Demystifying the private cellular networks

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Abstract

Private networks have existed for more than a decade now. However, the interest and focus have been at a completely different level since the arrival of 5G. In fact, 5G is termed "the technology for the enterprise," - leading to high expectations in the telecom ecosystem.

The reality, though, has yet to match up to the hype. This has led to many questioning whether 5G can deliver the promised benefits to enterprise customers.

Through this white paper, we share our perspective on the state of the evolution of private wireless networks (5G/LTE) and the opportunity that this technological development offers to enterprises.

The topics include:

• Significance of the opportunity in the private wireless networks

• Evolution of private 5G networks

• Vertical industries that are fuelling the private network demand

• Some private network deployment models

• Nagarro's take on private cellular networks.

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Table of content

01. Introduction: How big is the opportunity in private wireless networks

Private networks are here to stay and significantly grow – this is the key message from leading industry analysts. To understand why private wireless networks are of such great interest to enterprises, let's touch upon the key advantages:

Extended coverage

Enables coverage where public networks are either non-existent or have poor coverage, particularly remote areas

Customizable network

Allows enterprises to configure networks, devices to their specific requirements and implement stringent SLAs

Improved control and security

Offer stronger control of their cellular network. Ensures security of sensitive data network elements etc. and reduces DDoS attacks

High performance

Allows for deploying solutions that require high throughput, low latency reliability and a guaranteed QoS (Quality of Service)

Fig 1: Advantages of private wireless networks

In the next few years, it is estimated that private network deployments will go up to 1000s, especially as spectrums and networks become increasingly open and 'democratized' along with a rapidly growing ecosystem of integrators, vendors, and industry-specific solution providers.

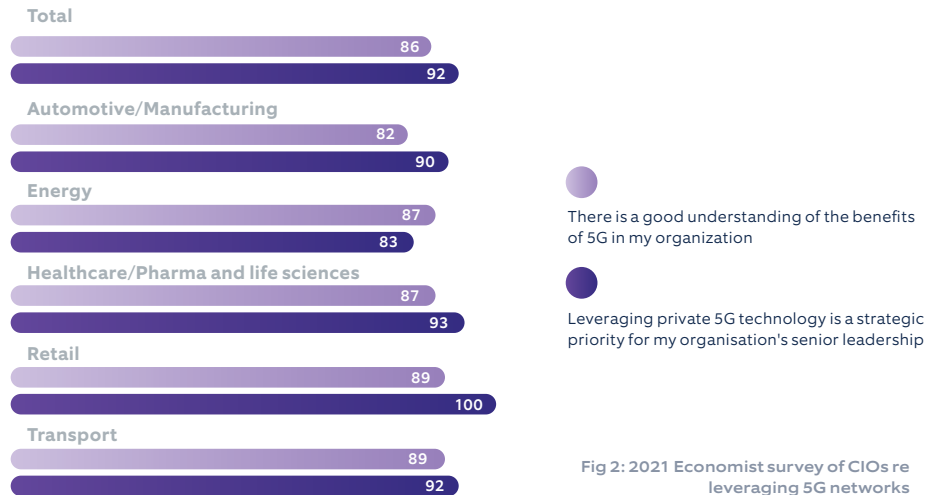Let us look at what a few of the leading industry analysts say:

ABI research of Dec 2022: Overall market for private wireless networks within industry verticals can reach ~USD 100 Bn by 2030. This includes radio access network, edge & core deployments, and professional services revenues, which alone will contribute ~USD 50 Bn (50%) to the market in 2030.

IDC: Private LTE/5G infrastructure revenues can grow at a CAGR of 38% and reach USD 9 Bn by 2026, a marked increase from USD 1.7 Bn in 2021.

Dell 'Oro forecast: Private wireless RAN revenues can grow 2X by 2026, with 5G NR surpassing LTE deployments by 2025.

2021 Economist survey of 200+ CIOs: More than 50% of the respondents stated they plan to implement a private 5G network within next 6 to 24 months.

