



Demystifying the private cellular networks

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01. 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 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

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

Private networks are here to stay and significantly grow – this is the key message coming from different leading industry analysts. To understand why private wireless networks are of such great interest for 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

It is estimated that in the next few years, the number of private network deployments will go up to 1000’s, especially as spectrums and networks becomes more and more open and ‘democratized’ along with a rapidly growing ecosystem of integrators, vendors, and industry-specific solution providers.

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

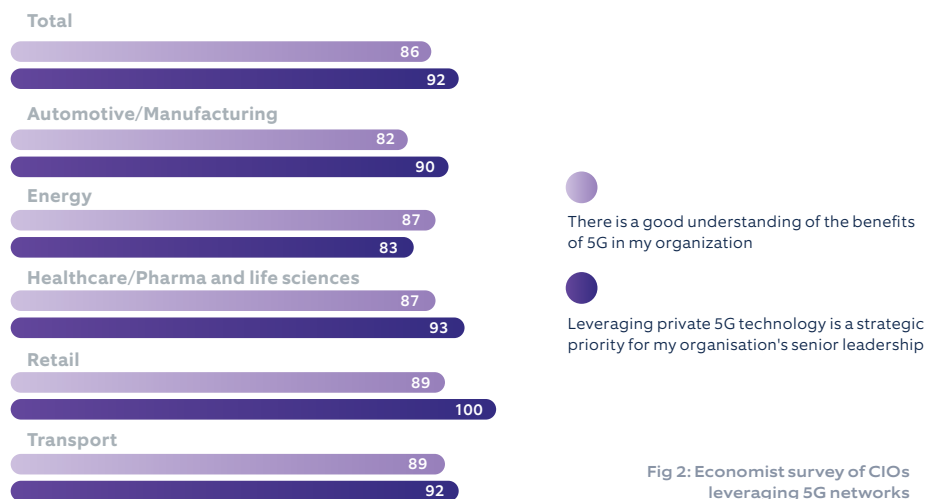
As per December 2024 report from Omdia, the private 5G market is projected to exceed USD 9 Bn by 2028, encompassing radio access network, edge and core deployments, and professional and managed services revenues.

SNS Telecom: As per Oct 2024 report, estimates that the private LTE and 5G network market revenues will be USD 6 Bn the end of 2027. Specifically, for the US market, annual spending on private LTE and 5G infrastructure is expected to grow at a CAGR of 18% between 2024 and 2027 to USD 3.7 Bn.

Dell ‘Oro forecast: Private wireless RAN revenues are projected to grow 2X by 2026 with 5G NR surpassing LTE deployments by 2025.

As per a CIO survey commissioned by Dell Technologies in 2023, 95% of the organizations have formally quantified or are in the process of quantifying the value of private 5G networks, with 89% already allocating the budget needed for private 5G investment.

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



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

03. A glimpse into the evolution of private 5G networks

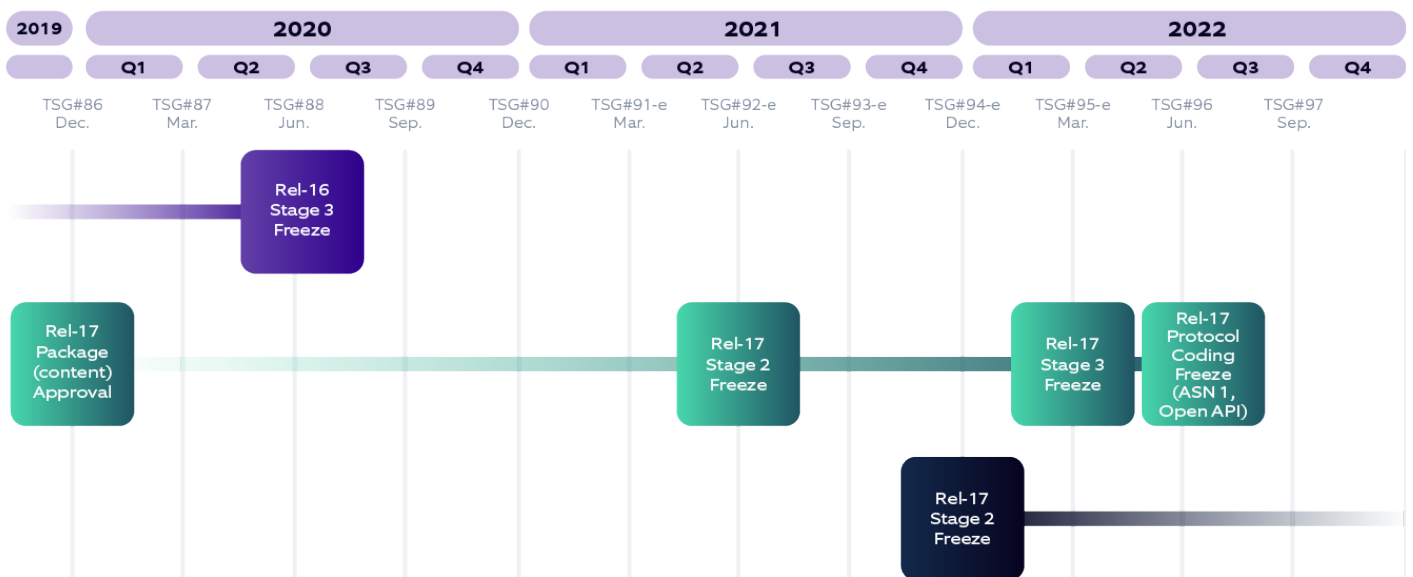
The evolution of 5G technology has heavily depended on the work done under the 3rd Generation Partnership Project (3GPP). This unites seven telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, and TTC) to the “Organizational Partners,” providing members a stable 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.

