Transitioning from 4G to 5G SA in a private wireless network

With a focus on the core

White paper

Today, 4G mobile networks are widely deployed across the globe. 5G is in the early stages of adoption and will offer additional new capabilities. Some enterprises have already adopted 4G and 5G technology to create localized private wireless networks, yet many enterprises that have an urgent need to modernize have not yet deployed either 4G or 5G communications. This is especially true of those with requirements approaching that of a carrier.

Roadblocks exist for deploying 5G standalone private wireless networks. These include lack of endpoint device availability, access to 5G-specific spectrum, spotty 5G radio coverage, and lack of compelling use cases that depend on unique 5G capabilities. A solution to this is to deploy a 4G LTE network now, and later add 5G standalone either as a hybrid 4G/5G arrangement, or as a full replacement.

In this paper we describe an approach that allows enterprises to start today with a 4G network, but also prepare the ground for an expected move to 5G standalone, then do so when the business benefits are clear. We cover the migration at a high level (network domains), and for the core network at a more detailed level. We show why cloud-native design is a key enabler for this migration and use a Nokia core network solution as a specific example to make the discussion concrete.

Contents

The new era of 5G private wireless networks

4G LTE has revolutionized telecommunications, providing consumers with mobile broadband across a large variety of device types, and enterprises with Internet of Things (IoT) capability. Today, communication service providers (CSPs) are deploying 5G for the next wave of digital transformation. 5G radio brings very high bandwidth and service density, while 5G stand-alone (SA) core offers very low latency, massive machine-to-machine communication, ultra-reliable services, extensive service automation, better security, and fully adopts a cloud-native approach to telecom.

Enterprise verticals with operations that cover large geographic areas can benefit from private wireless networks based on both 4G and 5G. Nationwide public safety agencies have a need for inter-agency coordination, mission critical communications for first responders, and fine-grained location service. Power utilities can use private wireless networks to help manage extensive distribution grids. Mainline railways that cover large geographic areas need train-to-ground communications for passengers, mission critical crew communications, and coordination between stations, trains, and sensors. Further, all these verticals could benefit from upgrading obsolete technology.

While the need to upgrade their communication systems is urgent, an immediate leap to 5G (for both radio and core) is difficult to justify, and sometimes not yet possible due to lack of licensed 5G spectrum. Compelling use cases that depend on capabilities unique to 5G radio or core are few. The endpoint market is still very new, resulting in limited variety of 5G capable handsets – making endpoint deployment more costly.

In the following we consider an approach that allows wide-area enterprises to upgrade their infrastructure today with 4G LTE private wireless, migrating to 5G technology when and where it makes sense for the organization. The approach leverages cloud-native platforms that have the flexibility to transition an in-service network at minimal cost. This 4G to 5G SA transition is expected to take place over a period of time, during which 4G and 5G SA operate in parallel as a hybrid network. We also offer guidance for large-scale enterprises in preparing for the move to a 5G-based WAN private wireless network.

Key transition challenges: from 4G to 5G SA

We provide here a brief overview of the industry situations for both carriers and large enterprises requiring private networks, and then explain the challenges that these enterprises will face in the 4G to 5G transition.

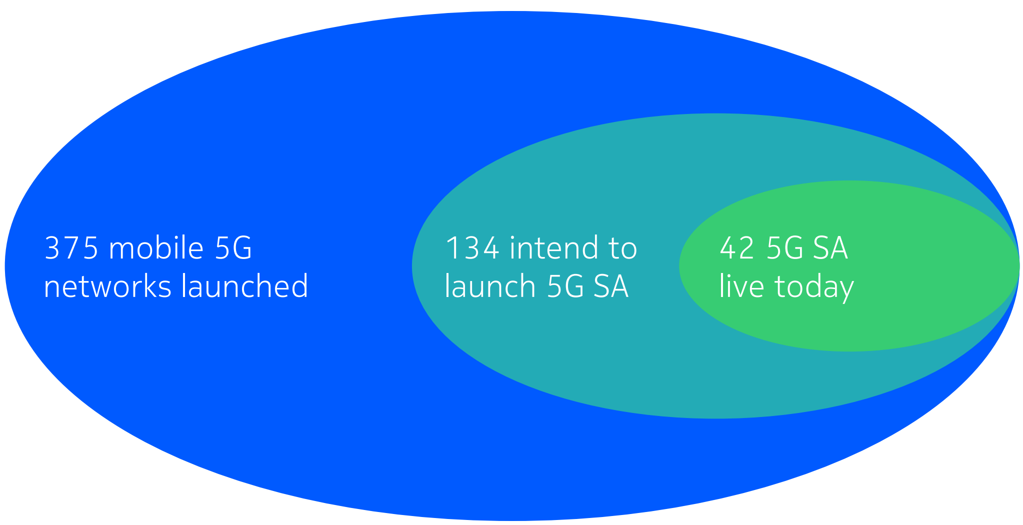
The CSP landscape

4G LTE networks are established globally and are composed of a 4G LTE Radio Access Network (RAN), a 4G VoLTE core, and the necessary backhaul and transport. Implementations vary widely, since early 4G networks consisted of network element products with purpose-built hardware, while more recently the industry has moved to cloud software.

CSPs are now deploying 5G networks, starting with 5G non-standalone (5G NSA), usually as a bridge to 5G Standalone (5G SA). 5G NSA networks deploy the 5G radio but continue to use a 4G core to provide subscriber services. 5G SA networks use the 5G core as specified by 3GPP releases 15 and later, which fully adopt a cloud-native approach to achieve flexibility and introduce a new service-based architecture (SBA).

Many carriers have already deployed 5G radio, transforming their network to 5G NSA, while a smaller number have deployed 5G SA. The GSMA reports[1] that as of Q3 2023, a total of 375 operators have launched mobile 5G or 5G FWA, whereas 134 operators intend to launch 5G SA, and only 42 operators currently offer services based on live 5G SA networks. This means that 89% of the 5G CSP networks today are 5G NSA.