Interestingly, a significantly high percentage of senior leadership teams across different industry verticals consider private 5G networks a strategic priority for the organization.

Total	
	86
	92
Automotive/Manufacturing	
	82
	90
Energy	
	87
	83
Healthcare/Pharma and life sciences	
	87
	93
Retail	
	89
	100
Transport	
	89
	92

There is a good understanding of the benefits of 5G in my organization

Leveraging private 5G technology is a strategic priority for my organisation's senior leadership

Fig 2: 2021 Economist survey of CIOs re leveraging 5G networks

Another survey by **Heavy Reading** for Qualcomm, Intel, and Ericsson came out with similar observations. It says that ~60% of the respondents (n=103) highlighted there is strong demand for private 5G/LTE networks across most industries.

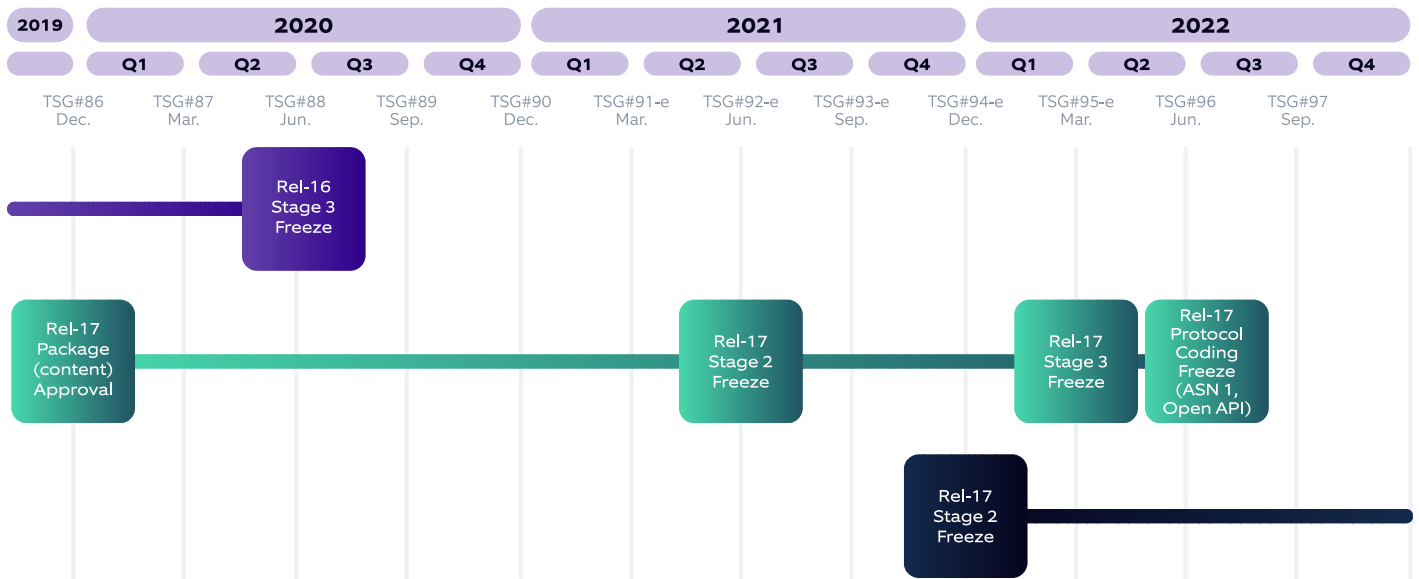## 02. A glimpse into the evolution of private 5G networks

The evolution of 5G technology has heavily depended on the work done under the 3rd Generation Partnership Project (3GPP). This unites seven telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, and TTC) to the "Organizational Partners," providing members a stable environment to produce specifications. While it originally started working on 3rd generation (3G) wireless technology specifications, 3GPP has become the focal point for most mobile systems – for LTE and 5G work, beyond 3G.

