line-of-sight conditions. This works particularly well where multiple TRPs are deployed with CoMP.

The requirement for positioning accuracy varies by application; in some cases, accuracy in the range of meters is adequate, and in other cases, tens of centimeter are needed. It is also influenced by factors such as time-to-first-fix and velocity of the tracked object. For example, some types of unmanned aerial vehicles may need decimeter accuracy, while tracking heavy industrial plant may only require accuracy in the range of meters. Depending on the network configuration, 5G networks can provide accuracy in the range of meters down to the 3GPP target of 20 cm.

To ensure 5G positioning is robust and accurate, the 5G framework can integrate non-3GPP techniques into a hybrid positioning scheme to improve accuracy and reliability. This typically means using on-device techniques, such as accelerometers, gyroscopes, compasses, computer vision, and GPS, to work in tandem with network positioning.

SPECTRUM FOR PRIVATE 5G NETWORKS

Private networks need spectrum. One of the major reasons enterprises do not routinely use mobile network technology is because it operates in licensed spectrum and requires either a license from the national regulator or an agreement with a license holder, typically a mobile operator. This licensed spectrum model will continue in 5G. However, a range of new spectrum options is emerging that will help private network adoption scale rapidly.

Spectrum Options for Industrial IoT

Private networks can use spectrum across a range of frequencies, subject to diverse license terms. From an industrial IoT perspective, it is important that spectrum is available, supported by a product and integrator ecosystem, and subject to stable regulations that allow for long-term planning. These are all important to for industrial users seeking to make major investment into operational technologies that have long life cycles.

Figure 9 summarizes four major spectrum options open to industrial companies looking to deploy private 5G networks. In Heavy Reading's view, all these options are valid and are likely to be used extensively, national regulations permitting.

Figure 9: Spectrum for IIoT

Spectrum Type	Description
Licensed Spectrum Owned by Operators	• Continuation of the classic spectrum licensing model • Protected use makes this spectrum attractive to users with reliability concerns • Mechanisms to lease/share spectrum for private networks are in development
Dedicated Enterprise Spectrum	• Model being pursued in multiple markets • E.g., Germany to allocate 100 MHz (3.7-3.8 GHz) to industrial users • Attractive where available; however, some risk of being a niche ecosystem
Unlicensed Spectrum (w/ Asynchronous Sharing)	• 5 GHz is the lead band; U.S. to open 6 GHz, with Europe to follow • Listen-before-talk regulations already embedded in 5 GHz • Most useful for private 5G networks that do not require URLLC
Unlicensed Spectrum w/ Synchronized Sharing	• In new unlicensed allocations (e.g., 6 GHz), there is an opportunity to introduce new sharing mechanisms • Over-the-air synchronization is a lightweight way to improve sharing • Enables more reliable performance in co-sited deployments; makes unlicensed spectrum suitable for URLLC applications

Source: Heavy Reading

The emergence of the Citizens Broadband Radio Service (CBRS) spectrum in the U.S. 3.5 GHz band shows how attitudes toward shared spectrum are changing. This and innovations such NR-Unlicensed (NR-U) will make it easier for non-operators to deploy mobile technology. Not coincidentally, 5G NR systems are in development for several shared bands.

Unlicensed 5G (NR-U) for Private Networks

3GPP is working to standardize the operation of 5G NR in unlicensed spectrum in Release 16. This has the potential to enable private networks to expand rapidly. Two main scenarios exist for unlicensed 5G:

- **5G NR deployed with a licensed anchor:** This is sometimes known as License Assisted Access (LAA) NR-U and is an analog of LTE-LAA. It is best suited to public network operators seeking capacity gain from access to 5 GHz spectrum. In time, it will extend to unlicensed 6 GHz and millimeter wave (mmWave) spectrum.
- **5G NR deployed in unlicensed spectrum only:** This is sometimes called standalone NR-U and is very interesting for private networks. There is an analog to standalone NR-U in MulteFire for LTE. However, in the 5G case, NR-U is being specified early in the 3GPP standards process. This makes NR-U more of a native mode of operation for 5G.

There are also two main modes of spectrum sharing proposed for 5G in unlicensed scenarios:

- **Asynchronous shared spectrum for NR:** This is the evolutionary path that works within the existing coexistence rules applied to unlicensed spectrum – i.e., NR must respect listen-before-talk (LBT) sharing protocols when deployed in these bands. NR can employ a number of techniques to improve reliability and availability in these shared spectrum bands.
- **Synchronous shared spectrum:** This is a more advanced scenario now under evaluation and development. It provides great potential to share spectrum more efficiently, with more predictable, reliable performance. However, this approach requires sharing mechanisms with a common synchronization reference among operators and will need support from regulators. In the U.S. initially, and later in Europe, the 6 GHz band is a good candidate for this approach.

