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THE BENEFITS OF CELLULAR MESH FOR PRIVATE 5G NETWORKS

An M37 Ventures Report
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ABOUT THIS PAPER

Overview

The demand for diverse electronic devices, real-time communications, and complex software applications is increasing. With that increase, many enterprises are quickly realizing the limitations of the different networks they have deployed to support their data demands.

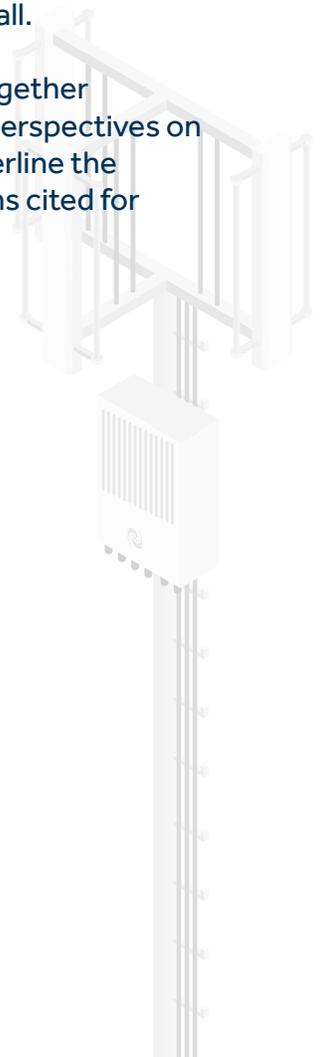
The Private 5G network for individual enterprises is a key solution for enabling data-intensive use cases locally as well as in the cloud for those organizations challenged with these connectivity problems – and they are evolving to handle many elements public cellular networks and WIFI coverage cannot.

Effective private cellular networks are available in different shapes, sizes, and approaches – as different as the many industries in which they can be utilized. Among the different approaches and technologies used for deploying private networks is cellular mesh technology – one of the newest form factors of network privatization.

The Paper & Our Process

M37 Ventures has put together this brief to explore one of the key technologies that will facilitate private 5G adoption for enterprises in the near future and beyond – cellular mesh technology. We interviewed senior technology leaders, telecommunications experts, buyers and distributors, and the engineers developing the technology to enable it all.

Additionally, we have put together resources, references and perspectives on the new technology to underline the perspectives and predictions cited for further learning.



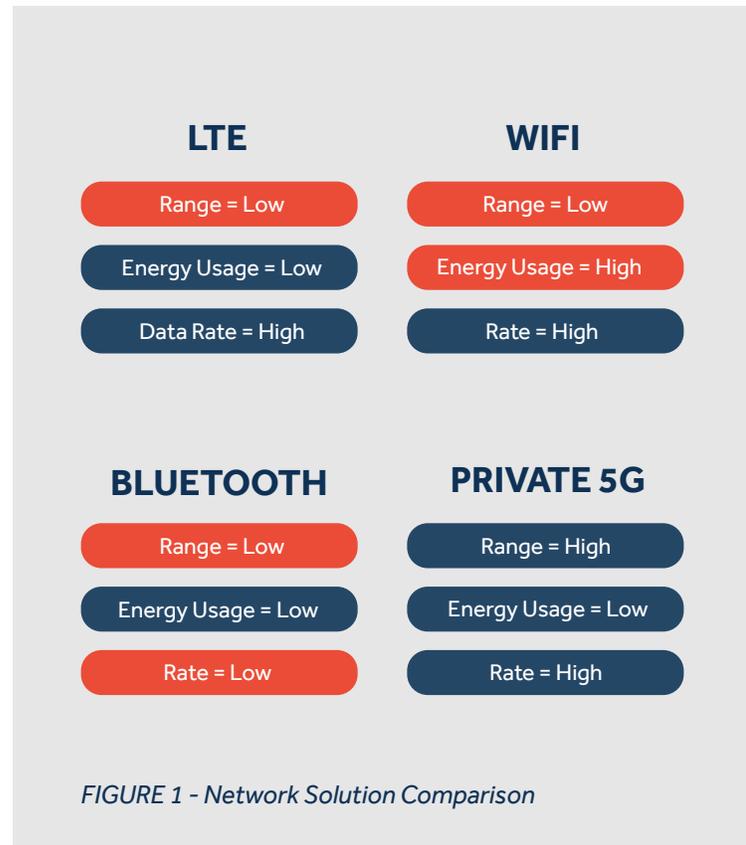
II

KEY POINTS & PERSPECTIVES

Companies are privatizing their networks now more than ever before. With increased speed, security, and reliability, the deployment of “private” networks is putting control back into the hands of enterprises, while simultaneously allowing them to remain on the cutting edge of connectivity.

