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Strategies For 5g Nr Networks Distribution In Rwanda

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Abstract

The fifth-generation mobile network has been developed and standardized with an intention of exploring the market beyond 2017. The question was to study the distribution strategies to fill out the needs of this strong network introduced for real-time feedback. Mobile operators proposed five alternative network architectures to 3GPP. The response to the question was to carry out the first distribution strategy which is Non-Standalone New Radio (NSA NR) in 2017 followed by a Standalone New Radio access network that was standardized in 2018. This study analyzes the distribution strategies of the 5G New Radio (NR) network, main technologies, benefits and drawbacks and compares NSA NR and SA NR distribution modes in terms of coverage, network capability, the inter-working which is between 4G and 5G, complexity and network distribution cost in Rwanda. This also highlights the potential challenges to implement 5G especially in Least Developed Countries.

Micro Operators have been also used to accelerate the deployment for new entries and presented some challenges where the proposed solution for them has been the planification of a huge amount of economic resources as well as skilled manpower. The study concluded that the reliable and efficient distribution strategies of 5G NR Networks will be based on Non-Standalone (NSA), Standalone (SA) and the Micro Operators considerations to accelerate its distribution not only in global context but also in Rwanda.

Introduction

The fourth generation of mobile communication (4G, also known as Long Term Evolution/Evolved Packet Core, LTE/EPC) has prepared the path for mobile broadband communication and has aided in the development of new mobile services and applications. Some of the new services and applications' communication requirements, such as enhanced mobile broadband (eMBB), massive machine type communication (mMTC), and ultra-reliable low-latency communication (URLLC), have exceeded the 4G network's capabilities.5G is being developed to meet these increased expectations [1]. Sufficient radio spectrum is required to achieve the very reliable, ultra-low-latency, multigigabit connectivity that 5G offers.

A significant amount of new standardized spectrum is required for the 5G network deployment in order to provide a quality 5G experience. This summary clearly analyzes and compares the NSA NR and SA NR distribution strategies of 5G networks in terms of coverage, network capability, Inter-working between 4G and 5G, complexity and cost of network deployment and the latest industry progress.

It reviews the recent market and technology related trends in 5G distributions where the concept of 5G micro operators was recently proposed to open the mobile market for new entries in order to accelerate 5G deployment, and also it defines feasibility and challenges of 5G Network deployment in Least Developed Countries.

The use cases of 5G can be broadly divided into three major categories:

- **Enhanced Mobile Broadband (eMBB):** On both 5G NR and 4G LTE, eMBB provides increased data bandwidth and moderate latency improvements. This will help with the development of today's mobile broadband use cases, including emerging AR/VR media and applications, Ultra HD or 360-degree streaming video, and many others.
- **Massive Machine Type Communication (mMTC):** mMTC is a

use case that requires the network to support the mass deployment of billions of low-cost, low-powered devices that communicate via mobile networks rather than Wi-Fi or Bluetooth. Hence, this is a critical requirement for 5G to support use cases including low-data-rate sensors, actuators, and machine monitoring systems.

• Ultra Reliable Low Latency Communication (URLLC): The eMMB and mMTC were created exclusively for humans and machines respectively while the URLLC was designed for human-machine interaction. This communication is supposed to have near-zero latency and packet losses allowing mission-critical applications like autonomous vehicles, augmented virtual reality, remote patient surgery using robots etc.

Proposed Network Architecture for 5G NR Distribution

Five different network architectures for 5G NR distribution have been presented to 3GPP by different operators due to diverse concerns on 5G distributions, which may lead to a fragmented 5G industry and market.

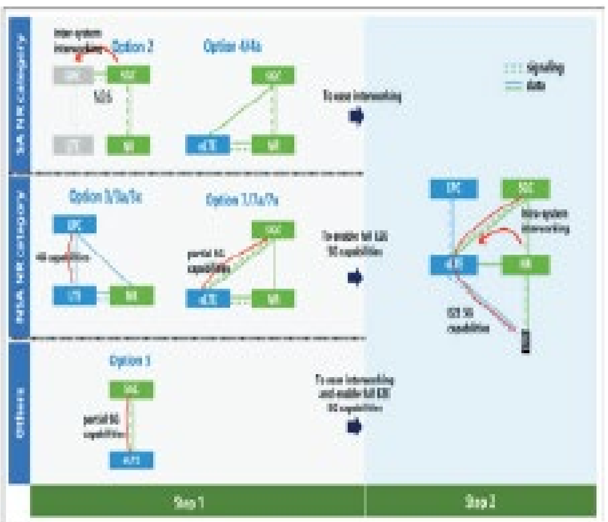

Figure 1: Five network architecture options proposed to 3GPP and the potential migration paths he five network architecture options identified by 3GPP fall into two major categories: SA NR and NSA NR.

