How to deploy and scale Private Wireless 5G Networks

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Executive Summary

Private cellular networks are an opportunity for a wide range of enterprises to implement digital transformation initiatives, such as Industry 4.0, that can greatly improve operational efficiencies and responsiveness to market trends.

Private cellular networks are based on 4G LTE and 5G New Radio (NR), the exact same technologies being used by mobile network operators (MNOs) around the world. Private cellular networks:

- Use a variety of cellular radio frequency (RF) spectrum bands that are licensed, unlicensed and lightly licensed.
- Enable diverse and growing standards-based ecosystem of network equipment and devices (e.g., phones, tablets, scanners, cameras, etc.).
- Offer carrier-grade security, scalability, and reliability.
- Deliver cutting-edge capabilities such as reliable, high throughput, ultra-low latency and Internet of Things (IoT) support.

Digital transformation is based in part on the notion that by combining data – from customers, suppliers, machines and/or sensors – with machine learning (ML) and artificial intelligence (AI), an enterprise can fundamentally improve its operations. Private cellular networks are key to this process because they provide value that that cannot be as easily found or replicated with other network solutions. Moreover, private cellular networks are deployable today built entirely on commercial off the shelf (COTS) hardware.

Once deployed, the private network will grow and adapt as the enterprise's needs change. For example, in 2021, Chicago O'Hare airport installed a private network as a dedicated wireless network to facilitate communications via video kiosks between passengers at the airport and remote support staff. That video communications platform will likely grow over time as more kiosks are needed, usage increases and new functionality is added. Thus, the initial private network solution must be able to grow and scale as needs change over the years.

iGR has forecasted the total five-year spending (2021 – 2026) on private Citizens Broadband Radio Service (CBRS) network build, operations, systems/network integration and applications in 12 different U.S. industry vertical to total $22.5 billion.

In a very real sense, it is the IT equipment vendors who are driving the adoption of private cellular networks – IT vendors view private cellular networks, virtualized radio access networks (RANs), Open RAN, as another iteration in the trend toward edge- and cloud-based approaches to network and software architecture.

Supermicro has developed a range of products to support private cellular network deployments and future growth. Initial deployments are relatively easy. Supermicro's approach ensures that those first installs are durable, reliable, scalable and, perhaps above all, futureproof.

Growth of Private Cellular Networks

What is a private network?

A private network can operate on 4G LTE or 5G New Radio (NR), in any spectrum band, and provides mobile/cellular (or fixed wireless) services to a specific set of devices which can be smartphones, tablets, cameras, machines or sensors – basically anything that can be identified via a SIM card.

With a private cellular network, the enterprise, not a mobile network operator, determines and controls who accesses its network. Typical use cases for private networks that span industry verticals include:

- Various Internet of Things (IoT) solutions that include sensors tailored smart building solutions (e.g., temperature, light, access, location, proximity, etc.).
- Introduce digital transformation solutions: For example, manufacturers are interested in 5G because the technology allows them to adopt Industry 4.0 initiatives.
- Neutral host networks: An enterprise installs a private network in its offices and then, via a standards-based approach, enables an MNO (e.g., AT&T, Vodafone, Telefonica, Optus, etc.) to provide cellular voice/data service via the enterprise's private network.
- Secure voice/data communications via the private network: This could be provided for employees or made available to third parties.
- Wired network alternative: Depending on the spectrum band used, a private cellular network can provide high-throughput connection to devices which could enable the private network owner to avoid pulling new wires and thus avoid those installation costs.

A few specific examples of how private cellular networks have been used include the following:

- Education: The Fort Worth, TX and Fresno, CA Unified school districts, among many others, deployed CBRS-based fixed wireless access networks so that students would have broadband internet.
- Ports: In the UK, Belfast Harbour and BT are building a 5G ecosystem across large parts of the more than 2,000-acre operational area of the port.
- Transportation: In India, Nokia is working with Alstom to deploy a private wireless network on the forthcoming Delhi to Meerut regional rapid transit system.
- Industrial: For a large industrial facility in Florida, MicroSeismic is using CTS's private LTE wireless Network-as-a-Service (NaaS) solution over CBRS to support sinkhole detection.
- Agriculture: A collaboration among Federated Wireless, Blue White Robotics and Inland Cellular brought a private CBRS network to a 2.1 square mile vineyard in California.