First – let’s set the baseline for networks as context: large enterprises and small ones alike are using multiple types of network deployments to enhance coverage and operational capabilities wherever their operations are taking place. This enables advanced or increased speed of connections as well as better security and control of their applications and data. These might include carrier networks (e.g. T-Mobile, AT&T, Verizon or Dish), WIFI, fixed wireless, microwave, Bluetooth or even fixed-line Ethernet networks.

Presently, enterprises have a wide variety of solutions and combinations to choose from to cover their facilities with critical connection to the network for tasks and operations. From public cell networks hosted on-premise by carriers, to WIFI and Distributed Antenna Systems (DAS), or WAN solutions with Ethernet and optical fiber backhubs, to Bluetooth transmitters, there are a variety of ways, with varying effectiveness, to bring

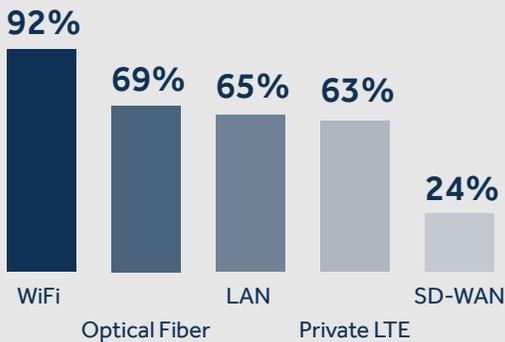


connectivity to where it is needed.

However, per *Figure 1*, each medium of connectivity has its own benefits, drawbacks, and unique capabilities that need to be factored in holistically when considering the current needs and future growth in the buyer’s network demands, and how it is being deployed.

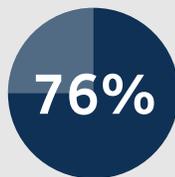
Connectivity in Manufacturing

Today



By 2024

plan to use private 5G networks



Manufacturing, a dominant industry in pioneering 5G solutions, sees growth in Private 5G in the next 2 years (Courtesy Accedian Report)

This brings us to our focus: privately deployed networks. A Private 5G Network is defined as a closed-loop connection that has the ability to cater to specific devices or users within a certain range, for access and connectivity via an unlicensed or shared spectrum.

A Private Network is defined as an implementation of 5G infrastructure where the radio frequency bands (spectrum), and hence the network and data, are controlled by an enterprise and can be restricted to a certain location or area. These bring a wide range of benefits in terms of speed, productivity and security.

The global market for 5G-based private networks is projected to reach \$13.92B by 2028, according to Polaris Market Research, thanks to the demands of industries like manufacturing, warehousing and logistics, agriculture, education, utilities, and entertainment venues. Alex Besen, Founder and CEO of The Besen Group LLC, also estimates that "the serviceable addressable market (SAM) for private 5G networks market will reach to \$3.2 Billion by 2026 in the US."

76% WILL ADOPT PRIVATE 5G BY 2024

44% INCLUDE 5G NETWORKS

8% 5G + 4G LTE SOLUTION

Central to the benefits of private networks is the access to network data. With public network deployments, service providers are unlikely or even unable to share the data with the customer creating it. Whether carriers should or shouldn't have to share this data is beside the point; the critical issue is whether they even have the capability to provide the data to individual customers without incurring a great expense. Brian Shield, CTO of the Boston Red Sox, weighed in on the importance of this data for enterprise buyers.

"Local cellular providers are reluctant to let the genie out of the bottle in terms of data. They do not have the ability to give the customer the insight on their data that is becoming more and more critical in use cases like large entertainment venues, warehouses, and manufacturing facilities. If you could provide a single pane of glass for data – information on partners, ingress/egress, IoT statuses, security situations – all that would be accessible and yours to leverage for the business."