• The non-standalone (NSA)

mode of 5G NR refers to a 5G NR deployment option that depends on an existing 4G LTE network's control plane for control functions, while 5G NR is entirely focused on the user plane.

• Standalone (SA)

5G uses the 5G NR access network on a brand new 5G network core.

Concepts of 5G SA NR and NSA NR

5G can be distributed in five distinct options (see Figure. 1), with the option 2 and 4 sets falling under the SA NR category and the option 3 and 7 sets belonging under the NSA NR category. Option 5 implies that the eLTE base station is connected to 5GC and that the distribution mode is unrelated to NR [2]. SA (standalone) options consist of only one generation of radio access technology while two generations of radio access technology are used in NSA options (4G LTE and 5G). Early deployments will use either non-standalone option 3 or standalone option 2 as the typical architectures supported by mobile network providers and operators, and these two alternatives have already been standardized. For the entire article, we'll use NSA to represent NSA option 3 and SA to denote SA option 2.

• Standalone option 2

The SA NR architecture is a 5G system that includes a New Radio (NR) and a 5G Core (5GC), with the NR functioning as the control plane anchor. When a 5G device is within NR's service area, it anchors at the 5GC and the 5GC manages its mobility. When the user equipment (UE) leaves NR coverage, it is moved to an LTE/EPC (Evolved Packet Core) network, where it connects to LTE/EPC like any other LTE device. This means that a 5G SA UE can only operate in one of two modes: 5G or 4G. In general, Standalone option 2 refers to a radio access network that consists of only gNBs (gNode Bs) that is connected to 5GC, with 5GC interacting with EPC. By enabling network slicing via cloud-native service-based architecture, SA option 2 has no impact on LTE radio and can fully support all 5G use cases.

• Non-standalone option 3

The NSA NR architecture refers to a system in which the control plane anchor for NR is LTE/evolved LTE (eLTE). When NR coverage is available, the device is anchored to the LTE/EPC(Evolved Packet Core) system, and NR is used as an extra data pipe. The NSA UE (User Equipment)only works as an LTE UE when it is outside of NR coverage. Since the interworking between LTE and NR is intra-system handover, the LTE system controls the mobility management of NSA NR completely. This gives a better user experience. The device must support dual connectivity under NSA NR, which means it must maintain both LTE and NR radio transmission links simultaneously. The radio access network is composed of eNBs (eNode Bs) as the master node and gNBs (gNode Bs) as the secondary node in the non-standalone option 3, and the radio access network is connected to EPC (Evolved Packet Core).

• Differences between NSA and SA

The main difference between NSA (Non-Standalone Architecture) and SA (Standalone Architecture) is that NSA anchors 5G Radio Networks control signaling to the 4G Core, whereas the SA scheme connects the 5G Radio directly to the 5G Core Network, and the control signaling is independent of the 4G network. As the name implies, NSA is a 5G service that is built over an existing 4G network rather than being a standalone service.SA, on the other hand, enables a 5G service to operate totally autonomously without interacting with an existing 4G core.

Analysis of SA and NSA

Selecting the network architecture from the five above mentioned alternatives, many issues such as radio coverage, network capabilities, terminal performance, 4G/5G interworking, complexity of network distribution, and cost for further evolution must be considered. This section describes the details [3].

• Radio coverage

When commercializing cellular communication networks, coverage is the key operators rely on because it impacts directly on service quality and capital Expenditure (CAPEX). If 5G NR cannot provide continuous coverage like the legacy LTE network, frequent inter-system inter-radio access technology (RAT) mobility between 4G and 5G will occur in SA as UE moves into and out of NR coverage, resulting in a degradation of the user experience. When intra-system intra-RAT mobility occurs in NSA as an NSA UE anchors in LTE/ EPC and the mobility management is handled by LTE/EPC, NSA may outperform SA.

If NR's coverage is better than LTE, SA is preferable. Mobile operators want to deploy the 5G NR network by leveraging existing LTE sites to make network distribution easier and control CAPEX. As the coverage performance of NR influences the choice of SA and NSA, it's critical to compare 5G NR's coverage to that of LTE.The NSA and SA New Radio Legs share the same data channel because they use the same layer 1 and layer 2 protocol functions, but the difference is in the broadcast and cell specific control channels.