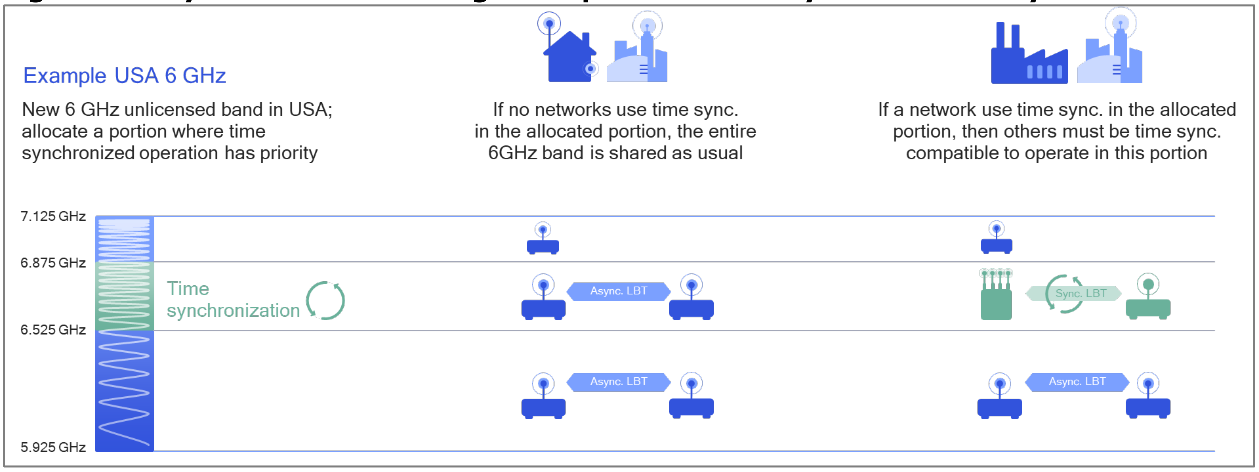
Coordinated Use of Shared Spectrum

Unlicensed spectrum is, by definition, shared spectrum. Interference with other users is controlled by power limits (low power is typical) and contention-based LBT mechanisms that allow networks to opportunistically exploit airtime. Contention-based systems work best when there are limited users competing for the channel, but end-user performance and spectral efficiency can suffer when there are many competing users. There are ways to offset this – particularly via network design – but it is nevertheless challenging for industrial applications with strict reliability requirements.

One proposed solution that preserves the benefits of unlicensed spectrum (i.e., deployable by all) and addresses the sharing challenge is to synchronize access to network airtime in a mutually beneficial way. In combination with spatial sharing (CoMP), this can increase capacity and enable predictable QoS, making unlicensed spectrum more suitable for URLLC services and industrial users.

This type of coordinated sharing requires fresh spectrum that is not encumbered by existing regulation, which rules out the 5 GHz band. An interesting option being explored in the U.S. is the 6 GHz band, which the Federal Communications Commission (FCC) is planning to allocate for unlicensed use. One proposal is to require time synchronized sharing in a portion of the band, as shown in **Figure 10**, while the remainder is shared as usual (i.e., in a similar way to 5 GHz). In this example, if there are multiple users – such as two industrial IoT users – in the synchronized portion of the band, they can coordinate using time synchronization.

Figure 10: Synchronized Sharing to Improve Efficiency and Reliability



Source: Qualcomm

In simulation results submitted to the FCC by Qualcomm Technologies, Inc. in response to the Notice of Proposed Rulemaking for 6 GHz, this technique has been shown to increase capacity by the following amounts:

- **Indoor:** NR-U Sync provides ≥ 25% capacity gain over asynchronous baseline (5 GHz LBT medium access procedure with NR-U)
- **Outdoor:** NR-U Sync provides ≥ 40% capacity gain over asynchronous baseline (5 GHz LBT medium access procedure with NR-U)

More detailed information on these NR-U simulations, with additional comment on synchronous sharing with CoMP, are available in this comment to the FCC's Notice of Proposed Rulemaking available here and in this ex parte filing available here.

Dedicated Enterprise Spectrum

In some markets, regulators are investigating, or already allocating, licensed spectrum to enterprise verticals to run private networks, particularly for industrial IoT. This typically means licenses with small geographic areas to ensure reuse and access to spectrum by as many companies as need it. This type of allocation would also benefit from coordination between adjacent networks.