-Brian Shield – CTO, Boston Red Sox

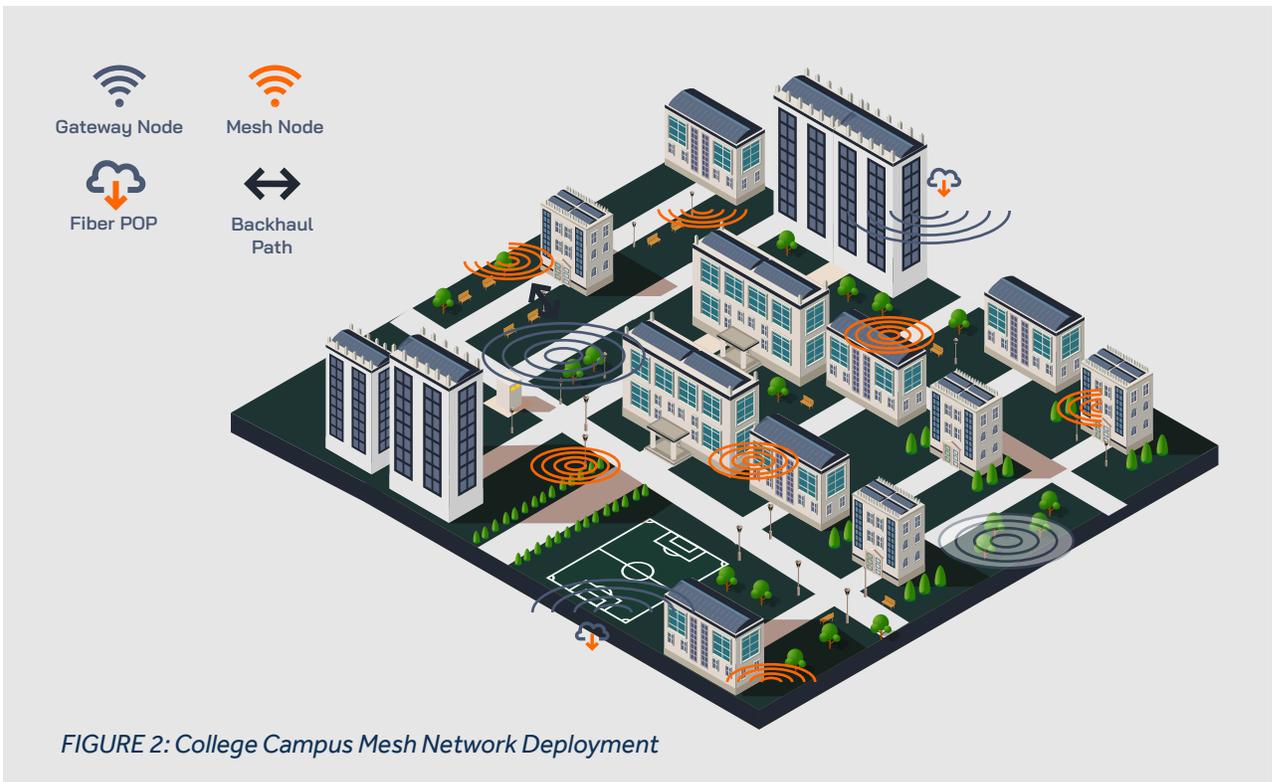
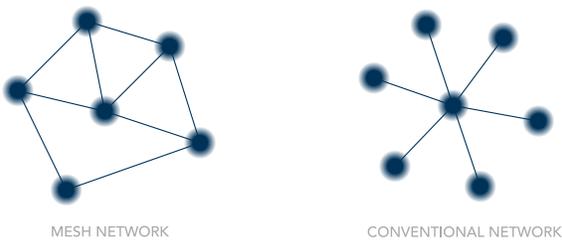
With private 5G deployments, the advantages don't stop at data access, ownership, speed, reliability, and flexibility. They also include increased privacy, security, and access that could power new applications

But Cellular Mesh – What is it? How does it work?

Cellular Mesh is a type of solution for private networks that utilizes at least one gateway node to carry connectivity

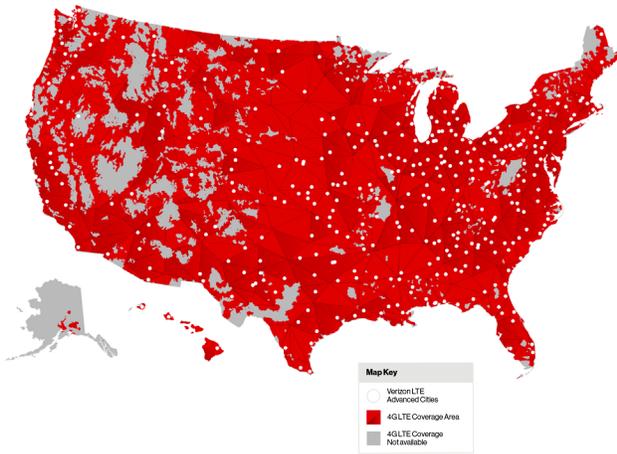
to other nodes, instead of using more fiber to deploy connectivity across large areas or backhaul signal. The connected nodes are radio devices that allow seamless two-way communication amongst each other, which creates overlapping coverage – a mesh of cellular nodes.

With advanced receivers as well as radio antennas, the signal and network can be efficiently shared throughout the nodal network to enable coverage. This is done without having to set up wired links from the data source or sources, resulting in lower costs to deploy, less disruption and construction, and more flexibility when it comes to changes in layout of a site or desired coverage. Only one gateway node is needed to the internet, cloud or Enterprise network for the system to work. *Figure 2* below shows a deployment on a college campus for illustration of a deployed mesh network.



How does Cellular Mesh work in the context of 5G and private networks?

Companies may move towards cellular mesh solutions for many reasons. Data processing needs are increasing, areas of connectivity are changing constantly, and it is becoming harder and harder to cover every nook with adequate transfer rates. Carriers are not capable of, nor interested in, covering everywhere in the world! That quickly leaves behind small corners and areas in the shadow of large buildings or hills in terms of coverage.