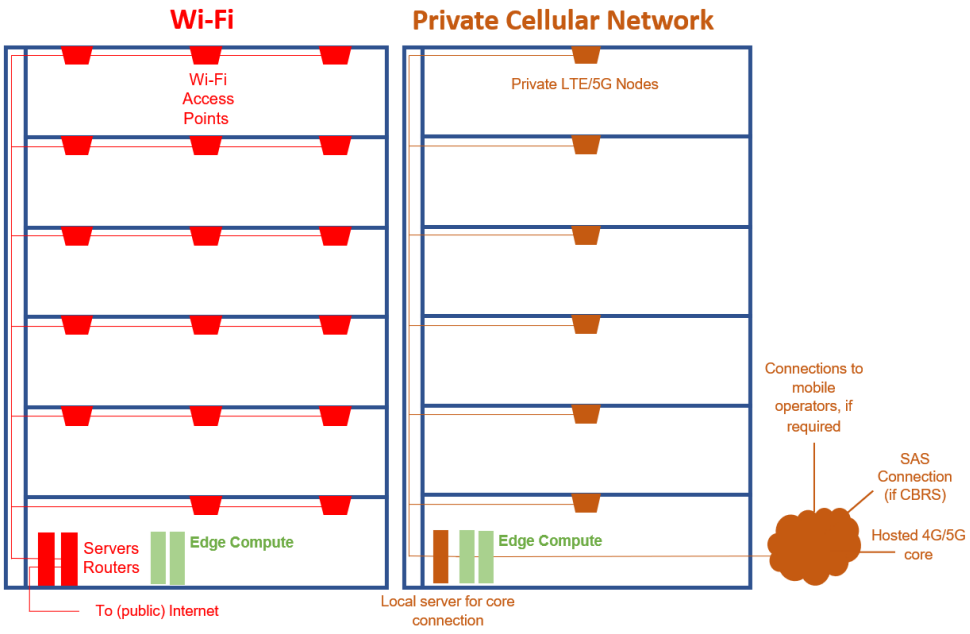
Private cellular network components

There are many components needed to deploy a private cellular network, including:

- Radios and antennas (the radio access network or RAN) form the "last mile" connection between cell site and smartphones or other devices. The cellular radio transmits and receives over various low-, mid- and high-band RF spectrum, using the 4G LTE or 5G NR air interface.
- Evolved Packet Core (EPC): In LTE, the EPC is the "brains" of the network and is responsible for the core IP processing functionality of the cellular network.
- SIM cards or eSIM: An electronic/embedded cards securely hold all the information required to connect to the cellular network.
- Edge compute is increasingly being incorporated into private cellular networks because it is a way to move application storage and processing functions closer to users/devices.
- Backhaul/WAN connection: This is the wired broadband connection between the RAN and the network core.

One common question regarding private cellular networks is how that network platform compares to the ubiquitous Wi-Fi. In short, the two network technologies are complementary. The following figure and table provide a side-by-side comparison of the benefits and drawbacks of each technology.