Figure 1. CSP 5G network deployments as of end 2023



Transitioning the radio network from 4G to 5G is a straightforward process, involving the overlay deployment of new 5G radio equipment that operates in tandem with existing 4G infrastructure. Likewise, transport and operations do not represent significant challenges. However, upgrading to the 5G core requires more effort, particularly when the CSP has deployed a 4G-only core. The small number of 5G SA networks live today demonstrates this, as well as the industry's current state.

1 Source: "5G in Context, Q3 2022", December 2023, GSMA.

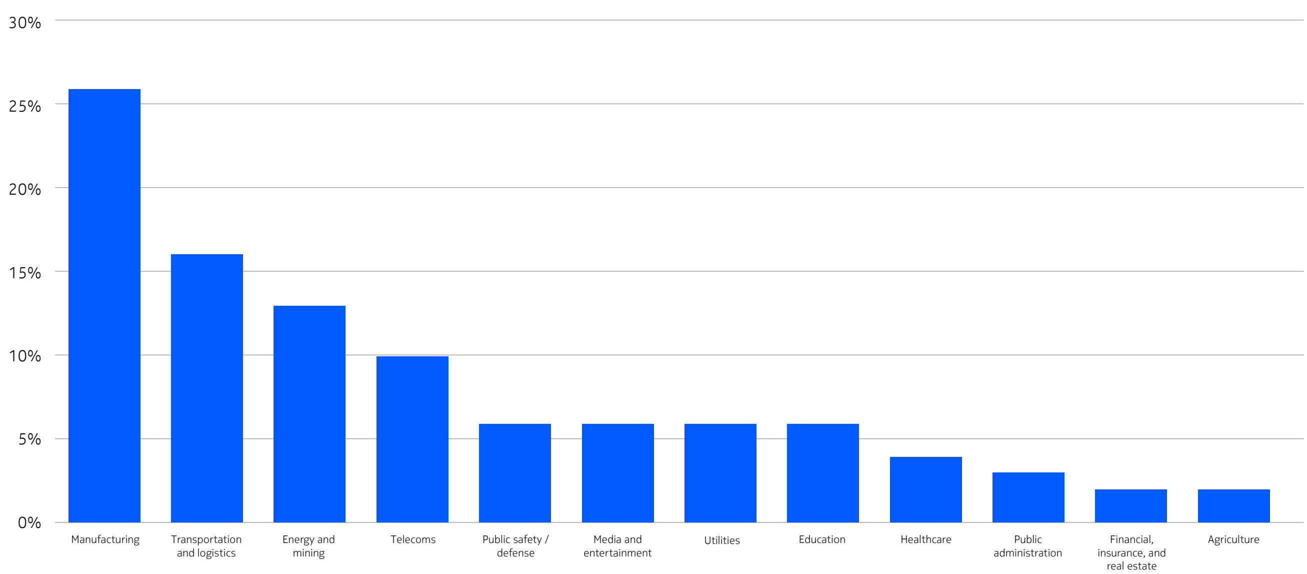
The state of private wireless networks

Private wireless 4G LTE networks have been deployed in various enterprise segments nearly from the time 4G LTE first became available. Early deployments were dependent on spectrum availability for private enterprises, which varied regionally. When 5G became available, private wireless networks based on this technology began in tandem.

Today an estimated 2200 private wireless 4G LTE and 5G networks have been deployed worldwide. Omdia[2] reports that the most common verticals include Manufacturing, Transportation & Logistics, and Energy and Mining at 26%, 16%, and 13% respectively. Utilities comprise about 6% of deployments while public safety and defense make up another 6%.

These implementations are mostly highly localized, serving small geographic areas. The network core for most deployments is small, purpose-built, and does not adhere to strict 3GPP compliance. Each vertical is addressing a specific problem, which differs from other verticals. Spectrum availability varies based on region. There is no single network management model[3]. Thus, the 4G and 5G private wireless network market is highly fragmented due to these market forces, as well as integration needs, costs, devices, and replicability.

Figure 2. Cumulative PWLS 4G and 5G network announcements through 2023



5G promises to be a transformative shift for enterprises using private wireless networks. Deployments are increasing, but growth is hampered by market fragmentation. The move to 5G networks has the additional issue of finding compelling use cases that depend on 5G, beyond high bandwidth applications.

Migration challenges

Given there is a 4G LTE network in place to be transitioned to 5G, the challenges to migration encompass technical, operational, financial, and strategic considerations.

2 "LTE and 5G Private Networks Tracker Report – FY23 Analysis", February 2024, Omdia.

3 Ibid, page 22.

Infrastructure upgrade costs: The transition to 5G SA requires significant investment in new infrastructure, including 5G-compatible antennas, base stations, and core network components. This can be a substantial financial burden for many enterprises.

Technical complexity: Implementing a 5G SA network involves navigating the complexities of new technologies such as network slicing, edge computing, and the 5G core. This requires a deep understanding of 5G specifications and standards.

Integration with existing systems: Enterprises must ensure that the new 5G network integrates seamlessly with existing IT and communication systems. This includes compatibility with legacy technologies and the ability to support current operational workflows.

Spectrum access and management: Accessing the necessary spectrum for 5G can be challenging, especially in regions where spectrum is scarce or heavily regulated. Enterprises may need to navigate complex regulatory environments to secure spectrum rights.

Security concerns: 5G networks introduce new security architectures and potential vulnerabilities. Enterprises must address these security challenges to protect sensitive data and ensure privacy, requiring updated security protocols and measures.

Skilled workforce: There is a need for skilled personnel who understand 5G technology and can manage the transition and ongoing operation of the network. This may require significant training or hiring new staff with the requisite expertise.

Network slicing and management: Leveraging one of 5G's key features, network slicing, requires sophisticated management tools and expertise to create and manage slices effectively, ensuring each slice meets specific application requirements.

Ensuring quality of service (QoS): Delivering the expected QoS for various applications, from low-latency requirements for industrial automation to high-bandwidth needs for video surveillance, can be challenging during and after the migration.

Interoperability: Ensuring interoperability between 5G SA equipment from different vendors, as well as compatibility with existing 4G LTE assets, can be complex. This includes managing potential issues related to standards compliance and vendor-specific implementations.