“Ever wonder why the carriers have to show a coverage map for 4GLTE and 5G? They have to because they don’t, can’t (and won’t) cover everywhere. If you could build your own

network and then own it, manage it, and deploy it with all the same benefits – but additionally access the data, WHILE saving money – wouldn’t that be great? With Private 5G deployments, you can, and solutions are coming out on CBRS band to enable that. A swath of 150 mghz spectrum is there for tech leaders to leverage.”

- Rob Strickland, CEO M37 Ventures, Former CIO T-Mobile, Leap Wireless

But one of the key reasons private 5G networks could accelerate in usage is the complementary benefits to the other solutions for private networking that are possible – it’s not a mutually exclusive approach. This allows companies that already are working on or have deployed 5G solutions to add to and expand that coverage strategically.

Adding to that, the nodal network itself is extremely resilient. Self-sufficiency, extreme flexibility of placement, and indoor/outdoor coverage from various RAN hardware types are all elements that make the mesh technology appealing for deployments.

Key points we will explore in this brief

We will explore these three key points further in the rest of this paper to understand why cellular mesh is so powerful for propelling enterprise 5G initiatives and should be considered as part of the implementation approach for companies looking at Private Networks:

- 1** Section III - How cellular mesh creates flexible and dynamic coverage
- 2** Section IV - How network performance and device coverage increase with mesh nodes
- 3** Section V - How cellular mesh allows for ubiquitous and resilient deployments



HOW CELLULAR MESH CREATES FLEXIBLE AND DYNAMIC COVERAGE

Mesh technology is especially advantageous when it comes to the propagation of signal for coverage, flexibility, and density. This goes beyond traditional indoor-outdoor applications and is incredibly adaptable and flexible for changing, growing or unique deployments.

An Example – Distributor in Rapid Growth Phase

Consider this: an retailer with rapidly-growing sales has a warehouse where they organize and manage their resources, inventory, and personnel. With the incredible speed of growth, they acquire more and more storage space at the facility every few months.

If they started with a standard network deployment, it might require constant re-deployment, reorganization of endpoints, and new fiber construction to run coverage to each end of the new space acquired. Additionally, coverage from WIFI is restricted to in-doors only and known to be a security risk.

Cellular mesh deployments would enable less-costly extensions of coverage through more nodes, which only require power and line-of-sight spacing in order

to immediately scale up coverage in these new areas of their operations. It would even enable coverage to the new building without requiring and additional hardware or construction – the network can be extended inside as well as out. A full indoor and outdoor cellular mesh would also eliminate the need for WIFI, thus providing a much more secure wireless network for the enterprise platforms to operate.

Easy to Deploy, Alter, and Manage

Because of the coverage, density, and flexibility of mesh networks, dynamic network changes can be sustained efficiently under a single, unified network experience.

“Using mesh network deployments ensures that the coverage over an area can be maximized whilst the amount of equipment that needs to be deployed to offer a high-quality, high-performance service can be minimized. It also means that both indoor and outdoor networks can be built that

offer extensive coverage even in environments where mmWave point-to-point connections would be difficult to achieve."

- Blu Wireless

The benefit is realized in another way – the mesh network makes it possible to manage distributed cloud or edges using a single management network layer. End users and owners of the network can observe the data from the entire system either from the core or a cloud management layer to monitor the health of the network, services and applications deployed on it, security threats, and more.

Scott Rice, former CIO of Sprint, comments on the benefits of the added flexibility and autonomy that come from owning the network instead of working through carriers.

"Companies with private network capabilities are no longer beholden to a large carrier to build localized solutions. This enhances the customer's ability to leverage carrier macro network connectivity needs more competitively."

- Scott Rice, CEO SPRice LCC & Former CIO Sprint

Compared to WIFI or Public Cellular options, cellular mesh solutions amount to less deployment costs and hardware, and they rely more on software than hardware to be functional as well as effective.

The Enterprise CIO Cellular Mesh Check List

Fully secure network (more than carriers):	✓
Indoor and Outdoor:	✓
Able to cover wide areas without hard wiring:	✓

IV

HOW NETWORK PERFORMANCE AND DEVICE COVERAGE INCREASE WITH MESH NODES

The power of cellular technology is now employable in more ways due to the dynamic architecture of cellular mesh. This translates to high-powered coverage for local areas from advanced small cell nodes. With the multitude of node types and performance levels that can be achieved, this makes cellular mesh technology equal in capabilities for network performance to other solutions.

Traditionally, mesh networks relied on unlicensed radio frequencies. However, with the opening of CBRS band (150 MHz of shared spectrum approved by the FCC in 2020 for private wireless broadband deployments in the commercial sector), a medium of high-speed connectivity is now available to optimize range and data transmission rates in mesh-enabled private networks.