Figure 1: Side by Side Basic Network Architecture: Wi-Fi and Private Cellular



Source: iGR, 2022

Table 1: Comparing Private Cellular and Wi-Fi

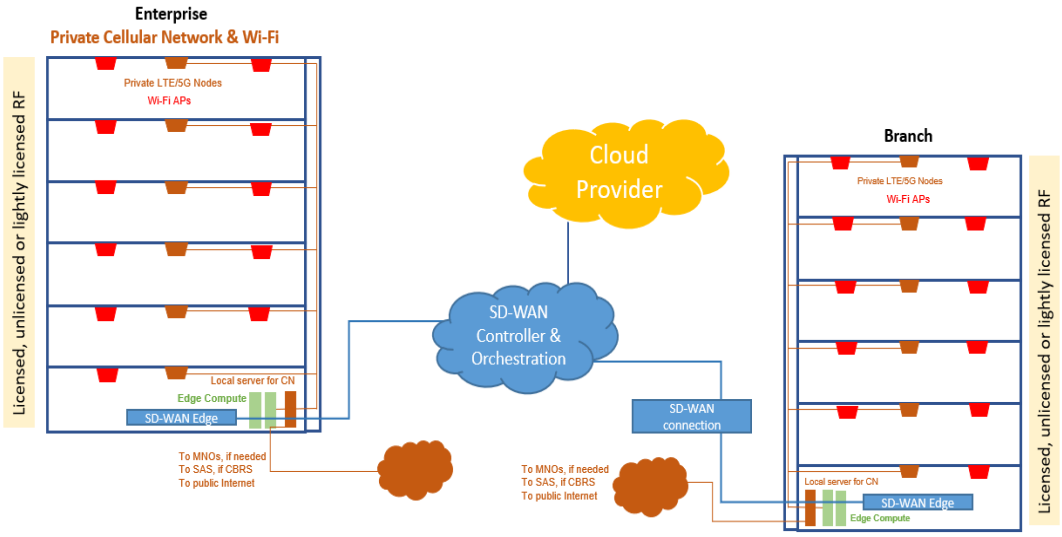
	Wi-Fi	Private Cellular
Benefits	▪ Relatively low cost and easy to install ▪ Well-established technology with a wide and varied device ecosystem ▪ Relatively easy to manage and maintain ▪ Unlicensed spectrum, which means the spectrum is free to use ▪ Cellular integration possible	▪ Can deploy without an MNO (if using CBRS in the U.S.) ▪ Supports high bandwidth/low latency services ▪ Wi-Fi and private networks can use the same building wiring infrastructure ▪ Can use 4G or 5G technology ▪ Can use licensed or unlicensed spectrum, depending on what is available per country ▪ Large ecosystem of network equipment, devices, and vendors ▪ Tools to deploy the 4G/5G core in the cloud and manage remotely ▪ Scale number of nodes and devices supported by adding spectrum ▪ Security, policy enforcement and network management tools are the same as for a cellular network, allowing policy to be defined per-device
Drawbacks	▪ Poor coverage: More Access points (APs) required to cover an area compared to alternatives ▪ Poor coverage means more nodes which means higher cost ▪ Poor upgradeability between versions – usually requires new equipment when a new version is released ▪ Poor policy and management capabilities: cannot differentiate traffic between users/devices ▪ Security questioned by many ▪ As more users and devices are added, it becomes congested due to poor traffic management	▪ More complex technology, unfamiliar to IT/OT staff ▪ Requires 4G/5G skillset and/or knowledge of cellular/RF networks and their management ▪ Limited 5G CBRS devices are available, but the ecosystem is growing quickly ▪ SIM management, although eSIM will greatly simplify.

Source: iGR, 2022

The following graphic illustrates how Wi-Fi and private cellular can be combined to cover multiple buildings, while also being interconnected via SD-WAN. Note that edge compute can be deployed in either scenario as a way to:

- Enhance local processing and thus potentially “offload” the data sent off premises
- Improve latency (by lowering it) and thus improve the efficiency/functionality of applications deployed on the edge platform.

Figure 2: Private Cellular, Wi-Fi and SD-WAN



Source: iGR, 2022

Benefits of a private cellular network

There are many benefits associated with private cellular networks:

- **Security**: Cellular networks use several levels of 3GPP-specified security architecture, which include SIM cards and UICC tokens, device and network authentication, air interface protection, and network and backhaul protection (via encryption and other techniques). In 5G NR, the security framework was expanded to include the use of the extensible authentication protocol (EAP) which is commonly used in enterprise IT environments.
- **Mobility**: LTE and NR are obviously designed to support mobile connections, which allows the private network to hand-off connections, resulting in seamless connectivity as needed.
- **Scalability**: This can be looked at in two ways. First, there is a diverse and expanding ecosystem of devices that can be used on cellular networks. And secondly, the number of devices which can be supported on the network - 5G will deliver support for up to one million devices per kilometer squared (or one device per meter squared) for urban environments.
- **Encrypted air-interfaces (LTE, 5G)**: AES is one of the algorithms that is used to protect the LTE air interface. IPSec is typically used to encrypt the backhaul connection.
- **Policy**: the policy function enables the network manager to define different user and device profiles, thereby enabling multiple levels of access and performance.
- **Manageability**: Enables the management of devices (updates, add/removes/changes, etc.) and subscriber information. This capability reduces the manual resources needed to manage the network and users, lowering operating costs and improving the ROI.
- **Spectrum availability and throughput**: Multiple spectrum bands are available worldwide, both licensed and unlicensed, to support private networks. These bands can support a variety of throughput, enabling high bandwidth applications as needed.