Regulatory and compliance challenges: Navigating the regulatory landscape, including compliance with local regulations regarding deployment, spectrum use, and cybersecurity, can be complex and time-consuming.

Return on investment (ROI): Justifying the investment in 5G technology requires a clear understanding of the benefits and a strategic plan for leveraging 5G capabilities to improve operations, reduce costs, or generate new revenue streams.

Energy consumption and sustainability: 5G networks, particularly those supporting high data rates and low latency, can consume more energy than their 4G counterparts. Enterprises need to consider the impact on energy costs and sustainability goals.

Vendor ecosystem and support: Selecting the right technology partners and vendors for 5G equipment and services is crucial. Enterprises must navigate a rapidly evolving vendor landscape, ensuring they choose partners that offer the best long-term support and technology roadmap alignment.

This is a reasonably comprehensive list of concerns provided as background information. For any enterprise performing this migration, only a subset may be relevant depending on the circumstances.

Understanding 4G and 5G networks

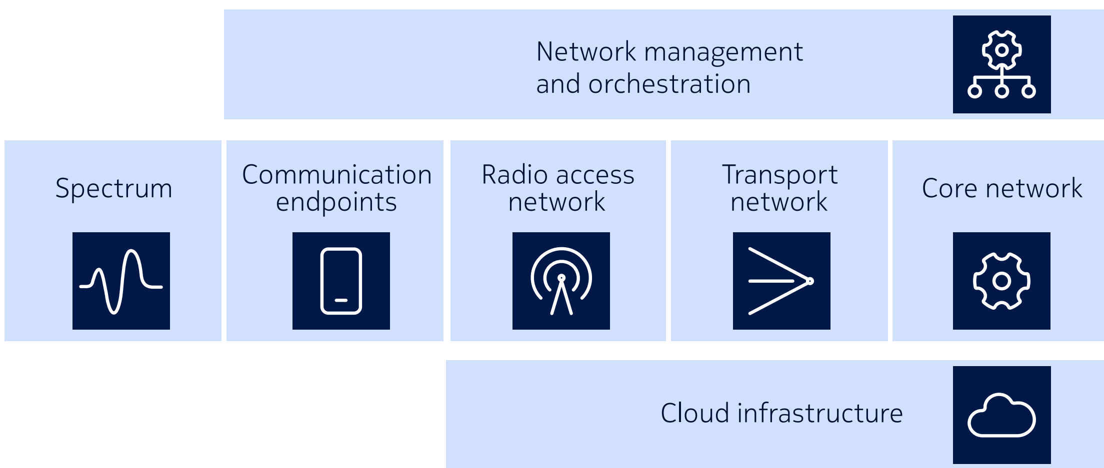
Here we provide a brief overview of the architecture of both 4G LTE and 5G networks. Both network approaches are an arrangement of equipment across several domains that work together to provide a communications platform.

Network domains

A network domain is a category within the overall system defined by its distinct function or role. Each encompasses a set of related functions, processes, technologies, and equipment that work together to fulfill a particular aspect of the network's operations.

Transitioning from 4G to 5G requires the transition of every domain, although not at the same time.

Figure 3. Mobile network domains



Spectrum - Spectrum refers to the radio frequencies used for cellular communication and is allocated by regulatory bodies in each country. It is a critical resource shared by both 4G and 5G networks. 5G introduces the new cm-wave and mm-wave bands, capable of extremely high bandwidth, but over shorter usable distances.

Communication endpoints – User equipment (UE), such as smartphones, tablets, drones, video cameras, body cams, and an expanding set of Internet of Things (IoT) devices, are the communication endpoints of mobile networks. They are tailored to the technology they serve, and may have a 4G radio, a 5G radio, or both.

Radio access network (RAN) – The RAN consists of base stations and antennas distributed across geographic locations to provide coverage.

Transport network – The transport network manages the movement of data and signaling and is the link between the RAN and the core network. It uses various mediums, including fiber optics, microwave, and satellite links.

Core Network – The core network authenticates users, routes calls and data, and manages mobility. While the 4G network employs an Evolved Packet Core (EPC) to manage these functions, 5G introduces a significant shift to a 5G Core Network (5GC), employing a service-based architecture that enables more flexible and efficient network management.

Network Orchestration and Management – This domain includes systems for dynamic resource allocation and automated network configuration, as well as operational and business support systems (OSS/BSS) for tasks like billing and customer management.

Cloud Infrastructure – Cloud infrastructure is the compute platform for network functions, especially for the core domain and network orchestration and management domain. It brings scalability and efficiency to both 4G and 5G networks, but 5G has been designed from the start to take advantage of cloud-native approaches such Service Based Architecture, which allows for network services to be flexibly introduced.

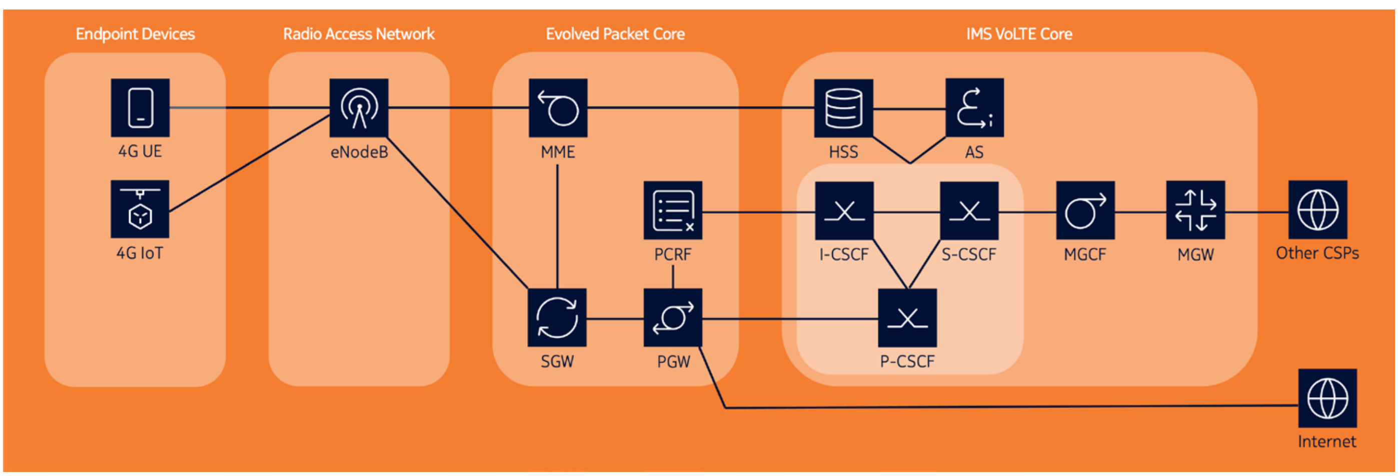
The anatomy of 4G and 5G networks

Understanding the structural components and services of 4G and 5G networks provides crucial insights into how the migration may occur.