Because of the capabilities of these high-performance mesh nodes, it is possible and relatively easier to get better network performance overall and better speeds. This translates to less energy use for the same coverage when compared to other solutions, leading to a more sustainable private network.

Devices Supported

Since CBRS is compliant with 3GPP standards, any hardware or software solution also compliant with these standards can be used in a CBRS-based network deployment. The greater compatibility is critical for companies looking to gain competitive advantages and adopt new best practices with advanced devices.

Modules Gateways and Devices



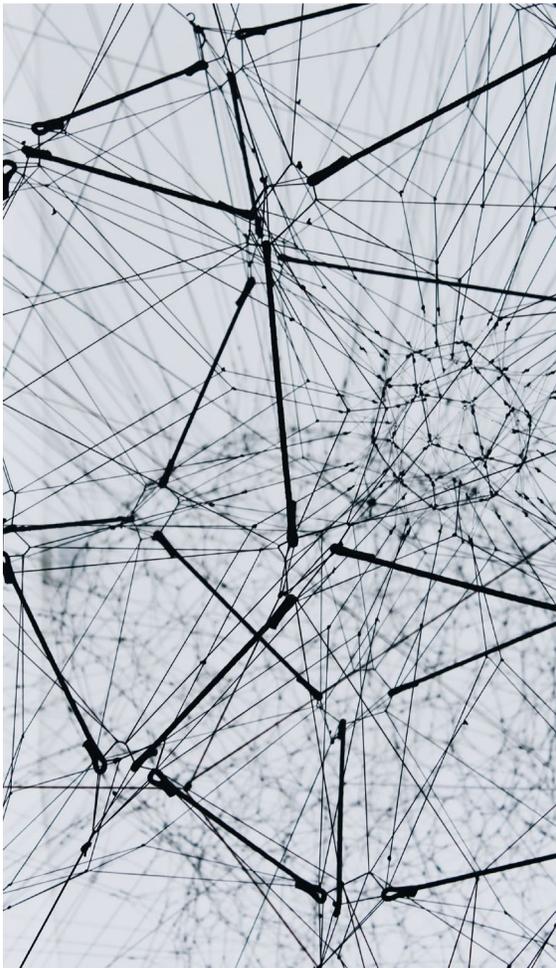
The many use cases become possible with the increased operability of devices. The OnGo Alliance's recent presentation, sponsored by Imagine Wireless, include a few key areas that enterprises will begin to explore and exploit as a result of CBRS-based private networks: IoT, Video streaming, PTT/LMR replacement, Mobile Access by Employees, IoT (Broadband/narrowband), Network Aggregation, Autonomous Guided Vehicles.

V

HOW CELLULAR MESH ALLOWS FOR UBIQUITOUS AND RESILIENT DEPLOYMENTS

Resiliency in Nodes

Coverage is clearly more achievable with mesh nodes – but what about their reliability? Network failures, connectivity issues, and disruptions in wired connections from operations like digging can cost thousands, or even millions.



Mesh networks are inherently self-healing and can be built to have recovery paths and alternate support sources to keep coverage moving. According to Blu Wireless:

“Mesh networking uses self-aligning beamforming technology that focuses wireless signals to a receiving device, combined with intelligent routing where various pathways branch to each connection point. Mesh networking also takes advantage of multiple ‘Points of Presence’ (PoP) connections to the core network, typically via connection to multiple high bandwidth fibre-based PoP nodes. By eliminating the need for a single point of connection this further improves the resilience of the network.”

Cellular mesh is a one-time expense, leading to overall reduced Total Cost of Ownership numbers when considering the externalities and risks associated deploying fixed network solutions that require more construction and

permanent hardware installments. Figure 3 below shows a deployment cost for a typical enterprise.

With a 450k square foot (50 indoor/50 outdoor) example, you can see the projected cost estimates to deploy a private network.

Warehouse Customer Profile

Warehouse Floorspace (Indoor) (sq.. ft) ⁹	230,667
Total Warehouse Coverage (sq.. ft.)	461,333
Indoor/Outdoor (%)	50/50
Number of Employees ⁹	714
Number of connected devices	1,443
Number of Indoor CBSDs	54
Numbers of Outdoor CBSDs	4
Total Number of CBSDs	58

Device Footprint

Video	PTT/LMR	Employee Mobile Access
384	179	143
Direct Computer Access	IoT Broadband	IoT Narrowband
36	100	500
Network Aggregation	Drones	Autonomous Guided Vehicles
100	0	2