3.1 Mapping the 3GPP releases

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



*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

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

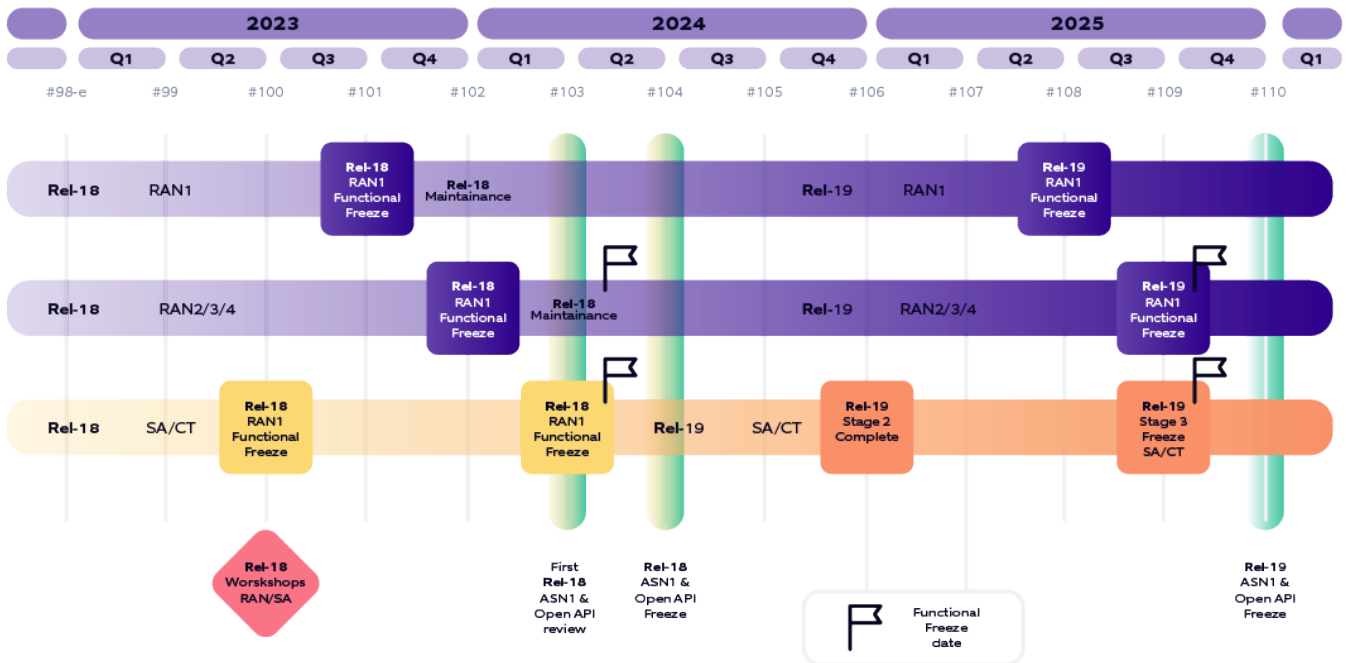
Release 16

- 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 5G
- 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...

*List of selected private enterprise focused features



Unfortunately, significant delays in freezing of Release 16 & 17 were experienced due to the global pandemic that slowed down the private network deployments.