4G LTE network architecture

The 4G network architecture is primarily based on the Evolved Packet Core (EPC), connected to various eNodeBs (Evolved Node B). The EPC handles all core network functions, including data routing, user management, and service delivery.

Figure 4. Simplified 4G LTE network architecture



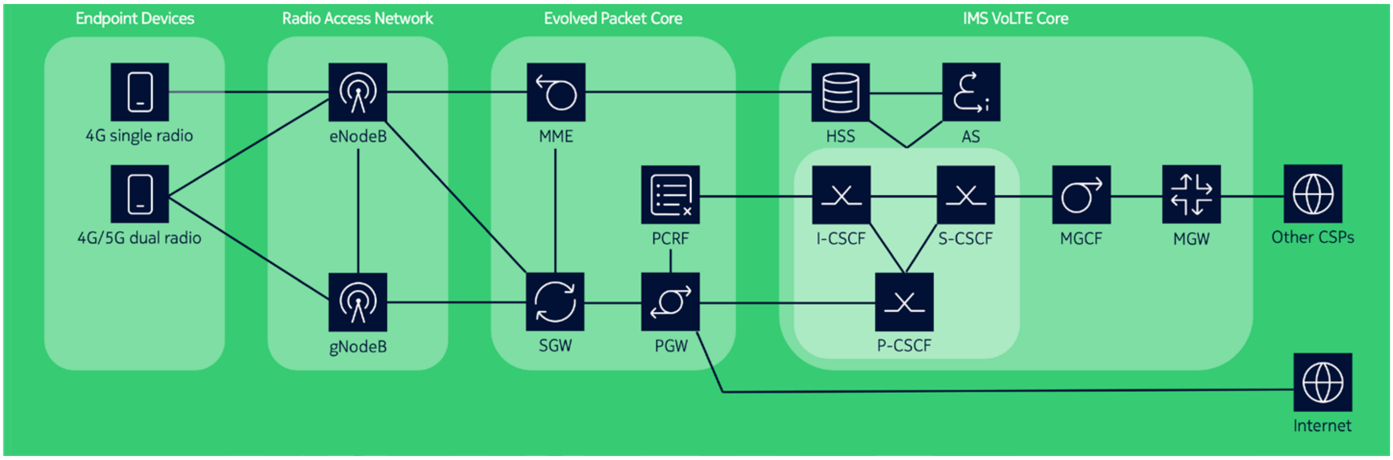
4G networks provide users with high-speed data services, voice communication over LTE (VoLTE), and multimedia broadcasting capabilities. These services are supported by a robust and mature infrastructure that ensures reliable and widespread connectivity.

5G NSA network architecture

A 5G network's architecture differs significantly depending on whether it is in a Non-Standalone (NSA) or Standalone (SA) configuration.

In a 5G NSA setup, the operator deploys 5G radio, including the 5G gNodeB into the RAN. The 5G gNodeB connects both to the existing 4G EPC Signaling Gateway (SGW), as well as to the 4G eNodeB. 5G-capable user endpoints and IoT devices can then connect using 5G to the network. This configuration is called 3GPP Option 3x. User endpoints may have dual 4G/5G radios, allowing them to use 5G radio for high bandwidth data services, and the 4G radio for voice calls or when a 5G RAN is not present.

Figure 5. Simplified 5G NSA network architecture

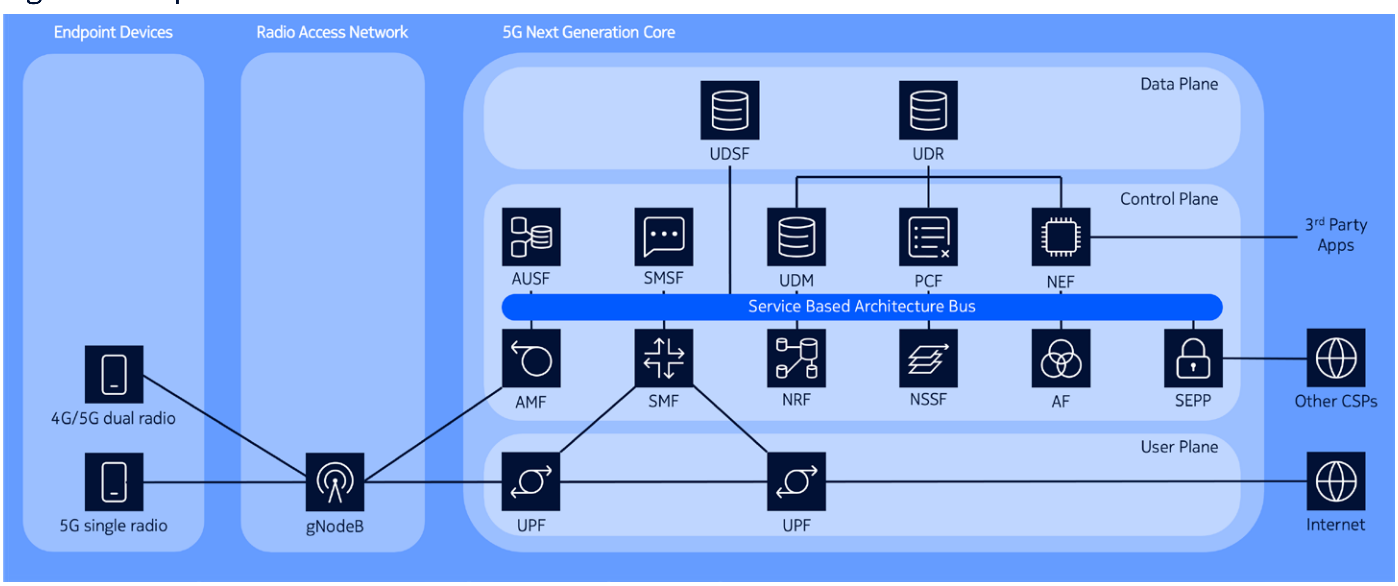


Users in a 5G NSA network experience faster data speeds and improved connectivity compared to 4G, without a complete overhaul of the existing network infrastructure.