• Network capabilities

Two types of Network capabilities have been distinguished in this section referring to the main target of NSA of meeting eMBB demand and then, its network capabilities will be different from SA. These types are:Network slicing and finer Quality of Service Treatment.

– Network slicing: Network slicing is a method of creating multiple unique logical and virtualized networks over a common multi-domain infrastructure where Mobile Network operators (MNOs) can quickly create network slices that can support a specific application, service, set of users, or network. Network slices can span multiple network domains, including access, core, and transport, and be deployed across multiple operators.

The importance of 5GC is to provide the E2E network slicing, which is the enabler to timely offer

the service and deployment requirements from the much diverse vertical industry and enterprise.

– Finer QoS Treatment: For NSA, the QoS management is aligned with that in 4G, since QoS is controlled by the core network, and the core network in NSA is EPC. Similarly, QoS in SA is aligned with that in 5G.

• Device Performance From the perspective of the device, the NSA and SA behave differently and result in various user experiences. Because the NSA keeps two radio links to LTE and NR at the same time, it seems that it will be able to achieve a greater peak data rate. Due to the constraints on the implementation of the NSA device, the practical performance of NSA is heavily influenced by the paired bands for LTE and NR, where some of them may introduce mutual interference and reduce device performance.

• Power consumption

The battery life of the terminal will have a significant impact on the user experience during the initial commercial launch of 5G. So the 5G device's power consumption is an important factor to consider. Since the 5G NR Network has a much higher bandwidth and transmission data rate, it consumes a lot of power. The NSA's power consumption may also be higher due to the device's dual connection. Three typical device modes, such as idle mode, connected mode, and data transmission mode, are considered to analyze power consumption, as shown in the figure below:

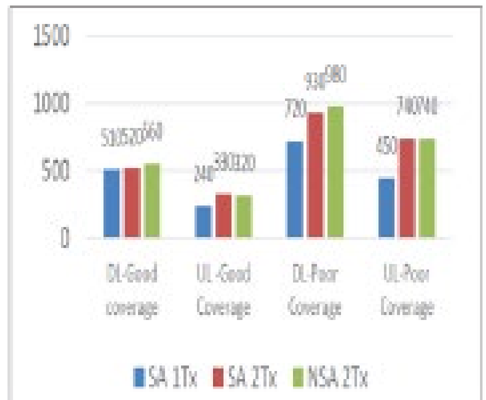

Figure 2: consumption of NSA VS SA

– Idle mode: only the necessary broadcasting or paging information is received and the power consumption has nothing to do with the UL. Because a similar amount of data is received from a base station, the power consumption of the NSA device and SA device is almost the same.

– Connected mode: only necessary and limited data is received and transmitted from the device.

– Data transmission mode: A simulation is performed and the bandwidth of 100 MHz taken into account for both NSA and SA. The transmission of UL data with the required DL feedback, as well as the reverse, is considered.

• 4G/5G Interworking

In general, as compared to the legacy 4G network, which has been optimized for many years, the initial deployment of 5G NR cannot guarantee seamless coverage. Interworking between 5G and 4G networks is required to ensure user experience and service continuity. The interworking performance is also a critical factor in the selection of SA and NSA. There is no 4G/5G interworking in the NSA deployment because the device always anchors in the LTE network. Naturally, voice service can be supported by existing voice over LTE (VoLTE).

For the SA deployment, When 5G NR coverage is available, the device anchors in that network, and when 5G coverage is no longer accessible, it switches to the LTE network. The interworking between 4G and 5G is performed through interface N26.Voice service in SA could be provided in two ways: Voice over NR and EPS fallback. for VoNR, both voice and other 5G services can be enabled at the same time.

For EPS fallback, When a voice is initiated, the device switches back to the LTE network, and the other 5G service is disrupted. As a result, EPS fallback cannot support both voice and 5G data services at the same time. In the following table, the latency and interruption time caused by UE movement in various NSA and SA scenarios are compared:

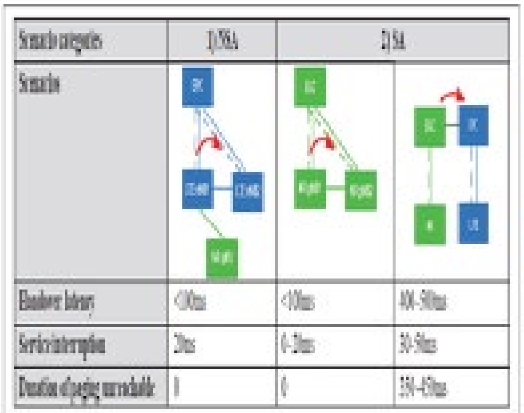

Figure 3: Performance analysis in different scenarios

Because the interworking of the NSA system is done as intersystem handover of LTE, it is assumed that NSA performs better.SA has similar performance to LTE's CS fallback, which is acceptable for a human customer.