Spectrum considerations

Each RF band has different propagation and throughput characteristics. Most of those bands are licensed to MNOs, but a few are not. Because there are many different bands available, an enterprise interested in a private cellular network can work with an MNO to use the RF band that best meets their use case – or do it themselves by using an unlicensed (or lightly licensed) cellular band such as CBRS in the U.S.

An enterprise deploying a private cellular network can use either 4G or 5G depending on what spectrum band(s) they choose:

- If the MNO controls the bands, then the enterprise must use what the MNO has deployed in that band (4G or 5G). Over time, 5G will be deployed in all spectrum bands by most (if not all) MNOs.
- If the enterprise chooses an unlicensed or lightly licensed band, such as CBRS in the U.S., then they must use either 4G or 5G, depending on what the equipment vendor or spectrum band supports.

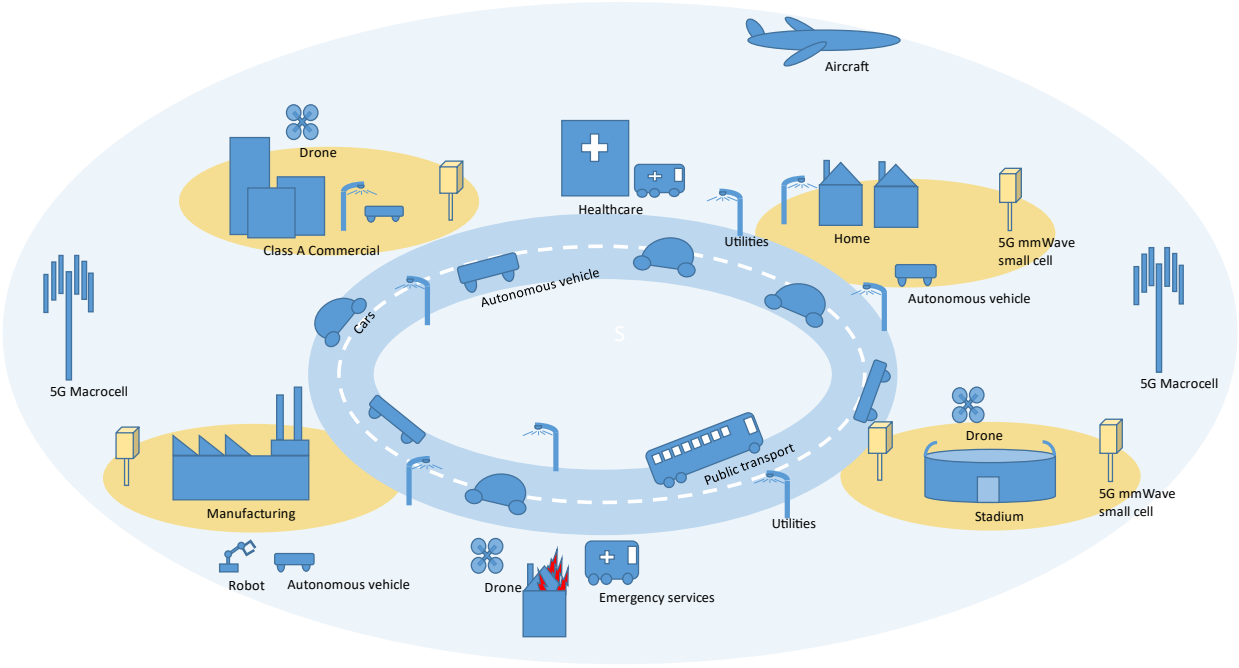
Either way, the enterprise will be using the same network and device technology as the MNOs use in their public mobile networks. In fact, the enterprise-specific equipment and technology are usually scaled-down versions of the same gear the MNOs purchase and deploy. So, enterprises benefit from access to highly reliable, durable, and resilient network gear that has gone through exhaustive testing and trials and is supported by a wide vendor ecosystem.

How is a private cellular network deployed in an enterprise?

