NIGERIAN COMMUNICATIONS COMMISSION

FINAL REPORT

CONSULTANCY STUDY ON 5G- THE EVOLVED TELECOMMUNICATION TECHNOLOGY OF THE FUTURE

Submitted
by

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EXECUTIVE SUMMARY

Digital connectivity is considered a key driver of future socio- economic activities in Nigeria. 5G is the next innovative step in the evolution of mobile wireless communications technology, promising improved connectivity, greater network speeds and bandwidth, and very low latency. It is the 5th generation in mobile technology which, at each step, has witnessed significant developments in communications networks.

It is a transformative technology that could have significant socio-economic impacts by supporting greater innovations such as Internet of Things, Cloud Computing and Artificial Intelligence thereby enhancing productivity and international competitiveness. 5G will provide a platform for Nigerian communities and businesses to harness the socio-economic benefits delivered by an advanced, data-intensive digital economy. It will facilitate Nigeria's recovery from the effects of the global COVID-19 pandemic.

5G is an opportunity for policy-makers and industry regulators in Nigeria to empower citizens and businesses and it will play a vital role in supporting the Government to achieve smart cities. It is an opportunity for the Nigerian Communications Commission to facilitate sector and industry verticals investments in high speed services thereby promoting mobile competition as well as fixed competition with the acceleration of 5G fixed wireless access services.

The broad objectives of the consultancy study were outlined as follows:

1. to investigate and provide possible solutions to some of the key challenges in the deployment of 5G cellular networks with regards to 5G drivers;
2. to determine the reliability and energy efficiency of 5G cellular networks;
3. to devise a means through which the 5G cellular network can support more users, more devices, more services without a corresponding impact on cost;
4. to determine what Nigeria needs to do differently or uniquely with regards to deployment of 5G; and
5. to provide an approach in addressing 5G electromagnetic field and public health concerns.

These objectives clearly indicate that the consultancy study is basically aimed at devising means of achieving a timely, responsive and optimal 5G deployment in Nigeria that will align with the scenarios depicted by these objectives for the wellbeing of Nigerians.

Towards providing a quality approach to 5G deployment in Nigeria, this study adopted a method which involved investigating and analysing 5G ecosystem components and drivers both in global and local perspectives. It examined international regulatory and industrial best practices associated with 5G deployment with emphasis on countries that have similar demographic and socio-economic factors as Nigeria. These practices cut across 5G demands in terms of finance, incentives, taxation, spectrum and infrastructure requirements, and electromagnetic field issues.

A comprehensive consultation with components of the 5G ecosystem in Nigeria was also carried out towards identifying possible challenges to a successful introduction of 5G, and provided an insight to problems that ought to be addressed in order to optimally harness the benefits of 5G.

The local consultation involved extensive engagements with stakeholders which include the major mobile operators, original equipment manufacturers, tower and passive network providers, cloud infrastructure providers, international transmission providers, fiber network providers, satellite network providers and the Government at the regulatory and policy levels of telecommunication, taxation, investment, health and petroleum. It also included stakeholders from the broadcasting, transportation, power, energy, security, manufacturing and health sectors.

In developing this Report, vital national planning, regulatory and policy documents were consulted and analyzed. These include the National Broadband Plan 2020-2025, the National Information Communication Technology Policy, Nigerian Communications Act 2003, the Economic Recovery and Growth Plan, Vision 2020 as well as recent guidelines and releases on 5G drivers (spectrum and infrastructures) issued by the Nigerian Communications Commission at the local level and the International Telecommunication Union at the global level. Analyses provided an informed view on the state of 5G drivers, and to a great extent, what needs to be done to tackle deficiencies in 5G drivers and accelerate 5G deployment in Nigeria as well as to position Africa's largest economy globally in terms of high speed mobile connectivity.

Importantly, the Nigerian economy exhibits multiple characteristics which strongly suggest that 5G deployment will generate significant economic benefits. The country faces ongoing service quality challenges in wireless telephony and broadband services. It also has relatively under-developed fixed line infrastructure, and presently faces significant opportunities for economic growth. Factors such as population size and distribution, rate of economic growth, the quality and extent of existing infrastructure, as well as access to capital for investment exert important influences on the national economic payoff from deploying new communication technologies.

Therefore, it is important that Nigeria prioritizes roll-out of 5G networks as a means of consolidating on the economic growth it is currently experiencing, to aid its post COVID-19 recovery and to lay the foundations for ongoing economic development and improvement in living standards for all Nigerians.

In addition, 5G deployment offers a stepping stone for an incremental development path that includes future deployments of fixed line infrastructure. Deployment of 5G will entail additional fiber connectivity to 5G base stations or nodes and this lays a solid foundation for future fiber- to- the- premises deployments while delivering high quality broadband over 5G fixed wireless access services earlier than would otherwise be possible.

