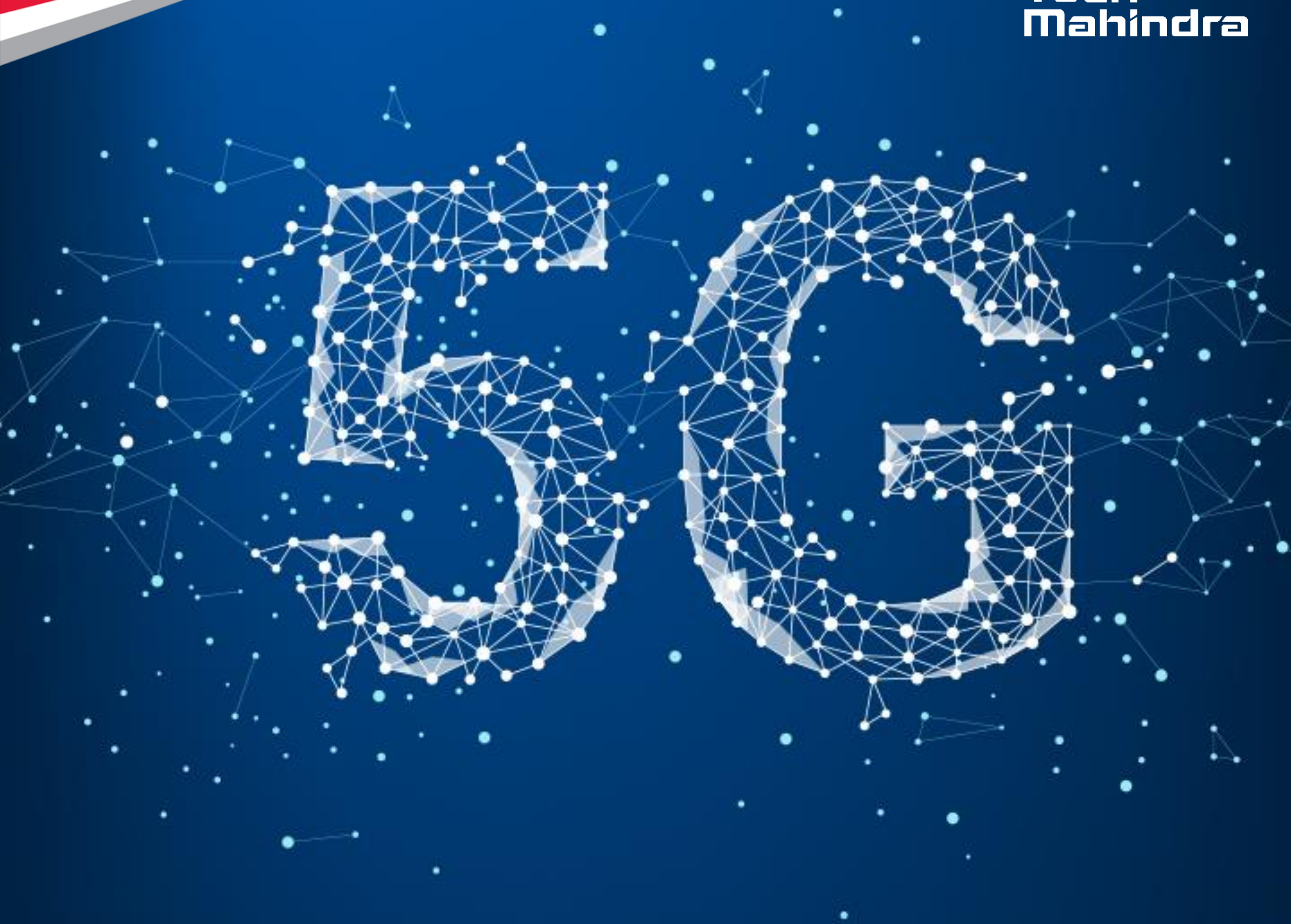

White Paper

Network Transformation to 5G

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1. Introduction:

Fifth generation (5G) technology is expected to fundamentally transform the role that Telecommunications technology plays in the society, unlike the previous technologies. 5G is also expected to enable further economic growth and digitalization of a hyper-connected society, where not only are all people connected to the network whenever needed, but also many other devices/things virtually creating the society with everything connected (i.e. Internet of Everything). Key changes in 5G as compared to previous technologies are shown as below:

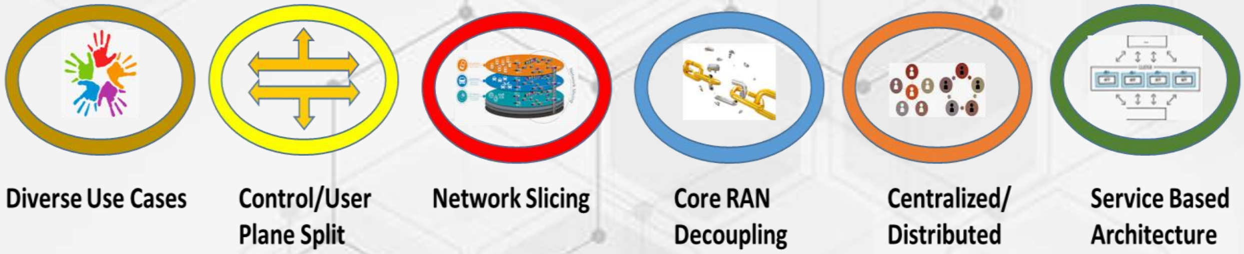


Figure 1: Key Changes in 5G

In the 5G era, a single network infrastructure can meet diversified service requirements. A Cloud-Native 5G network architecture desired to have the following attributes:

- **Network Slicing:**
  - Provides logically independent network slicing on a single network infrastructure to meet diversified service requirements of various vertical industries and provides DC-based cloud architecture to support various application scenarios.

- **Virtualized RAN**
  - Uses vRAN to reconstruct radio access networks (RAN) to provide massive connections of multiple standards and implement on-demand deployment of RAN functions required by 5G use cases.

- **On-Demand:**
  - Simplifies core network architecture to implement on demand configuration of network functions through control and user plane separation, component-based functions, and unified database management.

- **Reduce OPEX:**
  - Implements automatic network slicing service generation, maintenance, and termination for various services to reduce operating expenses through agile network O&M.

While previous generations of mobile networks were purpose built for delivering communications services such as voice and messaging (e.g. 2G) or mobile broadband (e.g. 4G), 5G will have flexibility and configurability at the heart of its design to enable mobile operators to serve IoT (Internet of Things) use cases and to support ultra-reliable, low latency connections as well as enhanced mobile broadband

In terms of spectrum bands earmarked for deployment of 5G, they can be sub-divided in three macro categories: sub-1GHz, 1-6GHz and above 6GHz. Sub-1GHz bands are suitable to support IoT services and extend mobile broadband coverage from urban to suburban and rural areas. This is because the propagation properties of the signal at these frequencies enable 5G to create very large coverage areas and deep in-building penetration. The 1-6GHz bands offer a reasonable mixture of coverage and capacity for 5G services. There is a reasonable amount of existing mobile broadband spectrum identified with this range which could be used for initial 5G deployments. Spectrum bands above 6GHz provide significant capacity thanks to the very large bandwidth that can be allocated to mobile communications and thus enable enhanced mobile broadband applications.

There would be significant changes in the network due to the advent of 5G technology.5G technology would bring new services and cover various vertical industries like smart cities, smart agriculture, Industrial, logistics and public safety agencies.

This Whitepaper would help in guiding the CSPs or Subject Matter Expert or Practitioners for devising the migration strategies from existing legacy networks to 5G NGC Architecture.

2. Key Drivers for 5G:

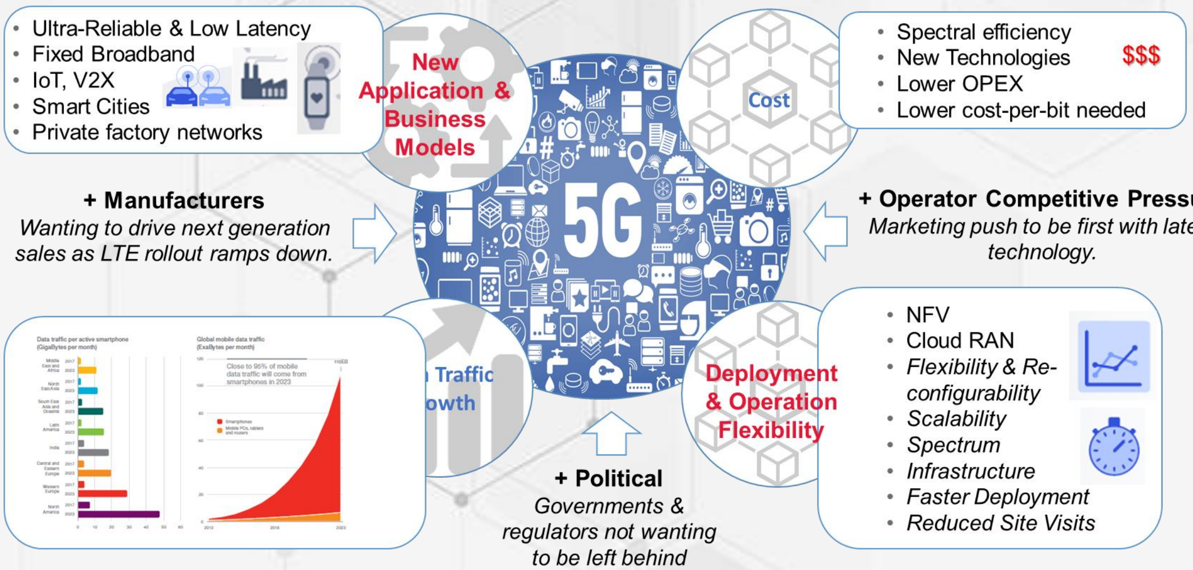


Figure 2: Key 5G Drivers

5G has three major use case classes: enhanced Mobile Broadband (eMBB), mIoT and ultra-reliable low latency (URLLC). The requirements for the use case classes and the use cases within each class vary significantly.