The following graphic illustrates how LTE/5G networks are used across a hypothetical city. Any one of these broad use cases can be implemented as a private cellular 4G/5G network using licensed, unlicensed, or lightly licensed spectrum bands.

A private cellular network could be deployed outside, on macrocells and/or small cells, and/or indoors on small cells. Some use cases, such as smart logistics or emergency medical services, would greatly benefit from a private cellular network that spans a city or geographic region. Others, such as an Industry 4.0 use case inside a factory might not require any wider area connectivity.

Figure 3: Cellular 4G/5G Use Cases



Source: iGR, 2022

The following is an overview of the basic steps when considering private cellular as a solution to the above use case:

- Identify the use case(s) and elucidate what the network must do with respect to capacity and throughput, latency, mobility, coverage (indoor/outdoor/mixed), devices required (e.g., sensors, smartphones, cameras), etc. The use case(s) will help the enterprise pick the appropriate cellular spectrum band(s).
- Identify the spectrum bands: Private cellular can use multiple different spectrum bands (which vary by country), an enterprise must first choose between a licensed band that is controlled by an MNO or an unlicensed (or lightly licensed band) that is not.
    - If licensed, then the enterprise needs to work with the MNO to get the private network deployed or, potentially, with a systems integrator (SI) who has an agreement with the given MNO.

- If unlicensed, or lightly licensed (like the U.S. CBRS band), then the enterprise can select and deploy its own network without MNO involvement.

- In either case, it makes sense to perform a detailed RF survey that will capture the propagation characteristics of those bands in the environment(s) in which the private network will be deployed.

- Design and planning: These involve architecting the private cellular RAN based on the RF survey results and the use case(s).

- Installation comes next, with the RAN deployed, the backhaul network configured, devices provisioned, etc.

    - RAN: Private cellular radios are deployed in the same way as Wi-Fi access points. Each site (node) requires a mounting point, power (which could be provided over Ethernet), and backhaul (Ethernet). All of this cabling needs to originate from an accessible place that provides, ideally, room for growth.

    - Core network: The EPC/5GC can be installed locally or in the cloud.

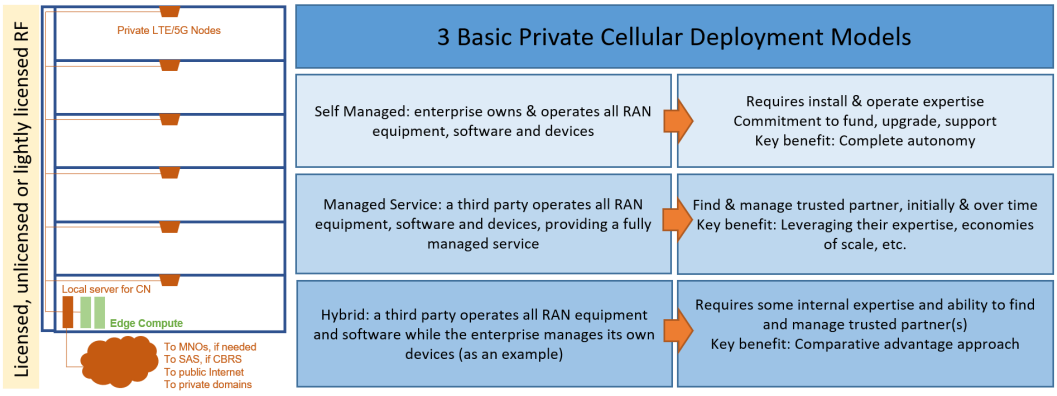
    - Security is a critical piece. Some of this is automatic, as the air interface is encrypted, but the new network is a "hole" in the enterprise's existing security architecture, and it needs to be protected.

- Configuration, testing, tuning, etc., are all important since the private cellular network needs to be tuned and optimized for the use case(s).

- Operation is the final phase of deployment. Network performance can and should be monitored via key performance indicators (KPIs), create alarms and alerts to automatically notify management of any problems as well as set-up automated actions to take place when issues occur.

Private cellular network solutions vendors have, to date, made their offerings reliable and robust, as well as friendly to the expertise of the enterprise IT staff who will be installing and maintaining the solution. In that vein, the following figure shows the three basic private cellular deployment models along with some of their key benefits.