Globally, 5G adoption is occurring very rapidly with 407 operators in 129 countries having invested in 5G as at mid-November 2020. Following multiple announcements of 5G deployments in 2020, 146 operators have now launched 3GPP compliant commercial 5G services. This indicates that Nigeria can harness significant economic benefits from early deployment of 5G. In effect, there are indications that Nigeria in particular is very well positioned to benefit from 5G deployment and that 5G deployment would have an impact on the Nigerian economy that is likely to be even more positive than similar deployments in regional peer nations.

In the long term, the economic benefits to the Nigerian economy of 5G are very substantial. In contrast, delaying or suspending the introduction of 5G in Nigeria will imply running the risk of the following:

I. Nigeria and its citizens will not benefit from the use case of Enhanced Mobile Broadband and the various technologies enabled by this use case;
II. operators will over-invest in older legacy technologies to support the ever increasing traffic growth when better spectrum efficient and low power options are available;
III. Nigeria will clearly miss out on the benefits of the use cases of Ultra Reliable Low Latency Communication and Massive Machine Type Communication meaning that key industries such as energy and manufacturing will be disadvantaged when compared to their regional and global competitors.

The Report recommends that the Government and the Nigerian Communications Commission should support the early introduction of 5G services in Nigeria, encourage mobile network operators and ancillary service providers to invest in this transformative technology and take further facilitative steps as required with regards to taxation, spectrum management and achieving 5G service affordability.

On the basis of technology neutrality of International Mobile Telecommunication bands, all existing spectrum licensees in these bands should be able to deploy 5G new radio through the use of dynamic spectrum sharing, part or exclusive use of their existing spectrum. If certain spectrum licenses do not currently permit this scenario, they should be amended.

In the short term, the optional spectrum bands to facilitate 5G deployment in Nigeria fall into two categories namely vacant spectrum in the current International Mobile Telecommunication spectrum bands and mmWave spectrum specifically the 26 GHz band (n258). Such additional spectrum will improve 4G services and provide a better opportunity for mobile network operators to deploy 5G services.

In relation to existing vacant spectrum, it is recommended that the NCC, in 2021, auction:

I. 2 Lots of 2 x 10 MHz of 2.1 GHz (n1) spectrum. To the extent permitted by law, Cobranet may wish to include its current spectrum allocation in Lagos in one of the Lots concurrently for auction;
II. 2 Lots of 2 x 10 MHz of 2.6 GHz (n7) spectrum subject to any reservation of spectrum to OpenSkys;

III. 1 Lot of 2 x 10 MHz of 700 MHz (n28) spectrum depending on the Government's view of whether such spectrum should be reserved or it should be auctioned on the basis that certain capacity on this band should be reserved for the national rural telephony initiative.

In relation to the mmWave spectrum, the NCC should consider whether it initially reserved part of the 26 GHz (say 750 MHz of the 3250 MHz available) or indeed the 28 GHz band for enterprise or private network use. The remaining 2500 MHz could be auctioned in Lots of 100 MHz with a cap of 800 MHz.

As soon as possible, the Nigerian Communications Commission should implement the following:

I. commence re-farming the key 5G pioneer band of 3.5 GHz spectrum in order to make available at least 110 MHz for 5G purposes on nationwide basis from 3400 to 3510 MHz. It should also explore whether additional spectrum in the 3300-3400 MHz and spectrum higher than 3510 MHz are available for 5G use by re-farming the n78 band;
II. consider re-farming the 2.3 GHz band in order to create larger contiguous blocks which may be better used for 4G/5G services.

Spectrum trading should ideally profit the 5G regime. Operators are also favorably disposed to satisfying part of their 5G spectrum requirements through spectrum trading. The 2018 Guidelines is considered flexible and efficient, but one aspect that may require review is the transactional cost. It is envisaged that spectrum holders may not be adequately motivated to lease or bequeath their spectrum holdings due to the significant transactional charges. It is still unclear how these significant charges will affect the motivation of licensees, who may be seeking to put together a large contiguous spectrum block for 5G deployment.

The Nigerian Communications Commission should facilitate 5G deployment in Nigeria by instituting a range of policy and regulatory reform detailed in this Report aimed at improving access to cell sites and towers, fiber connectivity to cell sites as well as small cell rollout over the next 12 months especially in relation to public land and street or road infrastructure. A nationwide adoption and implementation of the laudable harmonization of right of way charges of 145 naira per linear meter without additional charges is very important for the realization of a responsive 5G regime in Nigeria.

Furthermore, the Nigerian Communications Commission in collaboration with the Ministry of Communication and Digital Economy, Ministry of Health, bodies of telecommunication companies and operators, and professional health associations should engage in a public enlightenment campaign aimed at reassuring the public on the safety of 5G technology, and that the technology is similar with existing mobile services in terms of spectrum usage.

This study was carried out under the supervision of the Department of Research and Development of the Nigerian Communications Commission.