- **eMBB** – enhanced Mobile Broadband – offering GBit/s speeds.
- **MTC** – Machine Type Communication or massive IoT - to support huge volumes of connected devices – ultimately leading to everything being connected.
- **MCC** – Mission Critical Communications – which includes ultra-low latency (down to 1ms) and ultra-high reliability – the type of capability that might be needed for self-driving cars.

Use Cases are often portrayed by using the famous 5G triangle, as shown below. This pictorially highlights where each use case sits against the eMBB / MTC/ MCC classification.

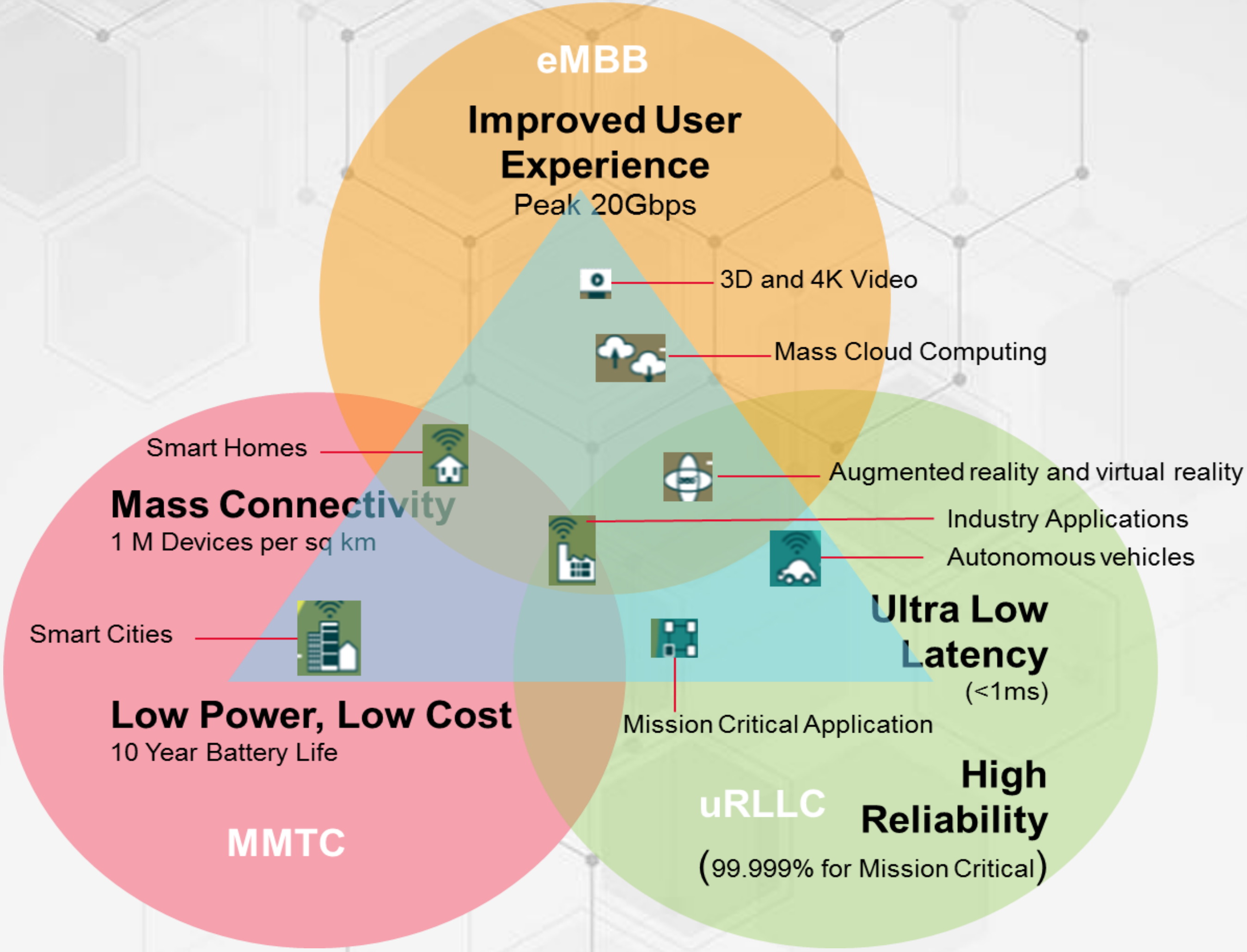


Figure 3: 5G Triangle along eMBB, uRLLC and MMTC

Courtesy: Figure for representation purpose only from ITU-R M.2083-0

To cater the various diverse requirements, Network slice emerges as a promising future proof framework for communication networks. Network slicing is the embodiment of the concept of running multiple logical networks as virtually independent business operations on a common physical infrastructure in an efficient and economical way. A network slice could span across multiple parts of the network (e.g. terminal, access network, core network and transport network) and could also be deployed across multiple operators. A network slice comprises dedicated and/or shared resources, e.g. in terms of processing power, storage, and bandwidth and has isolation from the other network slices.

3. Road to 5G:

The physical boundary between traditional EPC network elements such as MME, SGW, and PGW will be blurred with virtualization and software. This promotes the 5GC to be redesigned and become open and flexible enough to meet the diversity of service and business requirement in 5G era.

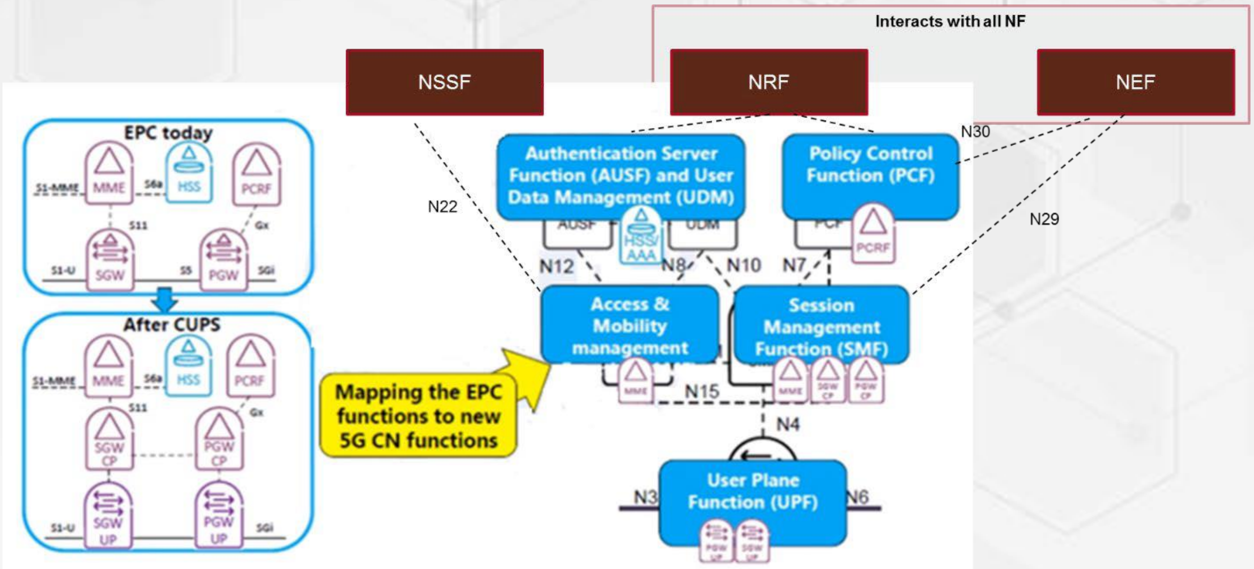


Figure 4: Road to 5G from EPC today

Courtesy: Figure for representation purpose only from Source

New 5G components introduced by 3GPP in 5G technology are as below:

- AUSF (Authentication Server Function): Supports 5G security processes
- AMF (Access and Mobility Management Function): Access control, mobility, network slice selection functionality
- SMF (Session Management Function): User sessions handling as per policy
- PCF (Policy Control Function): Similar to PCRF, policy framework for network slicing
- UPF (User Plane Function): Handles user plane path of Packet Data Unit (PDU) sessions
- UDM (Unified Data Management): Similar to HSS, subscriber information for fixed & mobile access
- NRF* (NF Repository Function): Registration and discovery of NFs via open APIs

- NEF* (Network Exposure Function): Exposure of NF capabilities and events, for 3rd parties
- NSSF (Network Slice Selection Function): Selecting the set of Network Slice instances serving the UE
- AF (Application Function): Interacts with the 3GPP Core Network in order to provide services

The new 5G Core components are directly mapped to the equivalent EPC Functions as below in Table.