Figure 4: Three Basic Private Cellular Deployment Models



Source: iGR, 2022

Use of virtualization and COTS

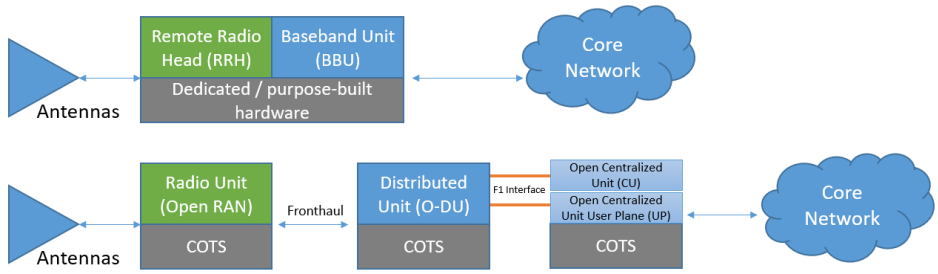
Multiple vendors have developed software-based RAN systems that run on commercial off-the-shelf (COTS) servers. The push toward software-based, virtualized RANs and Open RAN has driven the established cellular equipment vendors to invest considerable resources into transitioning from their proprietary software and hardware systems to software that runs on standard COTS servers, or if not true, then highly customized, Intel®-based architectures.

For the enterprise, one key driver of COTS is artificial intelligence (AI) and machine learning (ML) which are being used in various technologies (e.g., object detection via cameras, AR/VR, etc.) to enhance productivity, improve security, and automate various business processes. All-in-one, proprietary servers are insufficient for these types of use cases because they cannot scale beyond their configurations. However, COTS servers with pre-certified GPUs and workloads based on micro-services, virtualization, and containerization can enable those types of use cases.

The following figure is an oversimplified representation of how COTS can be used in the mobile network:

- Top diagram: Current mobile networks are architected with purpose-built hardware running purpose-built software at the base station site.
- Bottom diagram: Open/Cloud RAN software, along with architectural changes in 5G, cause the disaggregation of the radio unit from the distributed unit (which is basically the BBU) control and user planes.

Figure 5: Simple Example of the Mobile Network on COTS



Source: iGR, 2022

This trend, particularly in the context of the 5G Service Based Architecture (SBA) and the split control plane and user plane, which is also part of 5G, will enable operators and/or enterprises to:

- Choose separate network hardware and software packages.
- Scale the hardware independently of the software (and vice versa).
- Select from potentially a wider range of software packages than might be available from a single provider.
- Deploy the RAN and core network in a data center environment which they could either own and manage themselves or outsource to a third-party (e.g., AT&T has outsourced its core network operations to Microsoft Azure). In effect this allows the cellular operator to capture economies of "hyper" scale.

These trends are largely driven by hyperscalers and IT equipment vendors because they see private cellular networks to disrupt the cellular market. To these vendors, the RAN and core network should be software running on hardware – they view it as an IT challenge to be solved. Today, COTS hardware can deliver, via data center-proven approaches and architecture, the redundancy, reliability, and scalability necessary to run mission-critical communications and applications – as well as solutions that do not necessarily require all those capabilities.

Future proofing the enterprise private cellular network

Networks should be built knowing that they will scale over time. Private cellular networks are no different:

- Radios can be added or upgraded, along with new sectors and potentially new RF spectrum bands and/or functionality (carrier aggregation, higher modulation, higher orders of multiplexing, etc.).
- Core network capacity can be added to support more radios, devices and/or new applications. Because the core network is software, it can be upgraded relatively easily, assuming it was deployed on a server that is compatible with a future roadmap.
- Edge compute capacity can be added to support new applications and services.
- Adding new devices – UEs, sensors, cameras, automated guided vehicles (AGVs), point of sale devices, etc. – can probably be done without necessarily scaling the rest of the network. Still, there will likely come a point where the RAN must be scaled to support those devices.
- Backhaul capacity may need to be scaled up as the private cellular network grows.
- Security must also scale to support new devices, applications, radios, edge servers, backhaul, etc.

Note, as well, that although enterprise private cellular networks are relatively new, the principles of indoor/outdoor cellular network design are well known, and best practices have been developed over the past few decades.