A key focus for all 3GPP specification releases is to make the system backward and forward-compatible, where possible, to ensure that the operation of the user equipment is uninterrupted.

For 5G, many operators are starting with dual connectivity between LTE and 5G NR (New Release) equipment – using the 'Non-Standalone' work completed early in Release 15.

Mapping the 3GPP Releases 16 and 17

It is important to understand that though the 5G journey started with Release 15 for non-standalone service provider deployments, it was Releases 16 and 17 wherein most of the private 5G-focused features were introduced and more improvements incorporated (as highlighted below). Further advancements, particularly in extended reality (XR), network slicing, future factories, etc., are expected in Release 18 (5G – advanced) by 2024 end. All these developments are expected to increase 5G-enabled trials/POCs network deployments of new mission-critical use cases for different industries and public institutions.

2019	2020				2021				2022			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
TSG#86 Dec.	TSG#87 Mar.	TSG#88 Jun.	TSG#89 Sep.	TSG#90 Dec.	TSG#91-e Mar.	TSG#92-e Jun.	TSG#93-e Sep.	TSG#94-e Dec.	TSG#95-e Mar.	TSG#96 Jun.	TSG#97 Sep.	

Rel-16 Stage 3 Freeze

Rel-17 Package (content) Approval

Rel-17 Stage 2 Freeze

Rel-17 Stage 3 Freeze

Rel-17 Protocol Coding Freeze (ASN 1, Open API)

Rel-17 Stage 2 Freeze

*Stage 1: WG SA 1 work and "RAN content definition" completed TSG#86
**Stage 2: Studies completed TSG#90. Stage 2 Normative work completed TSG#92. Stage 2 exceptions completed TSG#93

Release 16

- IIoT - Improved reliability and efficiency for industrial applications and vertical markets
- Improved network slicing
- 5G NR enhancements for URLLC
- V2X - vehicle to anything, device to device for vehicle platooning, sensor data exchange, autonomous driving and remote driving
- NR based access to unlicensed spectrum
- Enhanced Service Based Architecture (SBA)
- Enhancements in location and positioning services (~3m accuracy)
- Enhancements in Time Sensitive Communications (TSC), NPN (non public networks)
- 5G wireless & wireline convergence
- NR mobility enhancements
- Satellite access in 5G
- Device (UE) power savings
- and more...

Release 17

- Reduced capability (Red-Cap) to support lower complexity IoT devices (e.g. sensors, video cameras etc.)
- Expansion of sidelink to include new use cases of device to device use cases (vehicular and public safety applications)
- Improve positioning and location accuracy (<1 m accuracy)
- Initiate studying of different XR traffic types
- Support frequencies up to 71 GHz (beyond 52 GHz)
- Enhancements to URLLC and private networks (e.g. unlicensed spectrum, lower layer improvements)
- Support for edge computing in 5GC
- 5G NR over NTN (Non Terrestrial networks)
- Broadcast and multi0cast enhancements
- Extend device power savings for both idle/ inactive and connected operation modes
- Support multi-SIM devices
- and more...

Fig 3: Timeline and features of 5G Releases 16 and 17

Unfortunately, significant delays in freezing Releases 16 & 17 were experienced due to the global pandemic. As per a recent GSA report of H1 2023, there are ~1,212 private 4G/LTE and 5G mobile network deployments globally - a ~28% increase over 2022.

It's important to highlight that from a technology standpoint, 4G/LTE remains the dominant technology in 74% (899) of the network deployments, with 5G being used in 44% (537) and both being used in 20%. This indicates that most currently deployed private networks are either 4G/LTE SA (Standalone) or NSA (Non-Standalone) deployments anchored by 4G/LTE.

Private wireless deployments – A diversified landscape

Key inferences that can be drawn are:

1. In most private network-enabled use cases that enterprises are currently deploying, the business and network requirements (e.g., throughput, latency, security, etc.) are addressed using 4G/LTE technology.