NG Core Network Function	Equivalent Core Network Function
AF	AF
NSSF	MME(DÉCOR) + HSS
AMF	MME + SGW-C
SMF	PGW-C
UPF	SGW-U+PGW-U
PCF	PCRF
AUSF/UDM	HSS/AAA/SPR
CM(Charging Management)	PGW+PCRF, OCS, OFCS
SMSF	SMF
BSF, SCP	DRA

Table 1: Equivalence of 5G NGC Core Network Functions with EPC Functions

4. Deployment Options:

From now until 5G realizes real deployment tractions in 2020, much of the available mobile network coverage will continue to be provided by LTE. Because the 5G will most likely coexist with LTE and other technologies such as Wi-Fi access, it becomes important that operators with deployed 4G networks have the opportunity to manage the existing network efficiently and provide a good underlying access layer into 5G, especially for NSA type 5G deployment.

It is possible to integrate elements of different generations in different configurations, namely:

Non Stand Alone NR: UE may be simultaneously connected to LTE and NR or to LTE for control plane and NR for user plane.

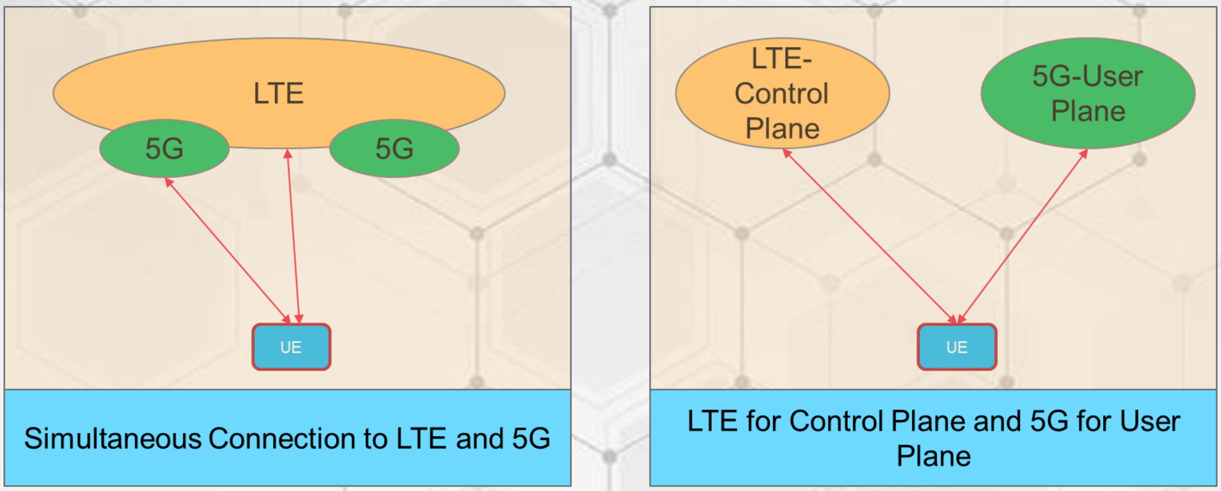


Figure 5: Non Standalone NR

Standalone NR: UE accesses standalone NR carrier and may not be connected to an LTE carrier

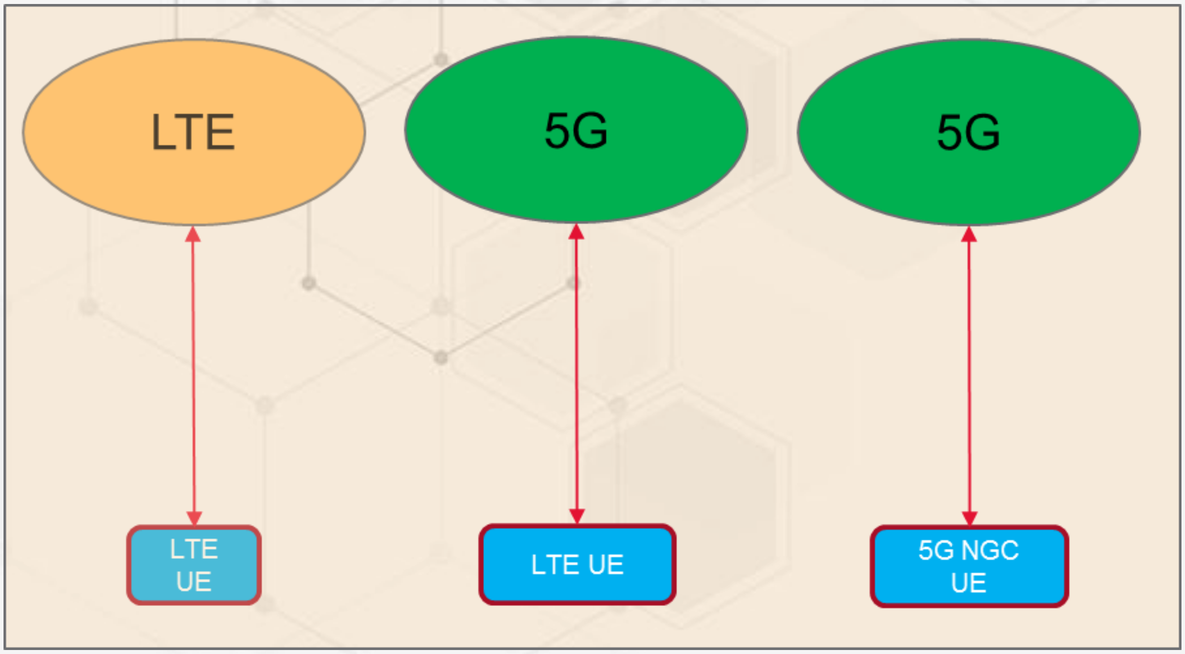


Figure 6: Standalone LTE or NR

Various deployment options are available in order to plan the evolution path from the existing network architecture to 5G based on technical, economic and strategic factors from operator.

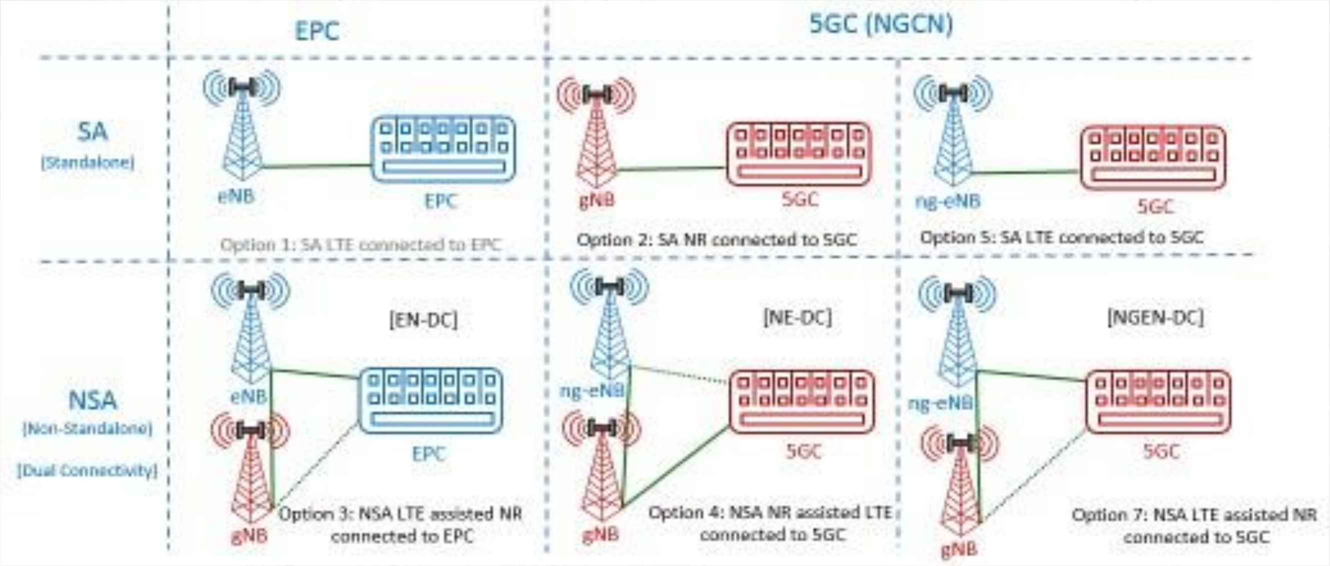


Figure 7: Deployment Options in 3GPP Specifications

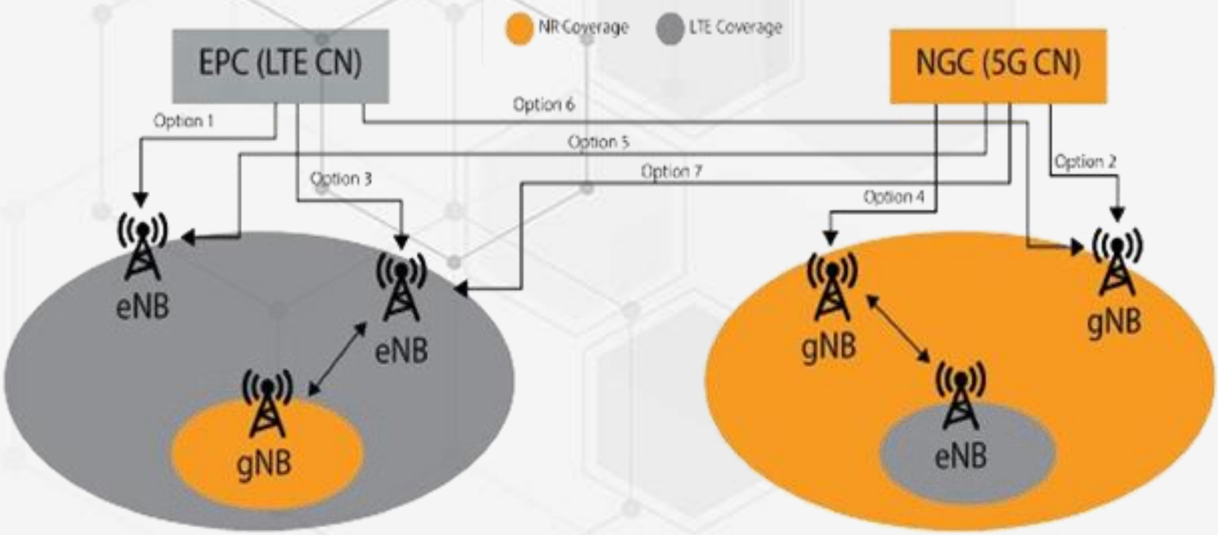


Figure 8: Deployment Option Supporting from Current to Future Network Transformation