Imagine Wireless estimates

Hypothetical Description

<p>Coverage Area</p> <p>Outdoor – Primarily vehicle yard and loading docks or incoming and outgoing distribution vehicles including cars, trucks, trains and boats.</p> <p>Indoor – Typically wide-open areas with extensive shelving and distribution equipment (conveyors, belts). Minimal office space. Exterior construction is largely brick, stone, stucco, concrete or metal.</p>
<p>Enterprise Types</p> <p>Target: Warehouses > 100 sq.. ft, including distribution, fulfillment and shipping centers; non-refrigerated warehouses, refrigerated warehouse, and ports</p> <p>Not targets: Warehouses < 50k sq.. ft, self storage</p>
<p>Example Customers</p> <p>Ingram Micro, Chef’s Warehouse, CVS, CommScope</p>
<p>Architecture Considerations (one or more of the following)</p> <ul style="list-style-type: none"> ✓ Hybrid EPC - SGw and PDGw Local ✓ Local Breakout – Data Center or Edge ✓ High Availability (fully redundant)

Upfront Cost
\$1,082,200
Monthly Recurring Cost
\$3,053
5-year Total Cost
\$1,265,380

eNobeB Hardware + EPC + Professional Services + SIM Cards = Upfront Costs
 eNodeB Software MRC + EPC Software MRC = Monthly Recurring Costs
 Scenario represented is a Turnkey deployment, not including Managed Services.

Figure 3 - A total cost of ownership analysis of a Warehouse deploying a Private 5G network. The OnGo Alliance estimates multiple scenarios to help companies understand their TCO potential in a recent presentation in partnership with Imagine Wireless.

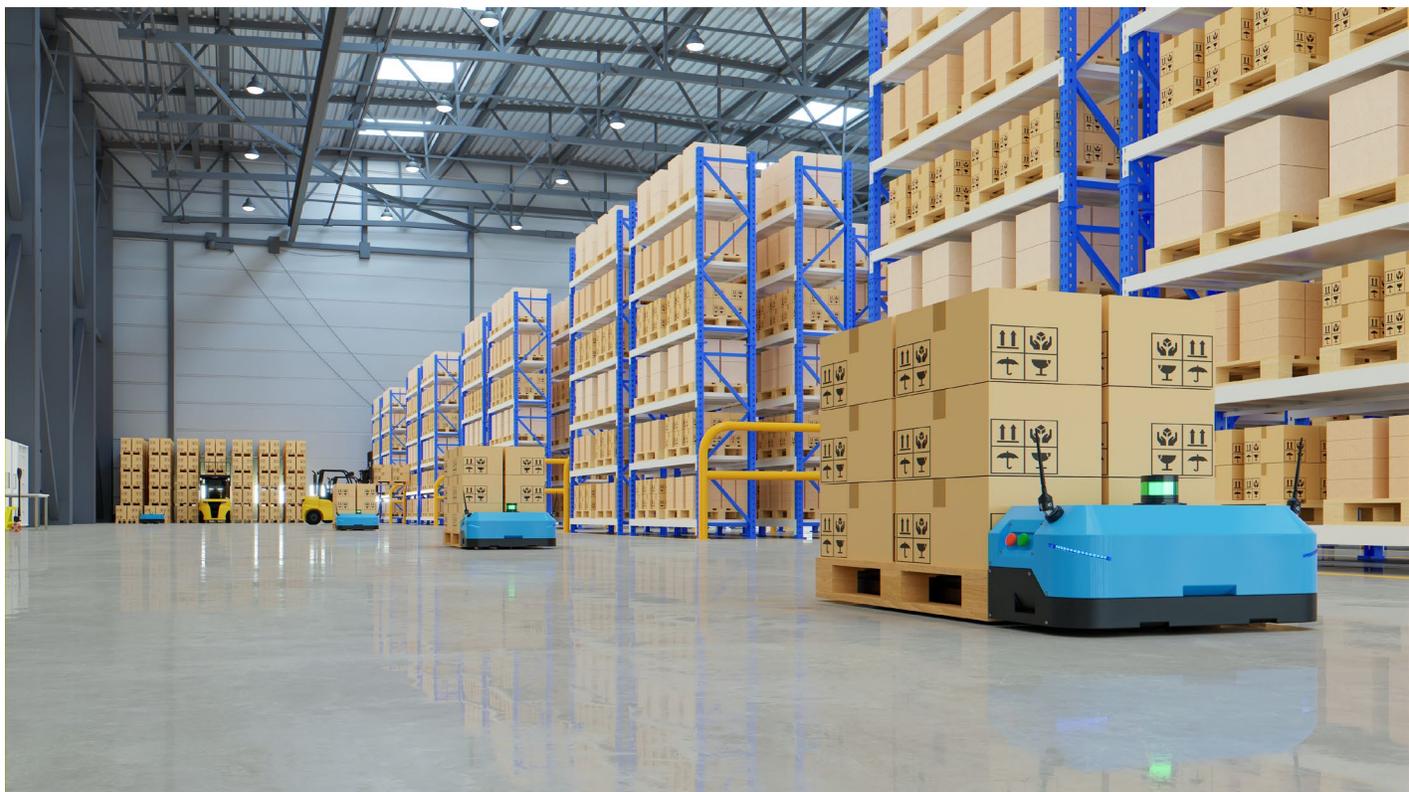
Courtesy OnGo Alliance, Imagine Wireless

Edge and Continuous Coverage Use Cases

Ubiquitous coverage and accessibility via devices on this spectrum generate more use cases and value for the network operators in the long run. This is including machine to machine potential and self-healing dynamics. Also, multi-carrier support is possible for “options where there weren’t as many before” – not driven by build alone.