2. 5G as a technology continues to evolve. Support for mission-critical use cases (latency ~1 ms), end-to-end slicing capabilities, spectrum availability, etc., still needs to mature fully.

From a geographical standpoint of deployments, though private network deployments are in more than 72 countries, the markets with the most deployments are in the US, Western Europe (primarily Germany and the UK), Japan, and China. Interestingly, this correlates to countries where spectrum 'democratization' has happened i.e., regulatory authorities allocating dedicated licensed spectrum to enterprises and institutions.

Enterprises are not going to use 'one' connectivity technology

There are a lot of discussions on whether 5G will substitute already-existing non-cellular technologies such as Wi-Fi, industrial ethernet, etc. It is important to understand most enterprise networks will remain multi-network, and these connectivity technologies will complement one another.

Wi-Fi technology is also evolving alongside 5G, with Wi-Fi 6 already deployed and Wi-Fi 7 under development. In most cases, enterprises will not be open to removing their existing connectivity infrastructure (wired or Wi-Fi), unless they have a compelling reason to do so. Given the status of 5G technology today, Wi-Fi will hold significance for most enterprise indoor scenarios (even for greenfield deployments), while fiber will remain for many high-performing static use cases.

In fact, a detailed study by STL partners in 2021 highlighted that while hybrid deployments are going to be the preferred norm, the next few years will see an increase of 5G-enabled private networks as enterprises start to deploy more advanced use cases with new 3GPP releases (e.g., Release 18 5G – advanced).

03. Vertical industries that are fuelling the demand for private networks

While private network deployments are happening across all industry verticals globally, manufacturing stands out as the dominant industry (with automotive as the dominant sub-group), followed by the extraction industry (oil and gas, mining), education (smart campus), and transport and logistics (including ports).

Interestingly, in 2022, Defence was amongst the fastest growing industries. It is important to highlight that most private network implementations are currently in the trial and/or PoC stage with a few commercial deployments.
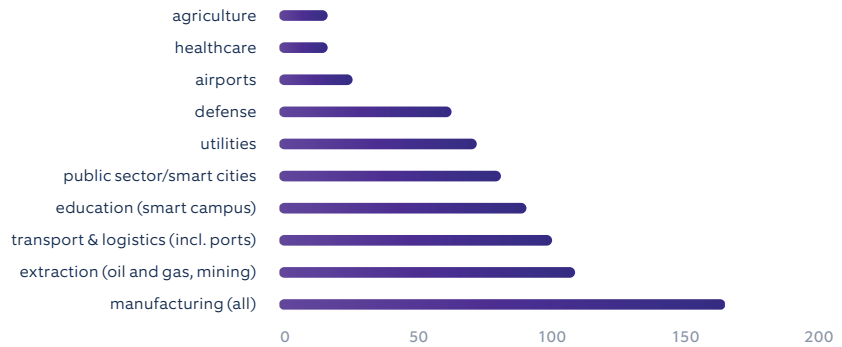

Fig 4: Private network deployments (trials, commercial). Source: GSA private cellular networks, Dec 2022

The industry-wide view, as mentioned above, is consistent with what we in the telecom BU at Nagarro have experienced during recent discussions with prospects and existing customers. We have categorized the key use cases for the top industry verticals, namely Manufacturing, Extraction (oil and gas, mining), and Transport & Logistics (incl. ports) across two categories – personnel safety and operational efficiencies.

Enhancing personnel safety

Connected worker
- Use of sensors to ensure workers are wearing all the necessary safety gear
- Real-time remote status of workers using wearable locators/sensors for real-time response

Worker safety solution
- Intelligent video analytics-based solution for workers operating with robots

Augmented/Virtual training
- Create digitally enhanced/immersive environments for training using real systems data

Drone based inspection
- Using drones for undertaking inspection of hazardous areas/locations within mines/oil rigs

Operational voice and video systems (PPT and PTV services)

Operational efficiencies

Predictive maintainance of assets and equipment
- Using AI/ML for improved asset performance by identifying beforehand whether asset requires replacement/repair

Real time defect detection
- Using video analytics and machine learning to identify defects in real-time during production, post-production quality checks etc.