Dedicated enterprise spectrum for private networks is contentious. This model is championed by large industrial companies because it gives them surety of tenure and predictability for network performance. This makes it ideal for industrial IoT. Some mobile operators are concerned that dedicated spectrum may result in fragmentation and inefficient use of spectrum and are resistant to the model. Heavy Reading believes dedicated spectrum to be an attractive proposition for industrial IoT and, while there are valid concerns that the ecosystem will be too small for large-scale exploitation, believes it will improve as more markets and enterprises adopt the model.

Figure 11 summarizes regulatory activity around the world on initiatives to allocate spectrum suitable for private mobile broadband networks in mid-2019. This is not a complete list, and the picture is constantly changing as more countries undertake evaluations, identify license terms, create application processes, and so on. The breadth of activity internationally indicates momentum for this model is increasing.

Figure 11: Shared Spectrum for Private Enterprise Networks

Country	Spectrum	Coordination	Status
Global	5 GHz	Unlicensed	Available
U.S.	3.5 GHz CBRS band	Exclusive and shared licenses	Deployments in 2H 2019
	6 GHz	Proposed unlicensed	Under evaluation
	57-71 GHz	Unlicensed	Available
	37-37.6 GHz	Shared spectrum; local licenses	Under evaluation
	116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz	Unlicensed	Approved; effective date TBD
China	5.9-7.1 GHz or portion of this band	Indoor only	Under evaluation
Hong Kong	24.25-28.35 (400 MHz)	Local licenses; regulator approval	Approved; available 3Q 2019
Australia	24.25-27.5 GHz	Under evaluation	Under evaluation
Japan	Phase 1: 2,575-2,595 MHz (as NSA anchor) and 28.2-28.3 GHz	Local licenses	Technical conditions approved; legislation planned in December 2019
	Phase 2: 4.6-4.8 GHz and 28.3-29.1 GHz	Local license; regulator database may be used, but not determined	Consultation planned August 2019; legislation planned 3Q 2020
Europe	6 GHz	Under evaluation	Under evaluation
	26 GHz	Under evaluation	Under evaluation
Germany	3.7-3.8 GHz	Local licenses	Assignment complete; available 2H 2019
U.K.	3.8-4.2 GHz (multiple 10 MHz licenses)	Local licenses (50 meters square); regulator database	Decision formalized; applications invited from end 2019
	57-71 GHz	Unlicensed	Available
Finland	Sub-licensing of 3.4-3.8 GHz	Local permission via operator lease	Assignment complete
Sweden	3.7-3.8 GHz	Consultation	Consultation

Country	Spectrum	Coordination	Status
Netherlands	3.7-3.8 GHz	Local licenses	Consultation
	2.3-2.4 GHz	Licensed shared access online booking system	Approved for programme making and special events (PMSE)
	3.5 GHz	Local license; online booking system	For industrial use; users may need to move to 3.7-3.8 GHz
France	2.6 GHz (20 MHz of time-division duplex [TDD])	Regulator database and approval	Approved for Professional Mobile Radio (PMR)

Source: Heavy Reading

CONCLUSION

The needs of industrial users and their application performance requirements are central to the development of the 5G system. The wireless industry is motivated to expand the addressable market for mobile systems and services. Meanwhile, industrial companies are motivated to contribute to 5G technology development because of the opportunity to redesign and optimize production processes using mobile network technology. The result is detailed, positive collaboration between the two groups.

The 5G system incorporates myriad innovations to support private networking natively, many of them intended to specifically address industrial use cases. 3GPP Release 16, to be frozen in March 2020, will be a landmark release for this market. The depth of R&D investment in Release 16 capabilities from across the industry is a mark of the importance of industrial IoT and should create confidence in the technology roadmap among customers.

Access to spectrum is one of the keys to unlocking the private networking market. The ability to deploy networks without dependencies on public cellular systems or licensed operators gives enterprises greater ability to control their operations and removes friction from the market. Dedicated enterprise spectrum and shared unlicensed spectrum are both important to accelerate the adoption of private networks. Simulations and trials show how NR innovations such as CoMP and synchronized sharing can be used to achieve consistent, highly reliable performance in these shared spectrum bands.

Dedicated and unlicensed spectrum does not, however, mean there is no room for operators in this market. Heavy Reading believes spectrum will, in many cases, be decoupled from the decision about who designs, operates, and maintains private networks. Already there is evidence that operators themselves see opportunities in dedicated enterprise spectrum, and several are preparing to offer managed private networks in these bands. There is also a very large market for wide-area and multi-site services to industrial companies alongside the private network market.

Private 5G mobile networks for industrial users are emerging as one of the leading advanced 5G use cases. The strategic importance of industrial IoT is reflected in today's industry R&D and investment priorities.