5G SA network architecture

In a pure 5G SA network, 5G Core (5GC), which is based on an entirely new service-based architecture, enables increased agility, enhanced security, and operational efficiency. The IMS VoLTE core remains intact (albeit with some slight signaling modifications), as an Application Function (AF) within the 5G Core.

Figure 6. Simplified 5G SA network architecture



A 5G SA network enables deployment of the full suite of 5G services with low latency, ultra-reliability, high bandwidth, precise location, end-to-end security, the ability to easily add new capabilities via SBA, and the ability to connect a vast number of devices, paving the way for advanced IoT applications.

Although the 5G Core superficially appears to be more complex than the 4G EPC, what has happened is that the 3GPP has decomposed the functions more finely in 5G. This results in more, but smaller, and more well-defined network functions, coordinating with each other through the service-based architecture bus.

Role of cloud-native platforms

Cloud-native approaches have marked a significant shift in mobile networks. Initially, 4G systems were largely built on traditional hardware-centric models. Now, nearly every vendor provides network software on cloud infrastructure. This allows network functions to be decoupled from dedicated hardware and implemented as software on general-purpose servers, leading to increased flexibility, cost-efficiency, and ease of scaling network resources.

Cloud-native for 4G LTE

4G core networks were originally deployed as bare metal appliance network elements, and then as virtualized network functions (VNFs). Migrating this kind of core to 5G is a major effort as the complete core would need to be replaced.

Next generation 4G LTE core, available today, is based on cloud-native software running as containers on Kubernetes. Vendors continue to offer hardware appliance products, as well as Network Function Virtualization implementations for maintenance compatibility with existing deployment environments, but the industry has settled on cloud-native CNFs as the long-term approach. This offers some level of investment protection in a transition to 5G core and can be thought of as a base level of being “5G ready”.

Cloud-Native for 5G

3GPP designed 5G to be cloud-native from the outset, incorporating cloud principles into the very fabric of the network’s architecture.

Cloud-native from the start - Unlike 4G, 5G standards specify cloud-native characteristics such as containerization, microservices, and dynamic orchestration. This allows for a more agile approach to deploying and managing networks.

Service-based architecture - 5G incorporates a Service-Based Architecture (SBA) that allows network functions to be modularized, reused, and combined in new ways. Each function offers services through APIs, enabling them to interact in a more decoupled and efficient manner compared to the monolithic designs of the past.

5G distributed cloud - 5G networks can more naturally distribute network functions geographically, closer to the edge of the network. Multi-access edge computing (MEC) brings compute and storage resources closer to the devices that need them, reducing latency and improving performance for critical applications.

This shift to cloud-native design resulted in a major update to the core architecture compared to 4G, although has had much less effect on other domains in the network.

A guide to transitioning the core to 5G

Some practical limitations for this discussion

This white paper demonstrates a pathway for the transition from 4G to 5G for wide-area private wireless networks. We cannot cover every possible transition, and so focus on a specific use case: we propose the deployment of a cloud-based next generation 4G LTE core network, and then transition it to 5G SA in a stepwise fashion.

We also limit the discussion to a transition from a cloud-native 4G solution to 5G because most large regional enterprises (such as power utilities, public safety, and mainline railways) have not yet deployed a 4G private wireless network. We show how these verticals can deploy 4G today, then migrate to 5G by taking advantage of cloud-native software.

The transition strategy outlined here will use Nokia Core Enterprise Solutions as an example case for concreteness. Nokia's other core offers have the same character, so this approach is also valid in those cases – such as for the Nokia 4G/5G Core Engineered System. Other vendors have varied product offerings, so this guide may not be applicable when considering their solutions.

High level: deploying 4G and migrating to 5G

In this section, we cover the initial 4G deployment, then its transformation to 5G at a network domain level. We assume that older 4G bare metal or virtualization technology has not been deployed – so that the 4G deployment here can start from a high level of 5G readiness[4].

First establish a cloud-native 4G foundation

In the initial 4G deployment, all the network domains must be established, with a view toward an expected migration to 5G. The following table provides both the necessary capability, as well as guidance to ensure that the transition to 5G is seamless.

Table 1. Domain actions to establish a 4G network

Domain	Establish 4G network	5G Considerations
Spectrum	Establish access to 4G spectrum.	Consider whether you will need 5G specific spectrum, like cm-wave or mm-wave. Also consider whether you will re-allocate the 4G spectrum acquired for use by 5G, and clear this with regulatory agencies.
Communication endpoints	Deploy endpoints capable of communicating with your 4G network. These may be handsets, tablets, or IoT devices, depending on your needs.	Consider using dual-radio 4G/5G devices, to avoid a full swap out of 4G-only devices. If you intend to run a hybrid 4G/5G network long term this may not be an issue.
Radio access network	Deploy 4G eNodeBs yourself, or partner to lease radio capacity from a carrier or neutral-host network provider.	Upon deploying 5G, this transition is straightforward, as the action will be to create an overlay 5G network with gNodeBs.
Transport network	Establish a transport network suitable for carriage of traffic. Alternatively, partner with a neutral-host network provider who will have that transport.	Ensure that the transport network can be expanded to the capacity you need in the case that your 5G use cases will require that.

4 The assessment of how "5G ready" an initial 4G deployment will be is generally a question of whether a network-level replan is necessary for the addition of the 5G components. In our approach here, we are using a Nokia core which has this interface integration and validation built into the core from the start, removing the need for such a replan.