Courtesy: Figure for representation purpose only from MediaTek 5G NR

5. Analysis of 5G migration options

Several migration paths are available for transforming the network from existing network to 5G NGC SA architecture:

- EPS to SA Option #2
- EPS to NSA Option #3
- NSA Option #3 to NSA Option #7 and SA Option #5
- NSA Option #3 to NSA Option #3 and SA Option #2
- NSA Option #3 to NSA Option #4 and SA Option #2
- NSA Option #3 to NSA Option #7 and SA Option #2

From the study and research, we consider only the NSA Option 3/7 and the SA Option 2 here, so that we can further discuss and analyses major technical issues of NSA and SA options.

Spectrum: Due to the coverage limitation and cost burden of mmWave band cells, it is best used only for sub-6GHz SA or NSA mobile networks.

Core network: Since Option 7 and Option 2 require new 5GC system, the development and verification of 5GC is needed. Besides, enhancement of EPC like CUPS of EPC for Option 3 is desirable to accommodate large NR capacity. To support inter-system mobility in SA network, interconnection interface between 5GC and EPC may be required which is not necessary for NSA network. When it comes to 5G-specific services, 5GC can naturally support them through new QoS framework and network slicing features.

In terms of devices, since Option 3 requires single EPC-NAS protocol, UE complexity is lower than that of Option 7 or SA Option 2.

RAN: Because the NSA networks can fully leverage existing LTE infrastructure as coverage layer, it is ideal in quickly deploying full-coverage 5G network with relatively small investment. However, this deployment requires upgrade of LTE eNB and EPC based on EN-DC for Option 3. LTE eNodeB upgradation would incur some cost but that can be trade-off by offering 5G eMBB high bandwidth and speed to existing customers and introduction of new services. Furthermore, significant upgrade of LTE ngeNB based on NGEN-DC and introduction of 5GC are required for Option 7.

Following is the technical analysis of the deployment options based on key aspects from NSA to SA Architecture:

Key Aspects	NSA		SA (Option 2)
	Option 3	Option 7	
System Availability	19.2Q	19.4Q	20.1Q
Deployment Cost	Low	Mid	High
Cost for LTE system Upgrade	Low	High	Low
Acquisition Cost for 5G Spectrum	Medium (mmWave bands can be used for SN cells)	Medium (mmWave bands can be used for SN cells)	High (Sub-6GHz band is required for coverage cell)
Required Time for Deployment	Short	Medium	Long
Migration Cost to SA	High	Medium	None
Support for new 5G Services	Not Supported	Supported	Supported
Voice Service for 5G UE	CSFB and VoLTE	CSFB and VoLTE	VoLTE and VoNR

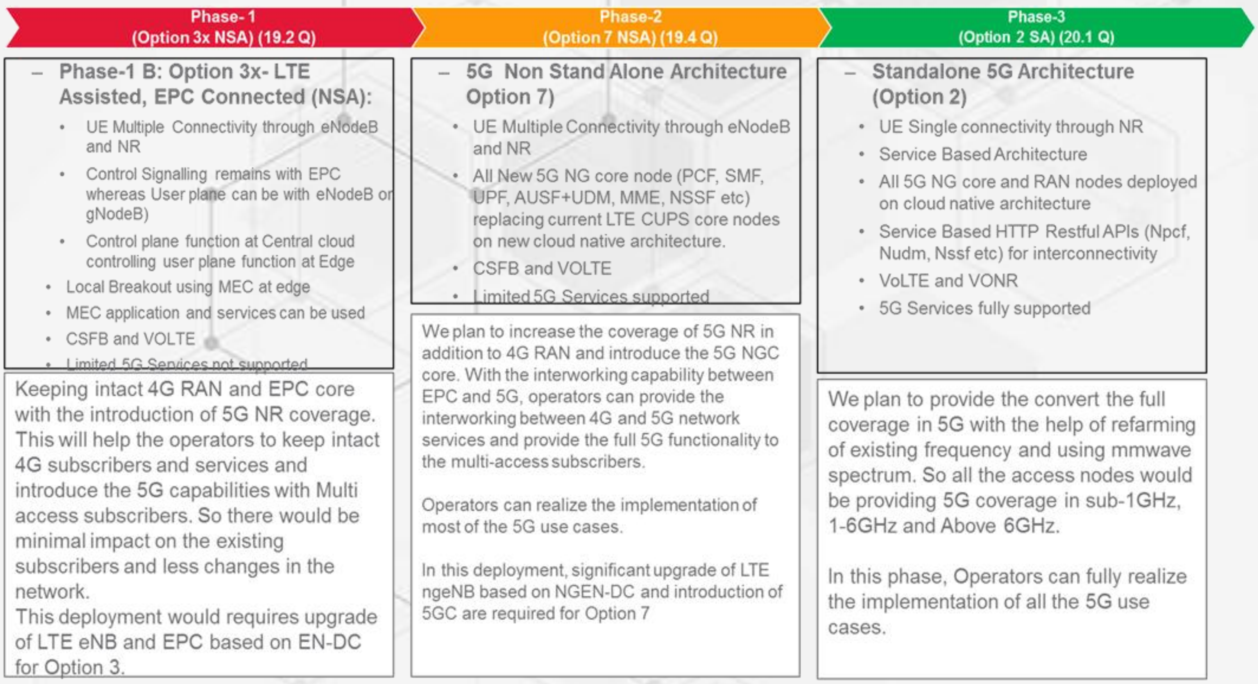
Table 2: Analysis of various Proposed Deployment Options

6. Phase wise Approach for Migration

We observe that there are significant trade-offs among deployment time, customer experience, TCO, and system/UE availability for 5G introduction. The technical and business aspects dealt in the previous sections indicate that smooth, phased migration of 5G network based on NSA and SA architectures is desirable for quick and stable introduction of 5G networks within 2019 timeframe.

Network deployments across the globe are getting started to serve the eMBB services by offering high speed and capacity in the initial stage and then will be extended to accommodate uRLLC and mMTC.

Based on the study and research, following is the proposed migration process in 3 different phases considering the deployment of eMBB services initially and followed by uRLLC and mMTC:



First of all, MR-DC plays key role in 5G-LTE interworking and migration. Of course, standalone EPC/LTE network has to be supported for a considerable time, especially to support inbound roaming users.

Further, 5GC may control mobile network as well as WiFi Aps through 5G's access agnostic core feature. Therefore, the promising band combinations of 3.5 GHz and 28 GHz for NSA and SA networks under consideration are as follows:

- NSA (MR-DC): LTE 1.8 GHz (master) + NR 28 GHz (secondary)
- SA (NR-DC): NR 3.5 GHz (master) + NR 3.5/28 GHz (secondary)

For the transport of user plane connection between the core network entity and master/secondary node, the following types of bearers are defined, each of which can be either an MN terminated or SN terminated bearer:

- MCG (Master Cell Group) bearer
- SCG (Secondary Cell Group) bearer
- Split bearer

MCG (Master Cell Group) bearers use only MN radio resources while SCG (Secondary Cell Group) bearers use only SN radio resources. Split bearers, however, can use both MN and SN radio resources. The split bearers transfer PDCP data between the SN and the MN via the MN-SN user plane interface (X2/Xn).

In non-standalone deployment, MR-DC is employed. MR-DC enables the UE to utilise radio resources provided by two distinct schedulers in two different nodes (MN and SN) connected via non-ideal or ideal backhaul, as described in 3GPP TS 37.340 One scheduler is located in the MN (Master Node) and the other in the SN (Secondary Node), and one node provides E-UTRA access and the other node provides NR access. The MN and SN are interconnected and at least MN is connected to the core network.