Asset tracking and efficient pick-up/store
- Real-time tracking of assets in a warehouse during pick-up/stock
- Real-time identification of right shelves for storing inventory

Centralized (remote) condition based monitoring of different assets & machinery

Remote tele-operations
- Of different equipment (AMRs, haulage trucks etc.)

Fig 5: Key use cases for top industry verticals

04. Examples of private network deployment models

In the following section, we briefly cover a few private network deployment models using the 5G network, along with the key benefits of each. It is important to understand the deployment model selected is a function of multiple factors, namely, UE/use case requirements (of data throughput, latency, jitter, etc.), data security and privacy needs, the enterprise's investment (CapEx and OpEx), and flexibility of customizing and operating the network.

Standalone 5G private network deployment

The deployment consists of an independent core and radio access network (RAN), completely isolated from the telco public network. This is where the UPF, AMF, SMF, UDM, etc., function, and all composites of the core network are on the enterprise premise. The spectrum can either be licensed or unlicensed. The unlicensed spectrum, such as Wi-Fi or CBRS GAA tier, is susceptible to much interference. Hence, enterprises aiming to deploy applications with stringent QoS requirements prefer a licensed spectrum. However, in applications where the QoS requirements are not very stringent, the unlicensed spectrum can be a great cost-effective alternative for enterprises.
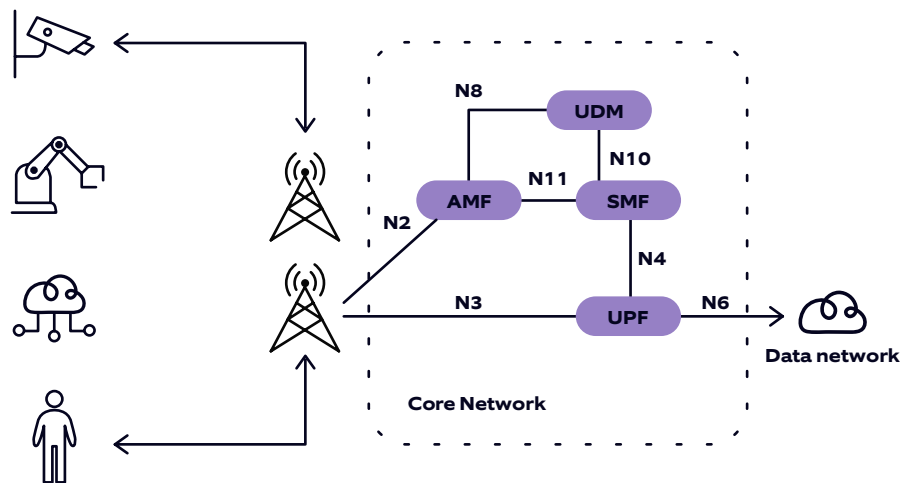

Fig 6: A standalone private 5G network

Benefits of the deployment model:

Ultra-low latency – Very low latency between the application server and UEs (end devices)

Privacy and security – All the operational and user data resides within the enterprise

Independence from a public network – Not tied to the telco roadmap, operations and maintenance, and capacity loading.

Shared RAN

This is a hybrid deployment scenario where the different application(s) are within the enterprise while leveraging the RAN and spectrum of a public network.