Domain	Establish 4G network	5G Considerations
Core network	Deploy the 4G LTE core.	Very important: the 4G core should be based on cloud-native software. The new 5G core is architecturally different from a 4G LTE core, so using a cloud-based core makes the transition to 5G far easier. Further, if the solution being deployed already includes both 4G and 5G functions, pre-integrated and validated, there is no true migration needed. Instead, adding the 5G portion of the network reduces to adding 5G access points. This approach provides a high level of 5G readiness from the beginning.
Cloud infrastructure	Deploy the cloud infrastructure needed to support the core, and other functions. The core may require a specific cloud platform specified by the vendor.	Ensure the cloud infrastructure deployed will support the new 5G core as well.
Network management and orchestration	Deploy the appropriate OAM&P capabilities as well as orchestration capabilities that you need.	These applications are typically software based and can easily be transitioned with the move to 5G.

Transition to 5G NSA

The next step is to deploy 5G radio and transition the network to 5G NSA. The table below indicates the actions required in the most affected domains.

Table 2. Domain actions to transition to 5G NSA

Domain	Establish 4G network
Spectrum	Establish access to the 5G spectrum needed for the network.
Communication endpoints	If you have not yet deployed dual-radio 4G/5G endpoints, now is the time to do this. Dual-radio 4G/5G endpoints should be provisioned to include a 5G DNN.
Radio access network	Deploy the 5G gNodeB stations to establish an overlay 5G network where it makes sense for your use cases. It is possible that 5G is only needed in limited locations.
Transport network	Likely few changes, other than to establish connectivity to the new RAN elements.
Core network	Make the configuration changes to the EPC to work with both the 5G and 4G RAN elements. Little other change in the core is needed.
Cloud infrastructure	No changes are likely needed.
Network Management and orchestration	Software updates or configuration changes will be needed to manage the new 5G RAN, and potentially for managing new endpoints.

Establish a parallel 5G core

In this step, a parallel 5G core is established to create a hybrid 4G/5G network. It is possible that this arrangement may continue for the long term.

At this high-level view, the parallel 5G core could be an overlay network, or it could be part of the same platform for the 4G LTE core – depending on vendor capabilities.

Table 3. Domain actions to establish parallel 5G core

Domain	Establish 4G network
Spectrum	No changes are likely needed.
Communication endpoints	5G only (single radio) endpoints may be introduced.
Radio access network	Rearrange the gNodeBs in the RAN to connect to the new 5G core's AMF and UPF when it becomes available.
Transport network	Make any changes necessary to handle 5G additional bandwidth needs, depending on the use case.
Core network	Add the new 5G core alongside the existing 4G core. Once the core network is tested, migrate the 5G traffic to the 5G core to create a 4G/5G hybrid network. If the original solution included both 4G and 5G functions pre-integrated and validated (thereby creating a high level of 5G readiness from the beginning), then this step is to enable 5G access points and anchor them in the 5G SA core. This results in a faster transition and lower TCO, because the 5G core has been there from the start.
Cloud infrastructure	If the new 5G core is a pure overlay, the cloud infrastructure may need to be expanded.
Network Management and orchestration	Software updates or configuration changes will be needed to manage the new 5G core elements.

Decommission 4G and scale 5G

With the successful establishment of the 5G core, the focus shifts to decommissioning redundant 4G components. It is possible that this step is not appropriate for many years, since there are many cases where operating both 4G and 5G simultaneously makes sense for coverage reasons.

Table 4. Domain actions to decommission 4G and scale the 5G network

Domain	Establish 4G network
Spectrum	No changes are likely needed.
Communication endpoints	Decommission the 4G-only endpoints in this step. Dual-radio 4G/5G endpoints can remain, but the 4G APN should be disabled.
Radio access network	Decommission the eNodeB radio elements.
Transport network	No changes are likely needed.
Core network	Decommission any 4G network functions that are no longer needed after de-loading all traffic. If voice services are needed, rearrange the IMS VoLTE part of the 4G network to work with 5G VoNR.
Cloud infrastructure	Release any surplus cloud capacity for other purposes.
Network Management and orchestration	Software updates or configuration changes may be needed to decommission any OAM&P or orchestration applications that were dedicated to 4G network management.