Lifecycle of a private cellular network

In 2021, Chicago O'Hare airport installed a private network as a dedicated wireless network to facilitate communications via video kiosks between passengers at the airport and remote support staff. That video communications platform will likely grow over time in one or more ways including:

- Number of kiosks and where they are located, which might require adding sectors and/or nodes and adding backhaul to the nodes and maybe to the entire network
- Increased Usage: This would mean more throughput required which would require more backhaul per node
- Extending capabilities: Maybe new functionality is added to each kiosk, which might mean scaling back-end servers, edge compute, etc.

A recent proof of concept private cellular network deployment in the agriculture sector uses the network as a digital foundation for autonomous drones and machine vision, AI-enabled mobile sensors, and an environmental control platform. This use case is focused on efficiently growing plants in a vertical farming environment. It could scale in any number of ways including additional sensors, drones, software packages, etc.

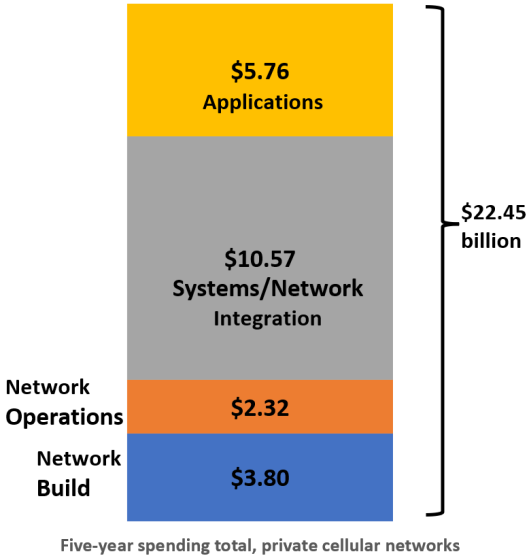
The education sector is replete with examples of private networks being used to provide internet connectivity to underserved homes in rural and urban areas. These networks can

scale simply because more and more homes connect, which will likely mean new sectors and/or nodes, which in turn means more backhaul, a larger core network, etc.

These same examples can apply to most industry sectors. For example, a warehouse might add a satellite facility, or a hospital might build a new wing. As those buildings are built, they will need to be included in the network.

Sizing the private cellular opportunity

Figure 6: Total Five-Year Spending on U.S. Private CBRS Networks



Source: iGR, 2022

iGR forecasted the total spending over five years (2021 – 2026) on private CBRS network build, operations, systems/network integration and applications in 12 different U.S. industry vertical markets.

Across those spending components, iGR estimated that the total spending opportunity over five years is $22.5 billion. The figure on the left shows how that spending breaks out by category.

Private networks add value

MNOs are in the business of providing connectivity, as are wired broadband providers, cablecos, etc. Most other enterprises are about developing, making, and selling a different type of product or service to as many people as possible. For those enterprises, the network is a means to that end, as are all the solutions running on that network. If owning and operating is less expensive than outsourcing it, then that is what they will do. If the reverse is true, then they will do that.

For an enterprise to invest in a private cellular network, it must add new value that cannot be obtained, as easily or cost-effectively, from the alternatives. Because private cellular networks can run on COTS, an enterprise's existing IT staff can, with some training and guidance, come to run that network as competently as they run their existing network infrastructure. IT is already familiar with many of the concepts that are just now, with 5G, coming to both public and private networks: virtualization, cloud-enabled, -ready and -based, edge computing, among others. And, as mentioned, the IT vendors are in the private cellular network vanguard.

The following section provides an overview of what Supermicro has brought to the private cellular network table.

Supermicro products and services

Supermicro offers a range of scalable products to support a greenfield enterprise private cellular network and its scaling over time. For example, Supermicro's products can be deployed in multiple locations: on the customer premise, at an edge data center, in a central office or at a remote data center – or anywhere in between. Having employed a building-block approach to its deep product portfolio that addresses the most common computing requirements,

The following graphic shows three of Supermicro's products, the SYS-210TP-HPTRD and SYS-210SE-31A SuperEdge systems and the SYS-220HE-FTNR, each of which are built for multiple applications, including edge compute, Flex-RAN, Open RAN and virtual BBU, telecom DRAN, CRAN and edge core application. The SuperEdge systems feature up to four hot-pluggable systems (nodes) in a 2U form factor which support 3rd Gen Intel® Xeon® Scalable processors.