Where it’s required, seamless capability to integrate to all use cases and users (handoffs) for consistent tracking, asset management, communications. This is a huge value proposition that is enabled by the consistency that is quickly achieved through a mesh network.

Overall, mesh nodes situated on the CBRS band result in ubiquitous coverage and accessibility via devices on this spectrum that generates more use cases and value. This is especially high in return on investment when considering the disaster and failure recovery capabilities built into the solution.



VI CONCLUSIONS & SIGNIFICANCE

As we found, Cellular Mesh provides extensive and flexible coverage with full performance capabilities that are resistant to failure.

The technology buyer responsible for covering bases not just for today's operations, but also for the future, must be aware of all the elements. Private 5G networks via Cellular Mesh substantially check off the boxes from the CIO checklist, developed by the OnGo Alliance.

As the technology continues to become available for deployment via solutions providers in the market, tech leaders should continue to learn and scope out solutions for their organization to stay ahead of the curve for the future of their organizations.



1 Problem Statement
 What problem are you solving?
 What business outcome are you looking to achieve?

2 Use-Cases
 How will the private wireless network be used? What are the desired business outcomes?

3 Business Case
 What is the TCO, ROI or the revenue model? What are the usage/cost/pricing assumptions?

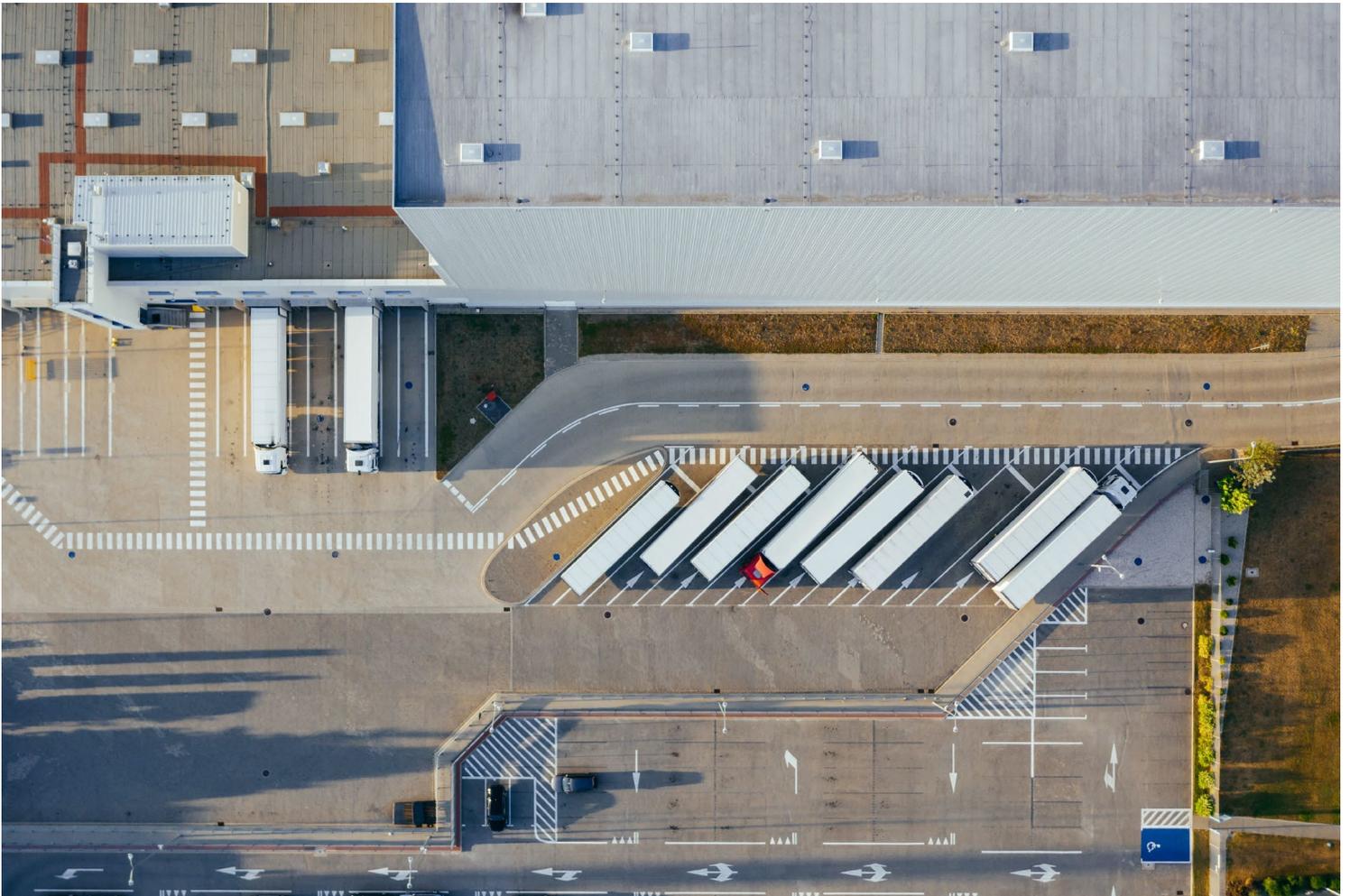
4 RFI/RFP
 This is an optional step. The RFI/RFP process can help crystalize requirements.