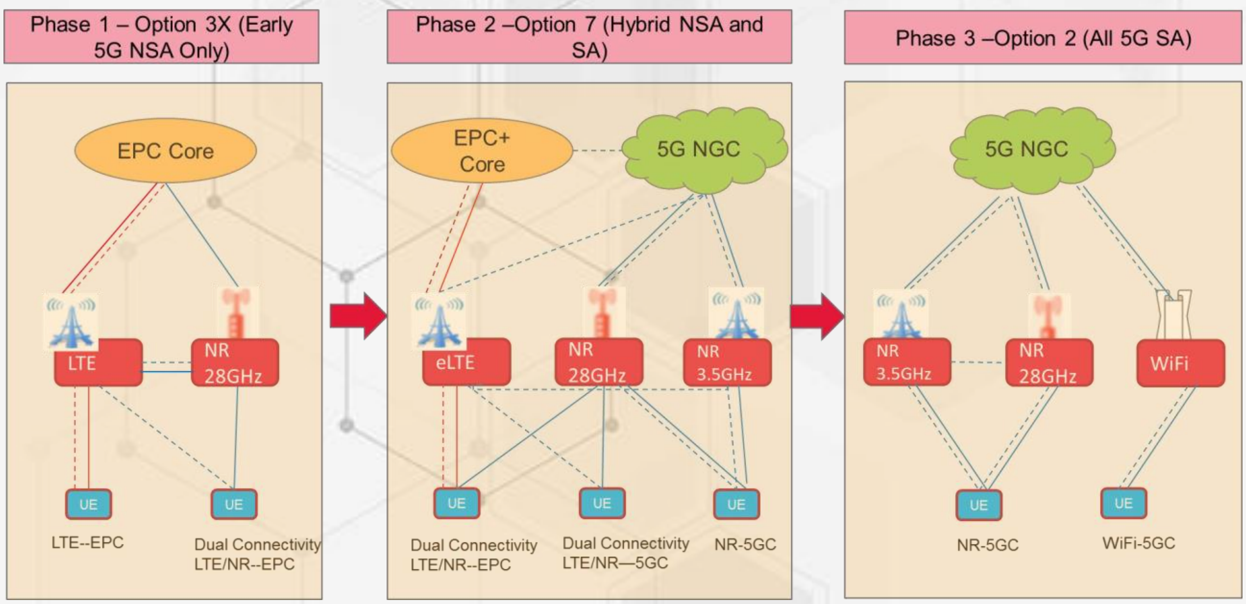


Figure 9: Phase wise Transformation LTE/5G using Frequency combination

- **Phase 1 (Early 5G):** The NSA Option 3x network is deployed where NR and LTE cells interwork through EN-DC. In EN-DC, Master node can be eNodeB whereas secondary node can be en-gNB. Implementing EN-DC in the network would have some bearing on the dual connectivity devices because of latching to both LTE-eNodeB and en-gNB. NR cells act as data boosting cells in hot- spot areas under nationwide LTE cells.

  In the first option, all access-agnostic components supporting the 5G RAT family are provided through EPC. This option may require evolution of EPC to enable 5G access-agnostic functions to be provided. With this option, there is minimal impact to legacy RAN. Nevertheless, the degrees of freedom to evolve the EPC in a manner that efficiently provides 5G RAT to support the diversity of use cases may be limited. Thus, legacy paradigms may be applied to all use cases, which may be inefficient and expensive.

LTE eNodeB upgradation would incur some cost but that can be trade-off by offering 5G eMBB high bandwidth and speed to existing customers and introduction of new services.

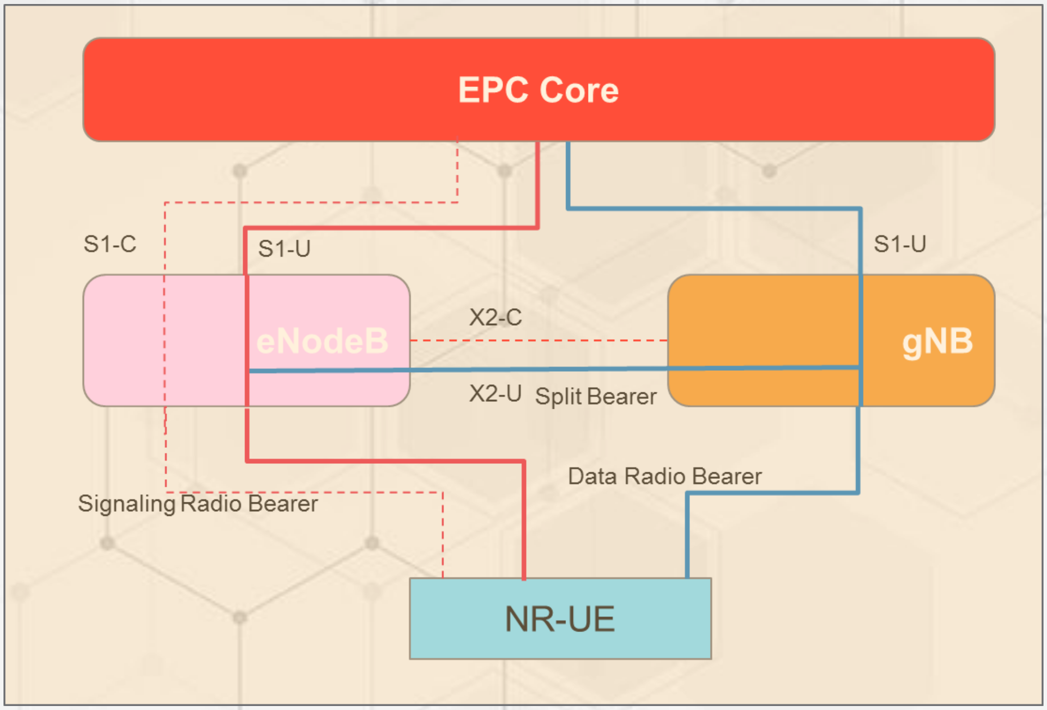


Figure 10: NSA Option 3x with Bearer Details

For deployment option #3x (EN-DC with the EPC), the master node is eNB and the secondary node is en-gNB (i.e. gNB that is connected to EPC), where eNB is connected to the EPC via S1 interface and to the en-gNB via the X2 interface. In this configuration, en-gNB may also be connected to the EPC via the S1 interface (user plane) and to other en-gNBs via X2 interface (user plane). Hence in EN-DC:

- MCG-bearer uses only E-UTRA radio resources
- SCG-bearer: uses only NR radio resources
- Split bearer can use both E-UTRA and NR radio resources

In this option, NR gNB terminates the S1-U user plane of the Split bearer for the NR UE and LTE eNB terminates the S1-U user plane of the LTE only bearer. The eNB and gNB have X2-C and X2-U connections, where the user data of Split bearer is carried over X2-U, and control signaling over X2-C.

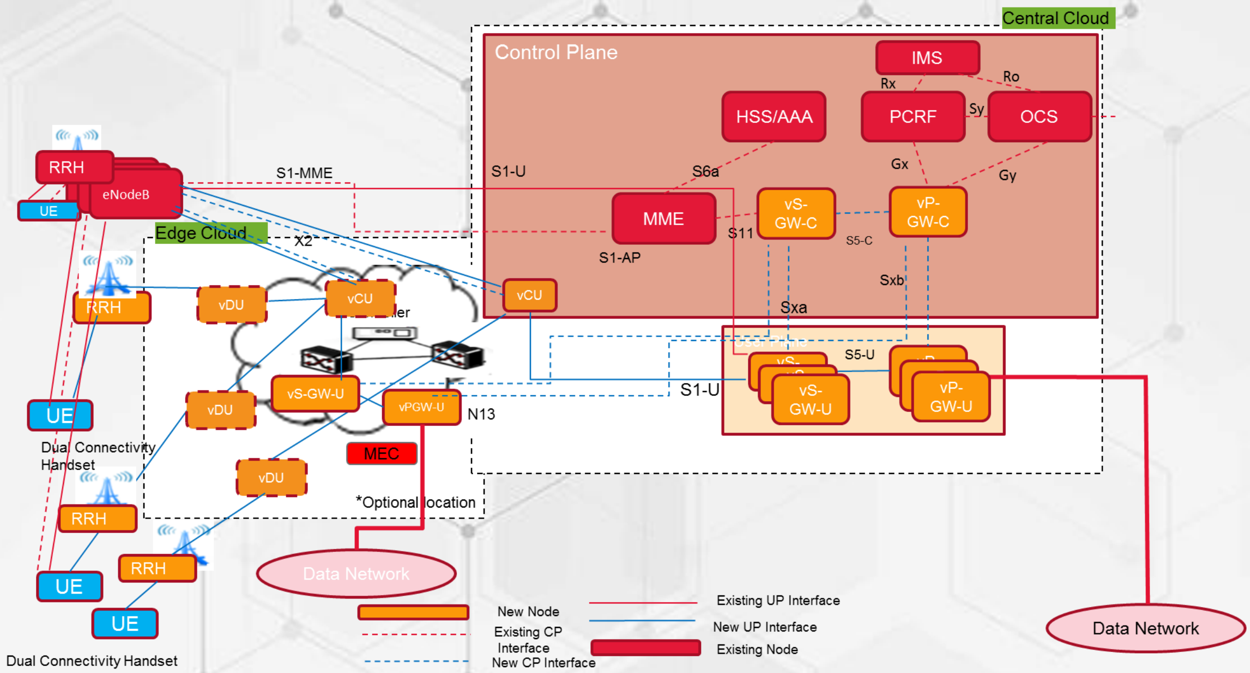


Figure 11: Phase 1 - Option 3x Non Standalone Architecture

- Phase 2 (Full-scale 5G): The NSA Option 3x network can migrate to NSA Option 7 network based on NGEN-DC. In NGEN-DC, master node can be ng-eNodeB whereas secondary node can be gNB. LTE eNB will be upgraded to support the LTE evolution (eLTE) of Release-15 onwards. It is also possible that the SA Option 2 network coexists with the NSA network or replaces the NSA network.