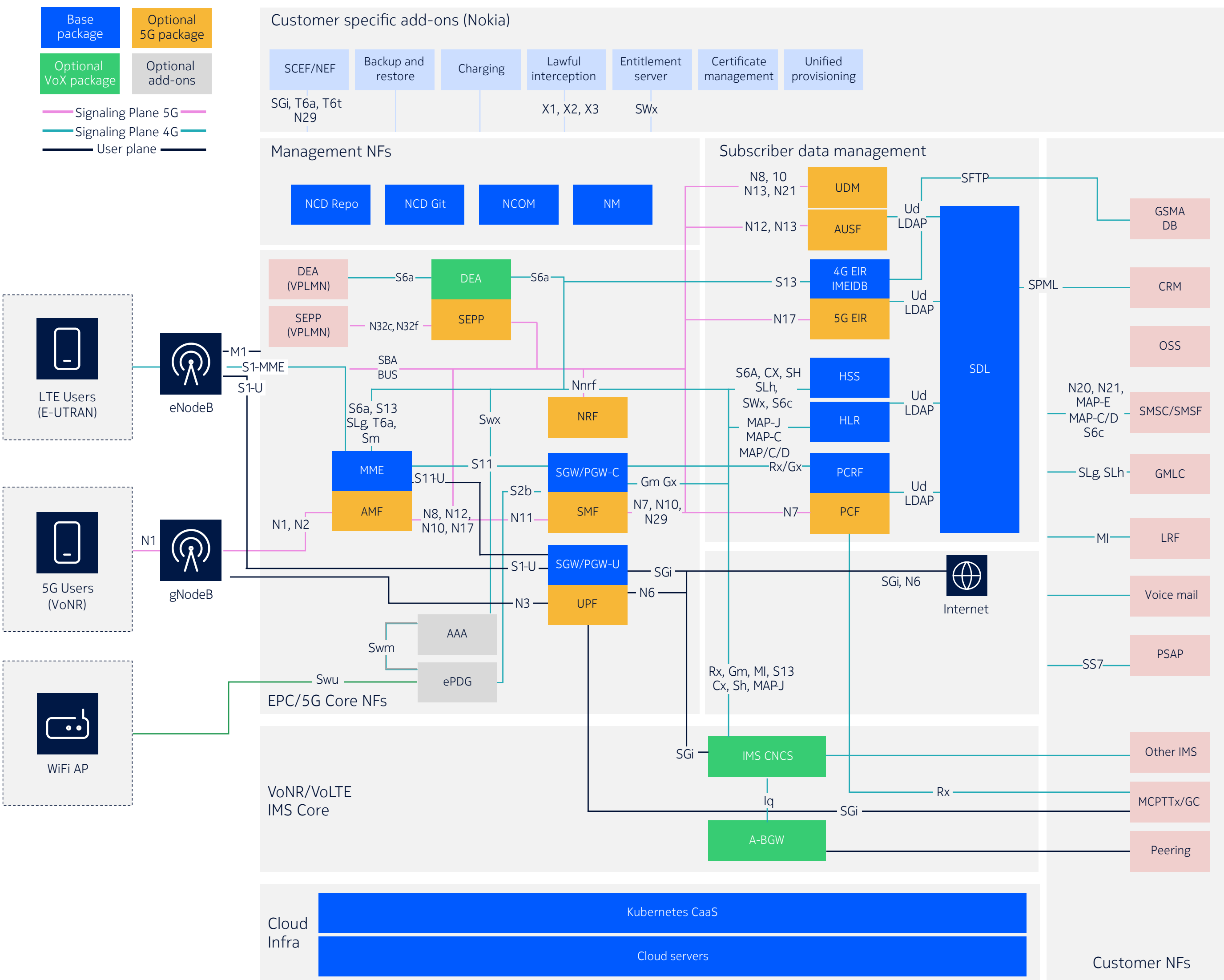
The cloud platform's non-discriminatory nature regarding workload types allows for a concurrent 4G and 5G core operation, requiring increased cloud capacity initially. However, once the transition reaches finality and 4G components are decommissioned, the liberated resources can be repurposed to expand the 5G core, enhancing network capability and preparing it for future services.

Detailed migration of the core domain

Since the core domain is the most complex part of the migration process, this section provides more detail using Nokia's Core Enterprise Solution as a concrete example. Core products from other vendors will have different approaches, depending on their product capabilities.

Nokia Core Enterprise Solutions are designed to power 4G and 5G private wireless networks for organizations such as power utilities, public safety agencies, and other verticals with similar needs. A simplified and approximate version of its functional architecture is shown in the following figure.

Figure 7. Nokia Core Enterprise Solution simplified architecture



The solution has a base package along with several optional packages, including a 5G option enabling a migration to 5G SA. If the customer needs Voice and Text subscriber services, an optional VoX package is available. There are also some additional add-on capabilities. This solution is an example where the 4G and 5G functions are present from the start, including pre-integration and validation for a very high level of 5G readiness.

Solution explanation

The left side of the figure shows the RAN and Wi-Fi® access, while along the right side are functions that the network operator provides, sourced from Nokia or other vendors. Along the top are some optional

Nokia products that the customer may choose to purchase, but these are not part of the Nokia Core Enterprise solution.

In the middle are the Nokia products that comprise the solution organized into the various subdomains of the core network. These are as follows:

Management NFs - These network functions are responsible for element management, operations, and CI/CD aspects of the Nokia solution.

EPC/5G Core NFs - These are the network functions that make up both the 4G and 5G core. Blue items are part of the base package, while yellow make up the optional 5G package.

Subscriber Data Management – Manages data associated with subscribers and endpoints as well as policy network functions, required for the core to function properly.

VoNR/VoLTE IMS Core – This is a full IMS VoLTE system in a single container for networks requiring voice services.

Cloud Infrastructure – At the bottom of the diagram is the cloud infrastructure, consisting of Nokia Cloud Platform (NCP) running on Dell or HP hardware. This domain provides the Kubernetes environment in which all the network functions reside.

The interface names and connections are shown, but it is not necessary to explain detail regarding these for the purposes of this paper.

Combo nodes

Nokia's core networks portfolio is based on a collection of products that are software-configurable to perform functions in a 4G context, a 5G context, or both. When the product is configured to provide both 4G and 5G capability at the same time, it is called a "combo node." It is this key capability that enables a smooth transition from 4G to 5G SA in the core domain.

What follows is a table that shows the Nokia product, and both the 4G and 5G functions.

Table 5. Nokia products to function mapping

Nokia Product name	4G core functions provided	5G core functions provided
Cloud Signaling Director (CSD)	DRA, DRE, Diameter Firewall	SCP, SEPP, BSF
Cloud Mobility Manager (CMM)	MME	AMF
Cloud Mobile Gateway (CMG)	SGW, PGW-C	SMF, UPF
Equipment Identity Register (EIR)	4G EIR (IMEIDB)	5G EIR
Nokia Policy Controller (NPC)	PCRF	PCF
Subscriber Data Manager (SDM)	HSS, HLR	UDM, AUSF

Not all products require differentiation between 4G and 5G. These include the NRD, which provides the 5G-only NRF function, and several products that provide a function applicable to both 4G and 5G.

5G readiness of the solution

5G readiness appears at three levels in the architecture of Nokia Core Enterprise Solutions.

Cloud-native software – Nokia core software is fully cloud-native, constructed of microservices in containers that run on Kubernetes.

Product level 5G readiness – The use of "combo nodes" allows the product to provide either a 4G function, the equivalent 5G function, or both simultaneously.

Solution level 5G readiness – Nokia's Core Enterprise Solutions are pre-integrated and pre-validated at the solution level. Because of this, the transition to 5G is much easier, and more akin to enabling 5G access points than a network migration.

Migrating from 4G to 5G

The network deployment steps that start off with a 4G core, and then later migrate to a 5G core are explained in detail in this section.