Complexity of Network Distribution

Since only SA NR can offer E2E 5G capabilities, the operator community has agreed that SA should be the target network evolution direction. For SA NR distribution, a new mobile network is created independently, with just a N26 interface introduced for interworking between 4G and 5G. As a result, the legacy network is only little impacted by SA NR. The supplier for the 5G network may be separated from that for the legacy network, making pricing negotiations easier for the operator. The NSA deployment will not require a new core network, but the current 4G EPC will need to be updated for 5G NR access, and the capacity should be increased.

To implement 5G NR, a hardware update to LTE eNB is necessary. To provide strong dual connection performance, the operator is required to use the same vendor for 5G and 4G networks, which means negotiating with vendors will be extremely difficult. The investment in EPC modification and capacity expansion will not be reused for the new 5GC based on the software defined networking/ network function virtualization (SDN/NFV) platform, which will be implemented as part of the transition from NSA to SA NR. Also, when NSA is converted to SA, the NSA gNBs must be improved even more. In conclusion, SA enables one-step deployment for all, while NSA deploys the 5G network in two steps. Because NSA deployment is only a stage in the development of 5G, its overall deployment will be significantly more complicated than SA's, implying a greater total cost from a CAPEX viewpoint.

5G Micro Operators

The other investigated deployment strategy in the read articles are the use of micro operators strategies with the main purpose of opening the mobile market for new entry with the intention of accelerating the deployment in case of the rise of high demands.

The Concept of 5G Micro Operators

5G networks will meet a range of deployment scenarios, each with strict end-to-end service quality requirements. The concept of 5G micro operators was recently introduced to open the mobile market for new entry to accelerate 5G deployment meeting location specific needs arising in certain high-demand areas. The micro operator concept enables various stakeholders to play a local operator role, deploying and operating local 5G small cell networks and providing context-relevant content and services in a specific area [4].

The three basic elements of the micro operator concept include:

- Planning and building of local small cell infrastructure;
- Operation and maintenance of the network infrastructure;
- Provisioning of tailored services within the specific location.

Overview of The Micro Operator Concept

A description of the micro operator concept based on the following considerations:

- The concept aims to respond to changing trends in 5G deployments where location specific services, indoor networks and sharing of infrastructure become increasingly important.
- Micro operators are based on the technical features of dense indoor small cell networks, higher carrier frequency operation, and network architectural openness to support multi-tenancy and network slicing for servicing numerous serviced providers customers.
- Regarding customers, the micro operator can operate a closed network to serve its own human or machine type of customers that are not served by MNOs such as in a factory.
- Alternatively, the micro operator can serve as a neutral host for other MNOs in a specific location, such as a campus, by serving their customers.
- In other cases, such as in a mall, a hybrid is possible, in which the micro operator serves both MNOs' customers and its own customers.
- The underlying regulatory framework is a major challenge for the deployment of the new micro operator concept.
- The key regulatory elements for the introduction of the new micro operator concepts including the operator role, spectrum authorization decisions, access rights to the infrastructure, and

building of indoor networks were preliminary views to access regulation, pricing regulation, competition, data and security, and authorization of networks and services.

The micro operator's role and level of involvement is highly dependent on the specific use case and can differ across sectors.

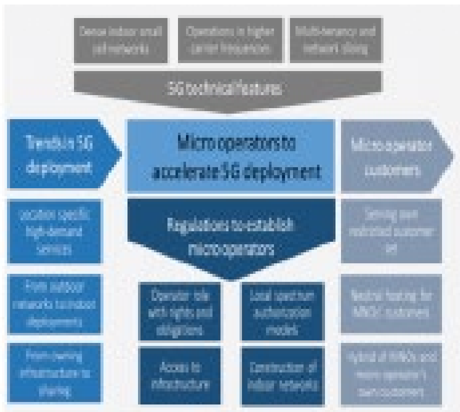

Figure 4: Overview of micro operator concept

Challenges of 5G Network Distribution in Rwanda

Despite the features and huge benefits, there are still potential challenges to implement 5G especially in Rwanda. Here below are some of them [5].