  Following are the key points:
  - EPC+ should support inter-CN interworking between EPC+ and 5GC.
  - Voice over EPS and/or 5GS is also required in order to provide VoLTE coverage. However, the support of fallback to 3G CS voice may be for further consideration.
  - Changes to the 4G RAN to support connectivity with 5G Network Core functions.
  - Service Based 5G NGC architecture is implemented in this option.

  For deployment option #7 (NGEN-DC with the 5GC), the master node is ng-eNB and the secondary node is gNB, where ng-eNB is connected to the 5GC via N3 interface and gNB is connected to the ng-eNB via the Xn interface. Hence in NGEN-DC

  - MCG-bearer: uses only E-UTRA radio resources
  - SCG-bearer: uses only NR radio resources
  - Split bearer: can use both E-UTRA and NR radio resources

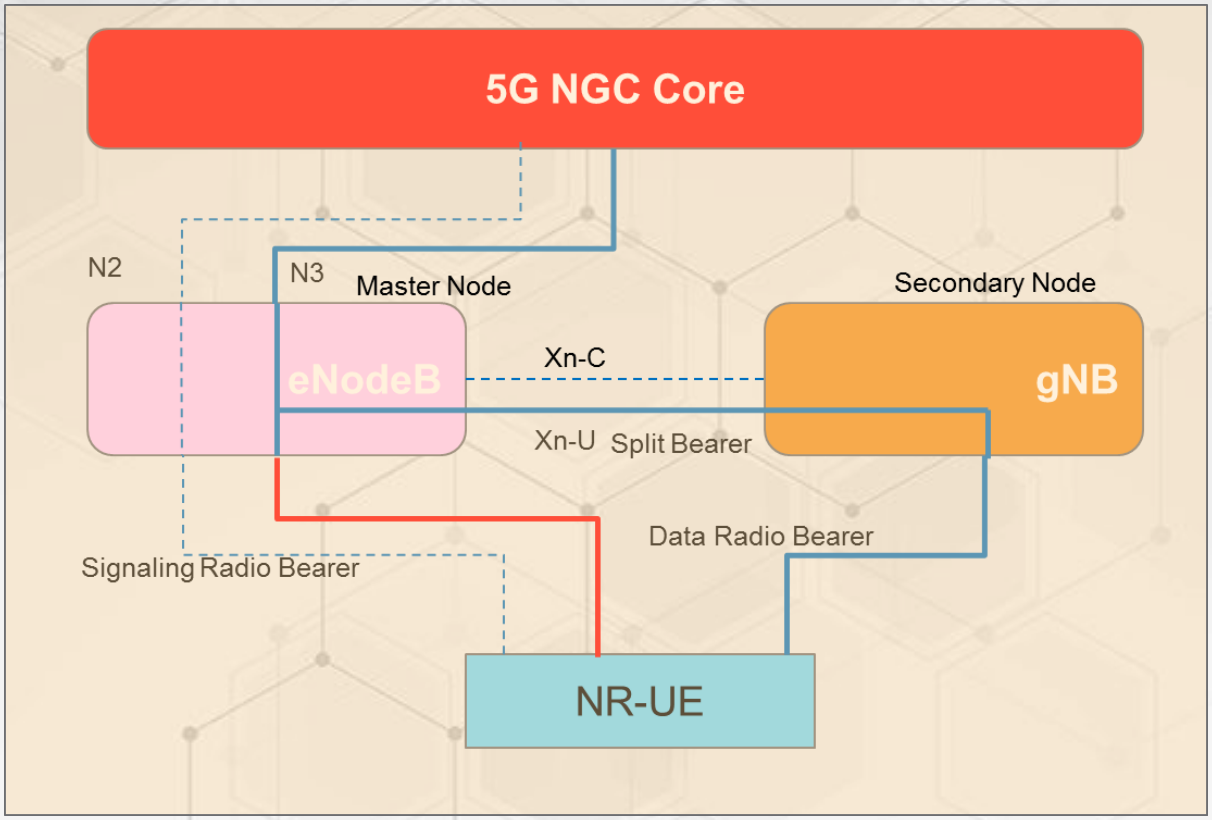


Figure 12: Option 7 Non Standalone Architecture with Bearer Details

During the migration from option 3x to option7, there would be intermediate stage where both the options are being supported using 5G NGC and EPC ate core network and eLTE, LTE and NR at RAN.

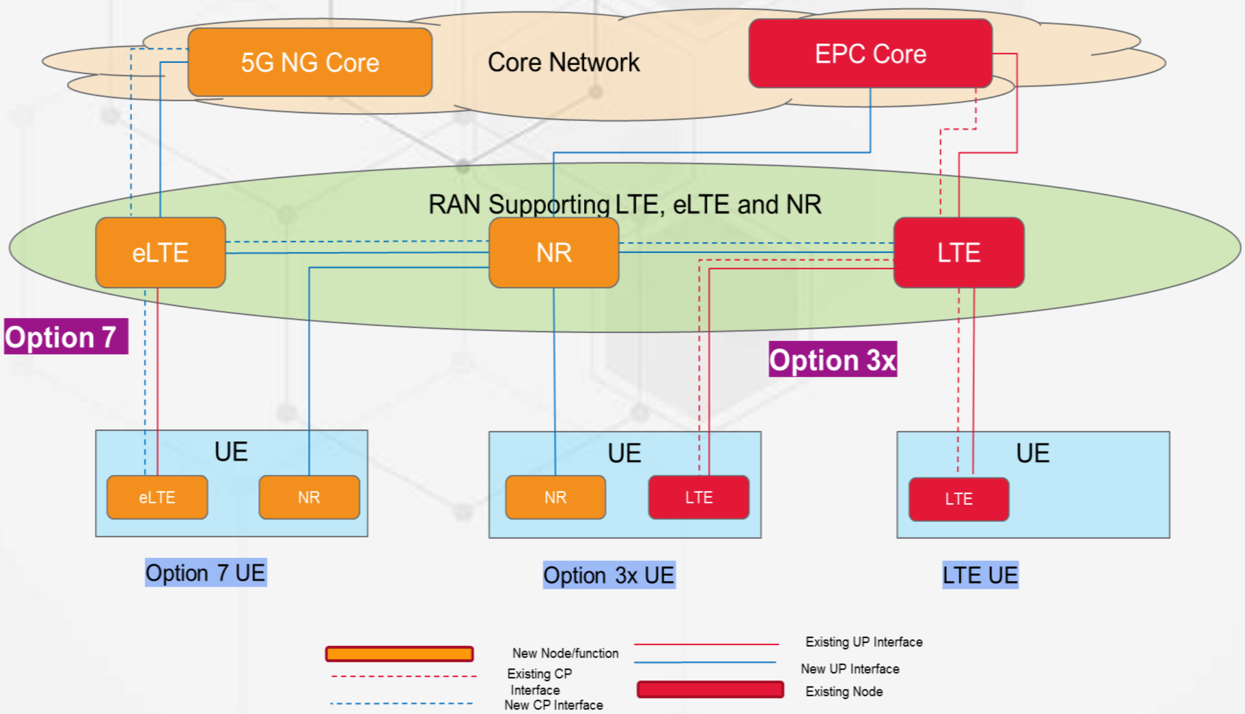


Figure 13: Option 3x and Option 7 Non Standalone Architecture coexistence with Legacy LTE

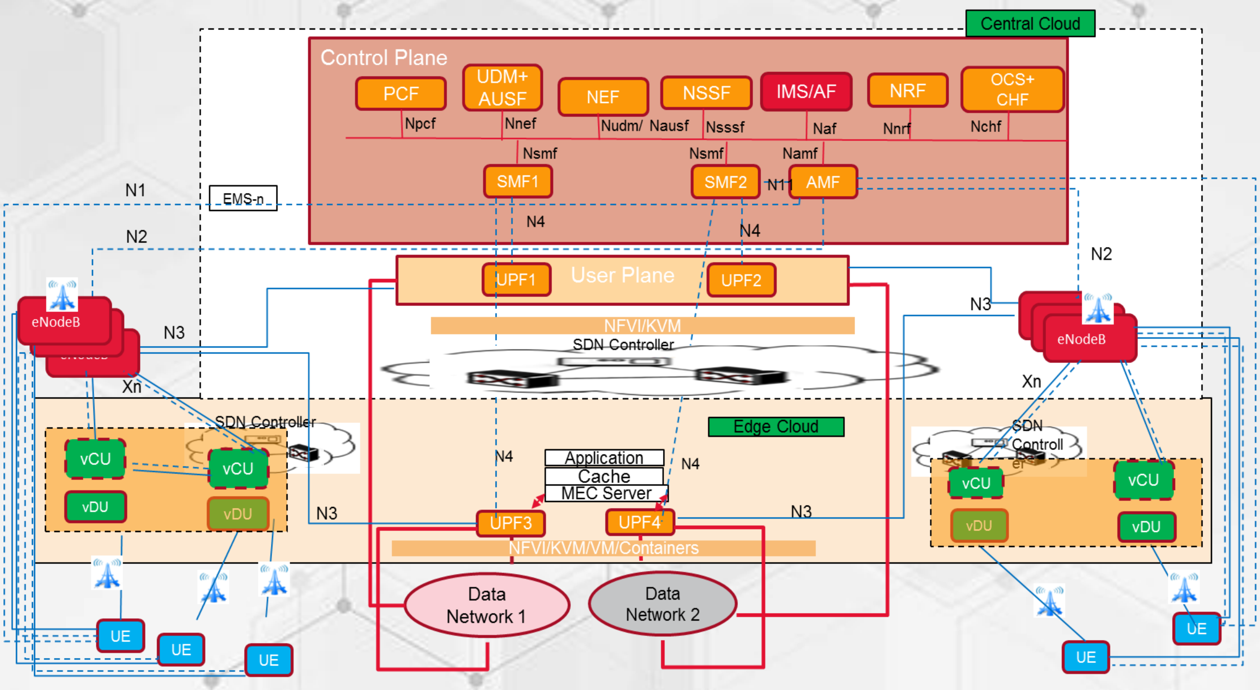


Figure 14: Phase 2 - Option 7 Non Standalone Architecture

Please note vCU placement in the architecture may vary based on the use case implementation