3.2 Private wireless deployments – A diversified landscape

As Mobile World Congress (MWC) 2025 approaches, there has been significant progress in the private wireless network deployments. As per a GSA report, as of Q1 2024, globally there were 1400+ customers across 75+ countries having private 4G/LTE and 5G mobile network deployments which is a 32% increase over 2022. This includes deployments starting from revenues of USD 50K. It's important to highlight that from a technology standpoint, 4G/LTE continues to be the dominant technology with 51% of the network deployments with 5G being used in 25%, and 22% deployments using both. This clearly indicates that the majority of the currently deployed private networks are either 4G/LTE SA (Stand-alone) or NSA (Non-Standalone) ones anchored by 4G/LTE, however standalone 5G deployments are increasing.

Key inferences that can be drawn:

1. In the majority of the private networks enabled use cases that enterprises are currently deploying, the business and network requirements (e.g., throughput, latency, security etc.) are getting addressed using 4G/LTE technology.
2. 5G as a technology continues to evolve and support for mission critical use cases (latency ~5 ms), end-to-end slicing capabilities, etc. are yet to get fully mature.

From a geographical standpoint of deployments, what we see is that though private network deployments have happened in more than 75+ countries, markets with majority of the deployments are in US, Western Europe (namely Germany and the UK), Japan, and China. In the Asia Pacific region, Japan and South Korea are leading the private network deployments. Interestingly, this correlates to countries where spectrum 'democratisation' has happened i.e., regulatory authorities allocating dedicated licensed spectrum to enterprises and institutions.

3.3 Enterprises are not going to use 'one' connectivity technology.

There have been 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 getting evolved alongside 5G, with Wi-Fi 6 already being deployed and Wi-Fi 7 getting released. In most cases, enterprises will not be open to removing their existing connectivity infrastructure (wired or wi-fi), unless given a compelling reason to do so. Even for greenfield deployments, as 5G technology exists today, for most of the enterprise indoor scenarios, Wi-Fi will hold significance, while fibre will remain for many high performing static use cases.

In fact, a detailed study by STL partners 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).

04. Which vertical industries 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 electrical equipment and automotive as dominant sub-groups), extraction industry (oil and gas, mining) and education (smart campus). Defence and peacekeeping and power utility companies round the top five. Ports has seen significant growth in private network adoption within last year. It is important to highlight that currently, majority of the of the private network implementations are in trial and/or PoV stage with a few commercial deployments.

Private network deployments (trials, PoVs, commercial)

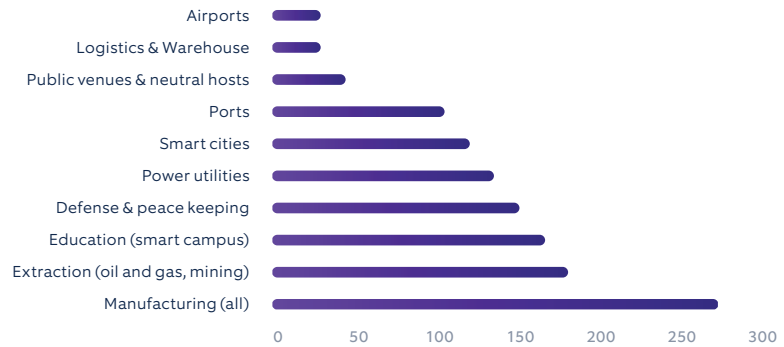


Fig 4: Private network deployments (trials, commercial). Source: GSA private cellular networks, Dec 2022

The industry wide view as mentioned above is consistent with what we in Telecom BU at Nagarro have experienced during discussions with prospects and existing customers in recent times. We have categorized the use cases for the **top industry verticals** as mentioned above, namely Manufacturing, Mining, Ports, warehouses covering key areas of Connected worker, operational efficiency and sustainability as mentioned:

Smart manufacturing

- Real time operational visibility into plant operations
- Digital twin for remote diagnostics and improved planning via what-if scenarios

Connected worker

- Immersive (VR) solutions for training/demos
- AR based remote express expert assistance

Mining

- Intelligent worker safety solution
- Dron based surveillance of hazardous locations within mines

Smart warehouse

- Real-time asset/inventory tracking
- LiDAR based solution for storage/retrieval

Ports

- Predictive maintenance of equipment/machines
- Intelligent video based perimeter security/theft prevention solution

Compliance & Sustainability

- Intelligent public safety solutions
- IoT-based real time environmental monitoring for GHG emissions

05. Examples of the private network deployment models

5.1 Standalone 5G private network deployment

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.