5 Enterprise Reference Architecture
 What core capabilities do you need to support the use-cases and, more importantly, the business outcomes?

6 Pilot
 This is an important validation step. Confirming financial and operational assumptions will be critical during the pilot.

7 Integration
 The private wireless network cannot be standalone. Integrating the private wireless network with back-office systems.

When considering these solutions, IT and operations leaders should be interested in cost, trade-offs and complementary capabilities. With cellular mesh as part of the overall deployment or an additional component for existing private network deployments, companies can be sure to cover all the bases and gain a favorable edge in future or new use cases that require this single-pane-of-glass approach.



VII

ABOUT THE SPONSOR: GXC



M37's efforts on this brief covering the merits of cellular mesh technology for private network deployments is supported by GXC.

GXC is an Austin-based company that provides enterprise 5G network solutions based on cellular mesh architecture. Their private network platform provides high levels of resiliency, flexible deployments, strong coverage in hard-to-reach areas, and a powerful distributed application platform that enables the future of 5G apps.

Founded in 2016 in Austin, GXC is led by academic doctorates/PhDs with several patents and published papers regarding cellular communications technologies. They are proponents of utilizing mesh architecture to bring more value to enterprises that need communication solutions.

Learn more at www.GXC.io

VIII

RESEARCH & SOURCES

What is a mesh network?

Blu Wireless

12th January 2021

<https://www.bluwireless.com/insight/what-are-mesh-networks/>

Accelerating the 5G rollout

Blu Wireless

<https://www.bluwireless.com/applications/5g-backhaul/>

Long distance radio vs. Short distance radio or 5G vs. Meshnet

SYS TEC ELECTRONIC

<https://www2.systec-electronic.com/en/long-distance-radio-vs-short-distance-radio-or-5g-vs-meshnet/>

Why the Service Mesh Will Be Essential for 5G Telecom Networks

The New Stack

3rd Mar 2021

By Sagar Nangare

<https://thenewstack.io/why-the-service-mesh-will-be-essential-for-5g-telecom-networks/>

The State of 5G 2021

F5.com

https://interact.f5.com/rs/653-SMC-783/images/f5-The_State_of_5G_2021_HD.pdf

Verizon chases \$7-8B private wireless market

Fierce Wireless

May 10, 2021

By Bevin Fletcher

<https://www.fiercewireless.com/private-wireless/verizon-chases-7-8b-private-wireless-market>

AT&T Private Cellular Networks

AT&T

<https://www.business.att.com/products/att-private-cellular-networks.html>

Strategic Design Considerations for Private Cellular

AT&T 5G

<https://www.business.att.com/content/dam/attbusiness/infographics/strategic-design-considerations-for-pcn-white-paper.pdf>

What explains the growth of private 5G networks?

Capgemini

February 4, 2022

<https://www.capgemini.com/2022/02/what-explains-the-growth-of-private-5g-networks/#:~:text=Another%20study%20found%20that%20among,of%205G%20with%204G%20LTE.>

Report: 76% of manufacturers plan to adopt private 5G by 2024

VentureBeat

October 15, 2021

<https://venturebeat.com/2021/10/15/report-76-of-manufacturers-plan-to-adopt-private-5g-by-2024/>

GSA notes acceleration in private 5G networks

Mobile World Live

August 11, 2021

<https://www.mobileworldlive.com/feature-d-content/top-three/gsa-notes-acceleration-in-private-5g-networks>

Private 5G Network Market Size, Share & Trends Analysis Report

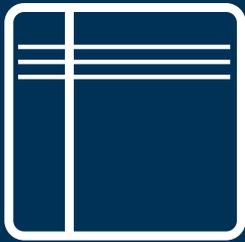
Grand View Research

<https://www.grandviewresearch.com/industry-analysis/private-5g-network-market>

Private Networks with CBRS: LTE / 5G -- Delivering Business Value

OnGo Alliance / Imagine Wireless

Presentation – March 2022



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