- Phase 3 (All-5G): As a long-term migration path of 5G, 5G unified network based on the SA Option 2 along with standalone LTE network will be operated. Refarming of LTE bands can be performed at this stage.

  In the final option, all components of the 5G RAT family are supported by the new 5G Network Function design. Other RATs (e.g., Wi-Fi) and the fixed network may also be supported through the new 5GFs design. This option allows the benefits of new technologies to be fully realized.

  Service Based 5G NGC architecture is implemented in this option.

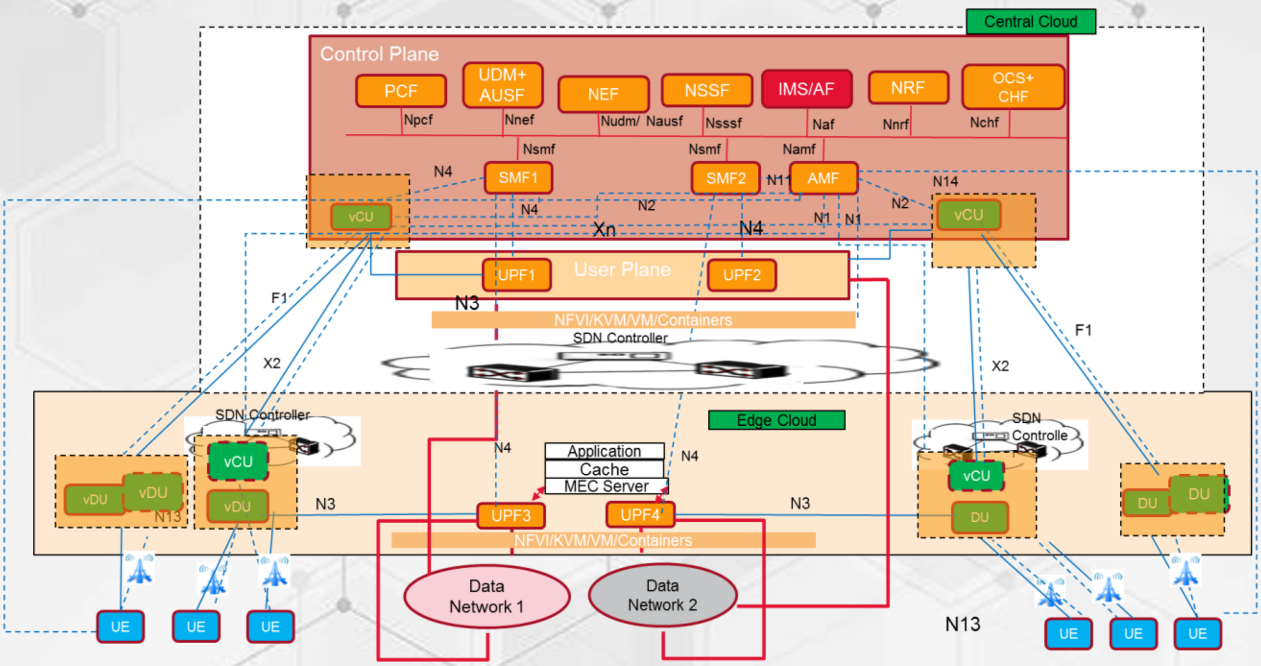


Figure 15: Phase 3 - Option 2 Standalone Architecture using Service Based Representation
Please note vCU placement in the architecture may vary based on the use case implementation

7. Orchestration evolution during the phases

5G and network slicing are emerging technologies that are complex and distributed and would require enhancement in MANO platform design and capabilities for supporting network slices, hybrid network consisting of PNFs & VNFs in a multi-domain (RAN vs Transport/WAN vs EPC Core/5GC core) scenario, supporting Service base architecture(SBA) and split of Control and user plane.

Service Provider (SP) need to deploy a disaggregated 5G Radio Access Network (3GPP 5G Option 2-2 configuration). Some of the disaggregated network functions are expected to be virtualized (VNF), running on a cloud infrastructure and while others will be PNF (e.g. appliance based peripherals). This disaggregation can include moving processing closer to the edge, and require deployment of Multi-access Edge Computing (MEC) components and applications in order to meet 5G performance goals

Some of the requirements arise from 5G technology which needs to be provided in Orchestrator are:

- Each Service Provider (SP) needs to support a rich set of advanced 5G wireless services, such as enhanced Mobile Broad Band (eMBB), massive Internet of Things (mIoT), and Ultra-Reliable, Low-latency Communications (URLLC), for mission critical communications
- These services have very different requirements on latency, reliability, availability, mobility, and bandwidth
  - Deploying multiple separate networks to support these varying requirements
  - End to End network slicing as defined by 3GPP provides specifications for efficient creation of multiple logical networks sharing a common network infrastructure while meeting the specified service levels for each of the services
  - Orchestrator must support the complete lifecycle management of such network slicing

- Automated configuration of a slice during the instantiation, configuration, and activation phases, a newly created set of identifying parameters collection is automatically configured
- Automated reconfiguration happens during run-time e.g. an active slice can be reconfigured automatically because of a change in the service requirements or service conditions

The design of the MANO architecture has revisited network management and orchestration functions of both the 3GPP and the European Telecommunications Standards Institute (ETSI) Network Function Virtualisation (NFV). The initial overall architecture proposed here extends the reference architectures of the 3GPP 5G System and ETSI NFV MANO by building on these architectures while addressing several gaps identified due to 5G technology within the corresponding baseline models.

One of the key results is the unique assembly and interworking of novel technologies within the architecture (SDN, NFV, enhanced network management and orchestration procedures, multiservice capable RAN, etc.) to facilitate network slicing.

In order to enable both an e2e service view and re-usable services from the different segments/domains in the network, the design must be done in such a way as to support:

- Abstraction of the services offered by the different domains/segments
    - o Ability to tie the services offered by the different domains/segments into an e2e service

    - o Support the network to provide isolation of physical resources and between the slices

Starting with the overall architecture design which elaborates on the fundamental structuring of Orchestrator into network layers and domains, this section further describes the architecture fundamentals for E2E Orchestrator deployment in Phase-1, Phase-2 (Option-7) and Phase-3 (Option-2).

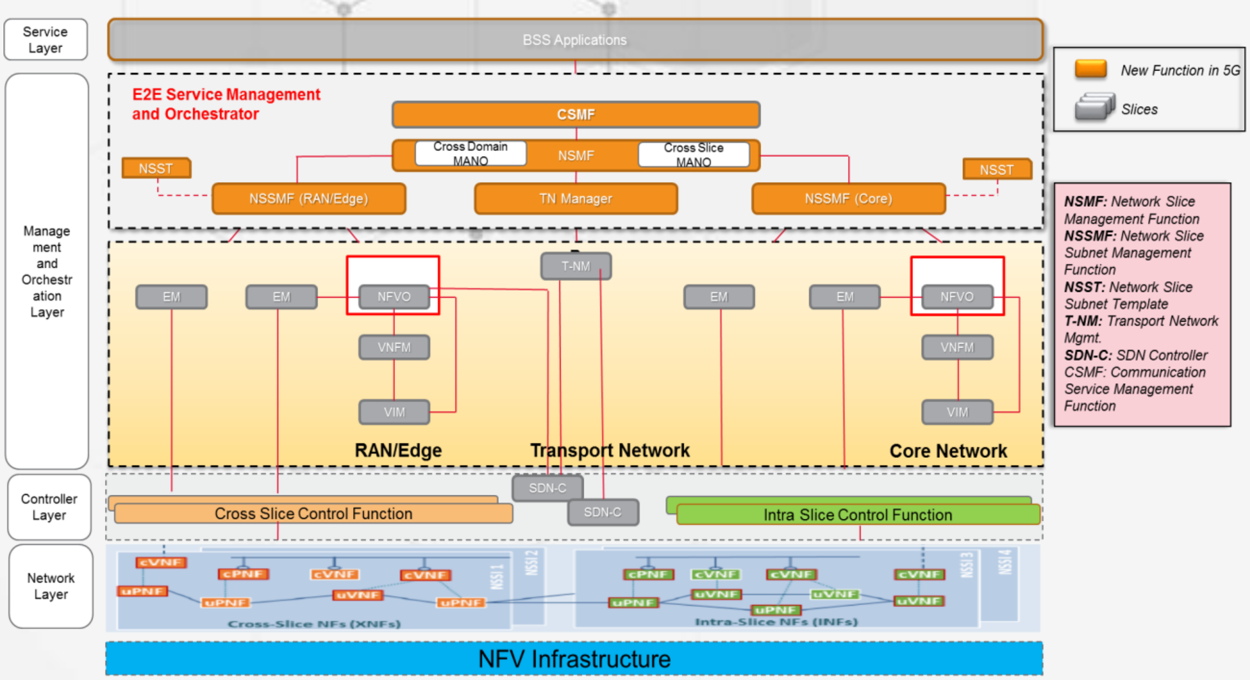


Figure 16: Overall Orchestration Architecture

The **Service layer** comprises Business Support Systems (BSS), business-level Policy and Decision functions, and services operated by a tenant or other external entities. These functions of the Service layer interact with the Management & Orchestration (M&O) layer via the CSMF, see below.