The advantage is that low-latency applications would leverage the data traffic from the local data network delivered to the UPF, while devices that do not require ultra-low latency, such as voice and internet, are delivered from the UPF of the telco. This means the low-latency applications are unaffected by the loading in the telco network. In this deployment, enterprises will use the telco's licensed spectrum.
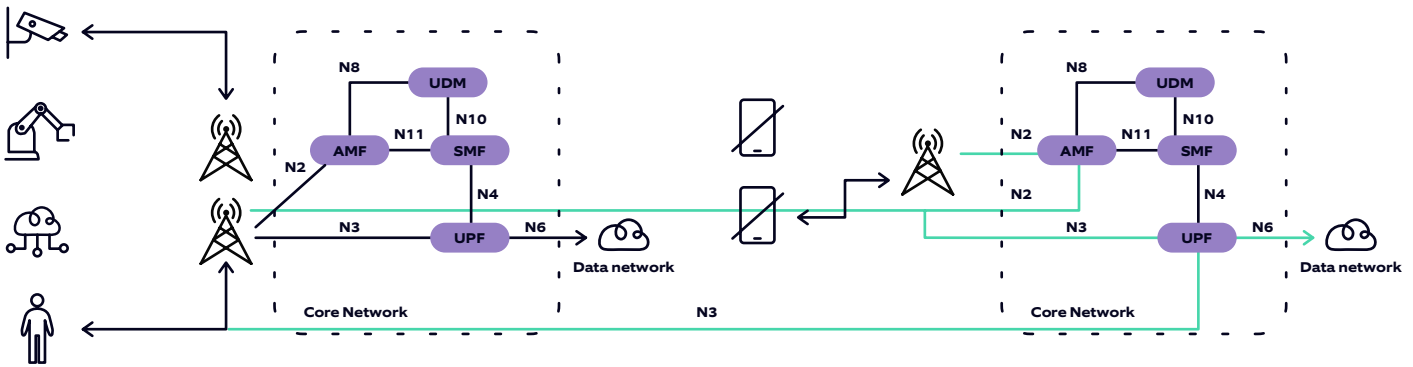

Fig 7: A shared RAN deployment wherein gnodeB is shared between enterprise and public telco

Benefits of the deployment model:

Lower CapEx by the enterprise in comparison to standalone deployment
Supports both latency and non-low latency use cases.

Other deployment models

1. Sharing of RAN and Control plane between the enterprise and the telco's 5G network

2. Network slicing model wherein a virtualized network (via network slicing) is created by the telco and reserved for the enterprise's private use.

05. Nagarro's take

How telcos and enterprises are moving on the private network journey

Telcos have not been able to capitalize on the private wireless opportunity as they would have liked. They gradually realize that the enterprise 5G market is an ecosystem play and have started forging partnerships with key ecosystem players like system integrators, OEMs, hyperscalers, application providers, etc. However, they now need to display a lot of agility and move at the speed of enterprise demands.

Nagarro acts as a systems integrator for telco clients, allowing them to offer services beyond connectivity to their enterprise customers. The enterprise approach to private network deployments is to typically identify a system integrator that can bring together the required players and anchor the private network's deployment, operations, and management. In this context, Nagarro brings the deep vertical experience of working with some of the largest organizations on various value-driven use cases.

Conclusion

The overall growth and adoption of private wireless networks by enterprises has seen a significant growth in recent times, particularly post pandemic. It's true that majority of the deployments are trials with very few commercial large-scale deployments, and this is an indicator that enterprises are taking a cautious approach.

Having said that, majority opinion of the key enterprise decision makers is that private wireless networks are a critical component of their strategic vision. Technology is evolving. For instance, 3GPP Releases 16 and 17 are frozen now, enabling a lot of new enterprise use cases.

Summing up, the growth opportunity that private wireless networks present for the entire ecosystem is real and significant, and this is only going to get bigger.

06. Appendix

Acronyms used in the white paper

3GPP   3rd generation partnership project

LTE   Long-term evolution

5G NR -U   5G New Radio - Unlicensed

UPF   User Plane Function

AMF   Access and Mobility management function

SMF   Session Management Function

UDM   Unified Data Management

QoS   Quality of Service

LFN   Linux Networking Foundation

RAN   Radio Access Network

CBRS   Citizen Broadband Radio Service

GAA   General Authorized Access

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