Step 1: Before deploying anything, include a 5G option from the start

It is assumed that the customer would want to avoid a forklift upgrade, or the need to create a complete overlay 5G network alongside the 4G network for cost reasons. Nokia's approach to this is to include the 5G functions from the start pre-integrated at the solution level as part of the optional 5G package when the core is initially deployed. The 5G functions will remain dormant, until the time comes to migrate.

There is some additional capacity in the cloud infrastructure needed for this optional package, of around 5 servers per data center site. It is possible to fit the core within a single rack in some applications, and in others it may take two racks. These additional servers may sometimes require an additional rack for the implementation.

Step 2: Deploy the 4G network, then the 5G NSA network

The rest of the network, including the RAN, transport, and other operations function should be deployed as well. These steps are described above in the domain-level descriptions.

Step 3: Identify the important 5G use cases

It is possible that no relevant 5G use cases will present themselves for some time. Therefore, the organization deploying the network should determine whether a migration to 5G makes sense in accordance with their business needs or organizational requirements.

Until there is a strong case for services that require 5G, the network should not be further transitioned. Simple high bandwidth cases can be addressed with 5G NSA.

Step 4: Begin operation in a 4G/5G hybrid mode

In this step, the 5G functions within the core are activated, and the network can operate with either 4G endpoints or 5G endpoints. The 5G endpoints will provide the services for those use cases that require capabilities that only 5G provides – very low latency, ultra-high bandwidth, and the like.

It is possible that this could be the final state of the network, operating with both 4G and 5G capabilities for the foreseeable future. For Nokia Core Enterprise Solutions, this state includes both 4G and 5G network functions in the same frame.

Step 5: Expand 5G coverage

If there is a desire to convert the network purely to 5G and decommission its 4G LTE aspects, the radio network must be expanded to provide coverage over the entire area required for the application.

At the same time, the customer may choose to replace dual-radio 4G/5G endpoints with 5G endpoints, depending on their operational requirements. For example, a single-radio 5G endpoint uses less power than a dual-radio endpoint, so its battery will last longer which may be an operational benefit depending on the application.

From the core's perspective, traffic is slowly moved from the 4G core to the new 5G core in the existing deployment.

Step 6: "Decommission" the 4G core components

In a Nokia Core Enterprise Solution with the 5G option, it's not possible to remove the 4G component, because it is really part of a combo-node product. Decommissioning in this case simply means that the 4G function is no longer receiving traffic.

Since communication traffic of any type requires compute capacity, this means that the same compute resources are now being used to service the 5G traffic rather than the 4G traffic. Therefore, a transition from 4G to 5G has been accomplished with a single system in place, and without requiring service outages.

Conclusions

In this paper we have detailed the pathway for transitioning from 4G to 5G SA in private wireless networks without necessitating a complete overhaul or causing service disruptions. The proposed approach is to leverage cloud-native infrastructure and adopt a phased deployment strategy at the network level. Necessarily, we have presented this within Nokia's architecture and product offerings, since such an approach will vary widely depending on vendor capabilities.

The approach that Nokia proposes is to build on a 4G foundation, and then upgrade the network using the combo-node capability of Nokia products. This minimizes risk and maximizes the use of current assets, ensuring a smooth transition that leverages the product design approach for this purpose.

Transitioning to 5G SA can be achieved efficiently with careful planning and the right technological approach, leveraging the key benefits of cloud-native software and 5G pre-integration. This strategy not only facilitates a seamless upgrade but also ensures that networks are future-ready, capable of adopting next-generation technologies without the need for disruptive or costly overhauls.

Abbreviations

4G EIR	4G Equipment Identity Register
5G SA	5G Standalone
AAA	Authentication, Authorization, and Accounting
AMF	Access and Mobility Management Function (5G context)
AUSF	Authentication Server Function (5G context)
BSF	Binding Support Function (5G context)
CMM	Cloud Mobility Manager
CMG	Cloud Mobile Gateway
CNCS	Cloud Native Communication Suite
CRM	Customer relationship Management
CSD	Cloud Signaling Director
DEA	Diameter Edge Agent
DRA	Diameter Routing Agent
DRE	Diameter Routing Engine
EIR	Equipment Identity Register
eNodeB	Evolved Node B
ePDG	Evolved Packet Data Gateway
EPC	Evolved Packet Core
GMLC	Gateway Mobile Location Center
GSMA	Global System for Mobile Communication
GSMA DB	GSMA Database
HLR	Home Location Register
HSS	Home Subscriber Server (4G context)
IMEI	International Mobile Equipment Identity
IMEI DB	International Mobile Equipment Identity Database
IMS VoLTE	IP Multimedia Subsystem Voice over LTE
LDAP	Lightweight Directory Access Protocol
LRF	Location Retrieval Function
MAP-C/D	Mobile Application Part C/D
MAP-E	Mobile Application Part E
MAP-J	Mobile Application Part J

MCPTT	Mission Critical Push to Talk
MCPTX	Mission Critical Push to X
MCX	Mission Critical X
MME	Mobility Management Entity (4G context)
NCD	Nokia Continuous Delivery
NEF	Network Exposure Function
NPC	Nokia Policy Controller
NRD	Network Resource Director
NRF	Network Repository Function (5G context)
OSS	Operational Support System
PCF	Policy Control Function (5G context)
PCRF	Policy and Charging Rules Function (4G context)
PGW-C	Packet Gateway Control (4G context)
PSAP	Public Safety Answering Point
SBA	Service Based Architecture
SCEF	Service Capability Exposure Function
SCP	Service Communication Proxy (5G context)
SDM	Subscriber Data Manager
SEPP	Security Edge Protection Proxy (5G context)
SGW	Serving Gateway (4G context)
SDL	Shared Data Layer
SFTP	Secure File Transfer Protocol
SMF	Session Management Function (5G context)
SMSC	Short Message Service Center
SMSF	Short Message Service Function
SPML	Service Provisioning Markup Language
UDM	Unified Data Management (5G context)
UPF	User Plane Function (5G context)
VoLTE	Voice over LTE
VoNR	Voice over New Radio
VoX	Voice over X

List of tables

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