The **Management & Orchestration layer** is composed of the M&O functions from different network, technology, and administration domains (3GPP public mobile network management, ETSI Network Function Virtualisation (NFV) Management and Orchestration (MANO), ETSI Multiaccess Edge Computing functions and management functions of transport networks (TNs). Further, the M&O layer comprises the end-to-end M&O sublayer hosting the Network Slice Management Function (NSMF) and Communication Service Management Function (CSMF) that manage network slices and communications services, respectively, across multiple management and orchestration domains in a seamless manner.

In the Virtualisation *MANO* domain, the ETSI NFV MANO architecture for lifecycle management (LCM) of Virtual Machines (VMs) can be extended towards LCM of virtualisation containers (e.g., Docker). Therefore, it comprises, besides the ETSI NFV components, corresponding functions for LCM of containers. Therefore, the Virtualised Network Function Manager (VNFM) has according components for virtual machine infrastructure (VMI) and container infrastructure (CI). Similarly, the Virtualised

Infrastructure Manager (VIM) can contains a VMI Management Function (VMIMF) and a CI Management Function (CIMF). NFV Orchestrator (NFVO) provides the dispatching functionality.

Further, the layer accommodates 3GPP network management function, such as, Element and Domain Managers (EM and DM) and Network Management (NM) functions. Such functions would also implement ETSI NFV MANO reference points to the VNFM and the NFVO. The CSMF transforms consumer-facing service descriptions into resource-facing service descriptions (and vice versa) and therefore works as an intermediary function between the Service layer and the NSMF.

The NSMF splits service requirements as received from CSMF and coordinates (negotiates) with multiple management domains for E2E network slice deployment and operation. NSMF further incorporates a **Cross-slice M&O function for inter-slice management** (e.g., common context between different slices/tenants, inter-slice resource brokering for cross-slice resource allocation, particularly in the case of shared NFs, etc.). In contrast, the **Cross-domain M&O function works on intra-slice level**, but across multiple network and technology domains. The M&O layer performs the management tasks on Network Slice Instances (NSI), which are uniquely identified by an NSI identifier. An NSI may be further associated with one or more Network Slice Subnet Instances (NSSI).

The **Controller layer** realizes the software-defined networking concepts and extends them to mobile networks, and therefore accommodates two controller types:

(1) the Cross-slice Control Function, e.g., a RAN controller for the control of Cross-slice Network Functions (XNFs) that are shared by multiple network slices, and

(2) the Intra-slice Control Function, e.g., a CN controller for Intra-slice Network Function (INFs) within a dedicated CN-NSSI.

These controllers expose a northbound interface towards control applications and a southbound interface towards VNFs and PNFs in the Network layer.The Controller layer facilitates the concept of mobile network programmability**.** Generally, software-defined networking (SDN) splits between logic and agent for any functionality in the network. This means that the NFs are split into the decision logic hosted in a control application and the actual NF in the Network layer (usually a uPNF or uVNF) that executes the decision. In other words, for the given uVNF or uPNF, the according cPNf or cVNF would disappear.
The controller resides between" application and NF and abstract from specific technologies and implementations realised by the NF, thus decoupling the control application from the controlled NF.

The **Network layer** comprises the VNFs and physical NFs (PNFs) of both control plane (i.e., cVNF, cPNF) and user plane (i.e., uVNF, uPNF). NFs can include, for example, control plane (CP) functions (AMF, SMF, AUSF, RRC, etc.) and user plane (UP) functions (e.g., UPF, PDCP, etc.), e.g. for resource elasticity, resilience, and security.

Generally, the Network layer can comprise different CP/UP architectures, i.e., also a 4G mobile network with EUTRAN and EPC functions could constitute an instance of the Network layer. M&O Layer facilitates domain-specific fault, configuration, accounting, performance, and security (FCAPS) management as well as domain-agnostic LCM procedures. For associating a UE to the correct NSI, the Network layer uses the Single Network Slice Selection Assistance Information (S-NSSAI), which is provided by the UE. Moreover, the CN part of the CP in the network layer is realized as a service-based architecture (SBA) as per the ETSI specifications.

NFV Infrastructure layer would fulfill all the visualized infrastructure needs for the deployment of 5G network including Compute, storage and Network. Various flavors of open stack and Hypervisors can be utilized based on the performance needs of the network.

8. Rationale behind migration option

In this section, we also discuss and analyses major technical, economic and business issues of NSA and SA options. The key comparison between 5G NSA and SA options for mobile network in terms of device availability, timeframe and service aspects can be summarized as follows. *Please note that the estimation of cost and time can be different depending on various technical and business variables.*

- **Operators Current Investment in Legacy Network**

  As we know that operators already have current investments in the Legacy 4G network and would not be cost effective to transition directly to Standalone 5G NGC architecture, instead would like to move safely.

- **5G Handset devices availability:**

  It is expected that Handset providers will be able to commercialize 5G network during 2019 as 3GPP 5G specifications will be completed during 4Q of 2017 as Phase 1 (NSA Option 3) and 2Q of 2018 as Phase 2 (SA) of Release-15 whereas the exact 5G commercialization plan may change depending on different market, economical and technological factors.

- **Deployment Options:**

  Since NR cells can be deployed in urban hotspot areas as capacity and speed boosting cells in NSA network, deployment time will be shortened and NR CAPEX will be lower than that of SA network. However, more investment will be required to upgrade existing LTE RAN for Option 7. In addition, acquisition cost for 5G spectrum for SA is higher than that for NSA since sub-6GHz band is required for Nation-wide coverage.

- **Migration Timeframe:**

  Selection of migration path will depend on the operators migration timeframes.
  Initial deployment of NSA network requires additional cost and time for migration to mature SA network.

When it comes to the upgrade aspects of LTE system, Option 7 requires more costs because of the major upgrade of legacy LTE base stations as well as the introduction of 5GC than other options.

- **5G Specific Services:**

  Option 3 has a big disadvantage as it is limited in supporting 5G-specific services due to the use of legacy EPC. On the other hand, nation-wide SA network will give best NR coverage quality although the coverage of initial SA network is limited. In addition, since Option 7 has evolved, 5G grade LTE access and core network capabilities, overall service quality is higher than that of Option 3.

9. Challenges in actual migration

There are several challenges the CSPs may face during actual migration. Some of them are described as below:

- **Migration timeframe from NSA to SA with 3GPP Release availability:**

  Different specification versions can be applied to NSA and SA networks separately.
  For example, NSA in 2019 with Release-15 and then SA in 2020 with Release-16 can be used.

- **Whether to upgrade to Option 7 after the initial deployment of Option 3 or not:**

  Option 7 offers better performance than SA Option 2 with MR-DC and ng-eNB capabilities.

  Besides, Option 7 can offer 5Ggrade services even for upgraded LTE users. Upgrade to Option 7 will be smooth when 5GC is deployed and full spec is available. However, migration to Option 7 from Option 3 may not be necessary as SA Option 2 network will be quickly deployed nationwide.

- **Partial refarming of LTE to NR band can be considered at the mature 5G stage:**

  Bandwidth expansion (up to 150 MHz) can be achieved through 1.8 GHz + 3.5 GHz NR CA. Co-existence between 5G and LTE needs to be analyzed further.

- **Support of legacy 5G devices:**

  For example, NSA Option 3 devices should be supported even for Option 7 and the SA networks

- **Early adoption of SA network for NR-based FWA (Fixed Wireless Access) service before 2019 timeframe**

10. Conclusion

This paper has provided a perspective on the migration path from existing legacy 4G networks to 5G networks using various deployment options. It has provided the analysis, rationale and challenges of migration which would help CSPs in devising their strategy for planning towards 5G. It has to be noted that the topics covered in this paper are still under research and subject to finalization in the next few months.

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3 3GPP TS 22.261: “Service requirements for the 5G system: stage I”

4 3GPP TS 37.340: “NR – Multi-connectivity – Overall description – Stage 2”

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13. Acronyms

EN-DC: E-UTRA-NR Dual Connectivity (EN-DC)

NGEN-DC: NG-RAN-E-UTRA Dual Connectivity MR-

DC: Multi RAT – Dual Connectivity

NE-DC: NR-E-UTRA Dual Connectivity (NE-DC)

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