• Spectrum allocation: 5G requires a high amount of spectrum in order to achieve higher data rates and massive network capacity. The requirement needed is a low frequency band of less than 1 GHz, a mid-frequency band (in 2.3 -3.5 GHz range) for its macro cells, and a high frequency band (mmWave in 26 -100 GHz range) for its micro cells. A modest bunch of clean-ups, harmonization and policy level interventions are required to make the necessary spectrum available for 5G that might create some extra challenges. Some of the spectrum is assigned to the government, so to recover it requires a hard discussion by the regulatory authority.

• Cost of increased network density: the number of base stations placed over a terrain against the population while continent like Africa the density of the population is low while a higher density requires higher cost determines the density of a network. In order to support the cluster of micro cells the density of 5G networks must be much higher. This necessitates extra challenges of financing and building satisfactory adequate for base stations to boost a coverage of 5G networks.

• Spectrum cost: The cost of spectrum could be a major factor that will make a difference in 5G roll-out from country to country in Africa as the most of the country as the spectrum usage required specific improvement to accommodate 5G.

• Lack of infrastructures: Infrastructure like towers, antenna etc to host base stations and accessories are required for their inter connectivity that is why is critical aspects to ensure coverage and capacity. Currently most of the base stations in 4G are not connected using 4G because of the infrastructure and maintenance cost while the 5G operators rely on fiber connectivity as an important factor for the backhaul. Mobile operators can use microwave radio spectrum but it requires a line of sight to be connected, which can be a potential issue.

• Dynamic Spectrum sharing: Cognitive radios are the distinct features of 5G that can resourcefully detect and use available channels in the region. Due to the payment issue in most of the countries it is not easy to use a spectrum sharing policy established among the mobile operators even if it is not allowed by certain Regulatory Authorities.

• Dealing with new security issues: 5G is new technology that comes with new risks. To deploy 5G it needed to consider at a given point cyber security issues that arise. There are also technical challenges that can create contiguous spectrum out of scatteredly assigned spectrum, high spectrum prices, poor mobile network infrastructure, lack of policy in dynamic sharing of spectrum, etc. Handling these issues needs a huge amount of economic resources as well as skilled manpower.

Conclusion

The 5G Network has been developed to satisfy the demands of new services and applications' communication such as enhanced Mobile Broadband (eMBB) communication, massive Machine Type Communication (mMTC)and Ultra-Reliable Low-Latency (URLL) communication that have exceeded 4G networks capabilities. Mobile Networks operators worry about the distribution and proposed to 3GPP five different network architectures for 5G NR distribution to be applied due to diverse concerns on 5G distributions to provide an effective and reliable 5G network that will fulfill all of the requirements. The proposed solution fall into two majors that maybe applicable in Rwanda: Non-Standalone New Redio(NSA NR) refers to a 5G NR distributions option that depends on an existing 4G LTE network's control plane for control functions, while 5G NR is entirely focused on the user plane and Standalone New Radio(SA NR) 5G uses the 5G NR access network on a brand new 5G network core.

The article clearly analyzes and compares the NSA NR and SA NR deployment strategies of 5G networks in terms of coverage, network capability, interworking between 4G and 5G, complexity and cost of network deployment and the latest industry progress where the conclusion was drawn that NSA performs better because the interworking of the NSA system is done as intra-system handover of LTE.

The performance of SA is similar to that of LTE's CS fallback, which is acceptable for a human customer. It reviews the recent market and technology related trends in 5G deployments where the concept of 5G micro operators was recently proposed to open the mobile market for new entries in order to accelerate 5G distribution, and also it defines feasibility and challenges of 5G Network deployment in Least Developed Countries (LDCs). The consideration of 5G deployment micro operators has been also validated as a good deployment strategy where mobile market for new entry is opened to accelerate 5G deployment meeting location specific needs arising in certain high-demand areas and it enables various stakeholders to play a local operator role, deploying and operating local 5G small cell networks and providing context-relevant content and services in a specific area.

Technical challenges have been investigated and found that they are creating contiguous spectrum out of scattered assigned spectrum, high spectrum prices, poor mobile network infrastructure, lack of policy in dynamic sharing of spectrum and the mentioned possible solution to these challenges is planification of a huge amount of economic resources as well as skilled manpower for its efficient use in Rwanda.

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