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

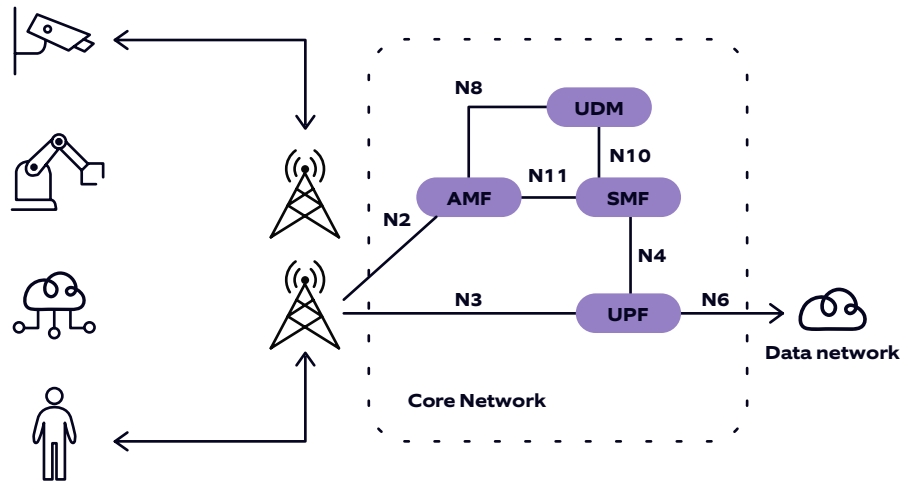


Fig 6: A standalone private 5G network

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 Telco roadmap, operations and maintenance and capacity loading.

5.2 Shared RAN

This is a hybrid deployment scenario where 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 Telco’s licensed spectrum.

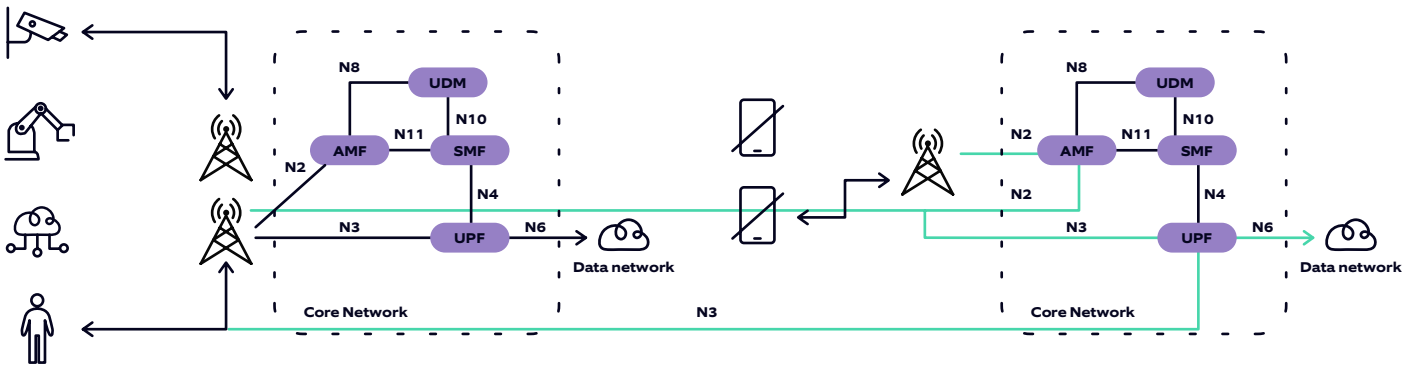


Fig 7: A shared RAN deployment wherein gnodeB is shared between enterprise and public Telco

Benefits of the deployment model:

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

5.3 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.

06. Nagarro’s take: How are Telcos and enterprises 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.

For our Telco clients, Nagarro acts as a value-added systems integrator, allowing them to offer services beyond connectivity for 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.

In addition, Nagarro's partner ecosystem allows us to bring different strategies around Public, Hybrid, and Private network permutations. Proof of Concepts/Value can be started with an investment starting at USD 50k which allows enablement of low latency, high bandwidth solutions to accelerate your digital transformation.

07. 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 also true that the 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. We are also seeing technology evolving, particularly with 3GPP Release 18 getting frozen, thereby enabling lot of new enterprise use cases.

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

08. Appendix

Key acronyms used

3GPP	3 rd 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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