Figure 7: Sampling of Supermicro Products

Source: Supermicro, 2022

A worldwide supplier of advanced and state-of-the-art servers and storage systems, Supermicro offers a wide range of servers that address many industries with optimized products for various workloads and environments. Supermicro's product features include front- or rear- access, short-depth, AC or DC power, wide temperature variances and long lifecycles, as different sub-systems can be replaced. Systems can be configured as rack-, wall-, pole-mount for both indoor and outdoor use cases. Some products also feature immersion cooling, and all offer redundant power supplies.

Supermicro offers many different application-optimized systems that are frequently used in private 4G/5G cellular, telco, and edge deployments:

Open RAN

- A low 1U, 16.9 inch deep, NEBS compliant system with a single 3rd Gen Intel® Xeon® Scalable processor, featuring 3 AOC slots for flexibility (SYS-110P).
- For locations that require short-depth, Supermicro offers a 2U, 11.8-inch model with the same 3rd Gen Intel® Xeon® Scalable processor and 4 Gen-4 PCI-E slots (SYS-210P).

Edge Compute

- The Supermicro SuperEdge provides high-density computing and flexibility at the intelligent edge, feature 3 independent, front-accessible nodes in a 2U NEBS

compliant form factor. Each node packs a 3rd Gen Intel® Xeon® Scalable processor and a range of add-on cards (SYS-210SE).

- For deployments that require data center class performance at the edge, the 2U, 4-Node Supermicro is a great fit, with a single 3rd Gen Intel® Xeon® Scalable processor per node. Additionally, each node offers great versatility and scalability in storage, I/O, and memory (SYS-210TP).
- The Hyper-E features dual 3rd Gen Intel® Xeon® Scalable processors in a 2U, 22.6-inch form factor with NEBS compliancy, delivering high computing power for both telco edge and core applications (SYS-220HE).

IoT embedded / compact edge products

- The ultra-compact fanless E100 box is available with a range of processors, such as the Intel® Kaby Lake-U Core™ i3, which can run applications such as kiosks, interactive information systems, or environmental monitoring (SYS-E100-9S-L).
- The fanless E302 is built for key applications such as smart medical systems, AI/ML, and industrial automation. The fanless feature allows the system to operate with an Intel® Xeon® Skylake D processor in environments where regular systems cannot (SYS-E302-9D).
- For networking and security at the edge, the 1U, front I/O gateway with Intel® Xeon® Skylake D deliver high performance and throughput in a short-depth form factor (SYS-5019D).

Summary

Major IT equipment vendors such as Supermicro and Intel® are leading the charge toward enterprise adoption of private 4G/5G cellular networks. As discussed, these networks offer multiple benefits, including:

- A diverse and growing standards-based ecosystem of network equipment and devices (e.g., phones, tablets, scanners, cameras, etc.)
- Ability to implement the network without MNO involvement
- Carrier-grade security, scalability, and reliability
- Capabilities related to reliable throughput, latency and IoT support that cannot be as easily found with other network solutions.
- Enable the implementation of digital transformation, such as Industry 4.0, that can greatly improve operational efficiencies and responsiveness to market trends.

By working with Intel's family of processors, Supermicro has developed a broad portfolio of private cellular network products that provide all the benefits listed above. Importantly, Supermicro's products also provide durability, a high degree of futureproof scalability beyond the initial network deployment. These factors are key because private cellular networks are not just another network solution. They are a foundation on which digital transformation initiatives can be built.

About Supermicro

Supermicro is a global technology leader committed to delivering first to market innovation for Enterprise, Cloud, AI, and 5G Telco/Edge IT Infrastructure. We are transforming into a Total IT Solutions provider with environmentally friendly and energy-saving server, AI, storage, IoT, and switch systems, software, and services while delivering advanced high-volume motherboard, power, and chassis products.

For more information, visit www.supermicro.com.

About iGR

iGR is a market strategy consultancy focused on the wireless and mobile communications and digital infrastructure industries. Founded in 2000 by Iain Gillott, one of the industry's leading analysts, iGR researches and analyzes the impact new wireless, mobile and digital infrastructure technologies will have on industries, the competitive landscape and on a company's strategic business plan.

A more complete profile of the company can be found at http://www.iGR -inc.com/.

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