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1.0. PROJECT BACKGROUND

1.1. Introduction

5G is the fifth generation of cellular communication technology which was conceived to address the need for ultra- fast, super- reliable and very low latency connections in the delivery of both fixed and mobile broadband to end users for diverse purposes. 5G was developed to provide use cases which are now re-defining the way people and things communicate with each other. Hence, it is consider a general purpose technology as these use cases can be applied to meet a wide range of objectives cutting across different spheres of life endeavours.

5G represents paradigm shift from preceding mobile technologies such as 4G and 3G in terms of improvement and user experience. One of the core targets of the 5G technology is to achieve a massive upgrade in data rates more than preceding generations in order to satisfy the requirements of the use cases. The key network component is the 5G NR system utilizing MIMO antennas which are developed to use 5G frequencies to provide beam forming functionality for enhanced capacity by boosting peak and average downlink cell throughputs[1].

The technology also promises better outcomes in terms of spectral and energy efficiencies of networks. It offers significant socio-economic benefits accruable from a robust platform for massive interconnection of people and devices. It can also be pivotal to post- pandemic and general economic recovery with supportive polices and responsive regulation.

For Nigeria to optimally harness the enormous socio-economic benefits of the technology, certain policy, regulatory and industrial requirements should be met. These requirements bother on spectrum, passive network and digital infrastructures as well as supportive policies and regulation which ensure their continuous availability in the right proportions for 5G deployments across the entire Nigerian landscape. They are considered as key 5G drivers, and are vital for a responsive 5G regime in Nigeria that will guarantee the realization of the scenarios depicted by the objectives of the study.

The study examined the global trends and developments in 5G technology and deployments, and identified the requirements that are key to successful 5G deployment in Nigeria. It measured the state of these requirements in Nigeria by investigating the various components of the 5G ecosystem in Nigeria and proposed means of improvement. It also validated the enormous importance of 5G to the economy of Nigeria. A total of 23 research items which relate to 5G drivers were identified investigated, analyzed and reported for the purpose of meeting the objectives of the study.

Spectrum is a key driver of the mobile broadband revolution. Hence, the success of 5G in Nigeria depends largely on how 5G spectrum requirements are managed. 5G deployment requires

[1] GSA, 5G Networks and Devices: a Global Snapshot, October 2019

contiguous and sufficient spectrum across multiple layers of spectrum classified as low, mid and mmWave bands to meet the demands of 5G use cases.

Also, spectrum management requires timely access to suitable spectrum to address coverage and capacity objectives of MNOs and possibly private enterprises in key sectors such as manufacturing and oil & gas. Exclusive nationwide spectrum assignments of large contiguous bands at reasonable prices will guarantee robust 5G investments and optimal socio-economic gains for Nigeria.

In addition to making key 5G spectrum available in the Nigeria, it is necessary to enact supportive polices and improve regulatory approaches to facilitate availability and accessibility of passive network infrastructures as well as high capacity digital connectivity across the country. In deepening fiber connectivity for 5G deployment, there is need to improve ROW. Improving access to towers and sites for 5G deployment and accelerating the fiber connectivity to base stations to support traffic loads are also important. Likewise, there is need for solid measures to ensure protection of associated network equipment.

Therefore, regulatory framework and industrial practices should be fine-tuned to ensure sufficiency in spectrum, backhaul and international transmission capacity, cloud infrastructure, tower and site space and power requirements. These drivers constitute the key aspects of the study as addressing deficiencies in regulatory and industrial practices is vital to achieving timely and responsive 5G deployment that will guarantee investments and high service quality.

In addition, 5G use cases cut across mainstream telecom industry as well as vertical industries such as energy, security and manufacturing. In securing 5G for Nigeria, the requirements for these use cases should be adequately satisfied if the core targets of 5G must be met.

The report details findings and analyses and applicable recommendations with regards to objectives of the study. It consist of an executive summary and five chapters. The first chapter provides the background of the study, detailing the research focus, objectives and scope. The second chapter reviews global developments in 5G deployment with emphasis on providing an informed view on 5G requirements. It also gives a detailed account of the benefits and importance of 5G technology to Nigeria. The third chapter deals with the methodology and work plan deployed for the research while the fourth chapter is an account of the global and local findings as well as analyses on 5G drivers aimed at satisfying the objectives of the study. Finally, the fifth chapter details the recommendations arising from the results of the study.

1.2. Research Focus

Basically, the research focus was to identify challenges to successful introduction of 5G that would meet the objectives of the study, and develop possible solutions to these challenges which bother mostly on satisfying spectrum, passive network and digital infrastructure requirements. How to guarantee sufficient and affordable spectrum release in a timely and sequential manner is a key requirement for 5G deployment. Likewise, regulatory and industrial approaches to increasing the availability of necessary passive and digital infrastructures will complement spectrum availability in ensuring a smooth introduction of 5G networks that would provide ultra-fast, super-reliable and low latency connections in a ubiquitous scale.

The research focused on possible Nigerian challenges listed as follows:

- timely, sufficient and affordable release of spectrum;
- integration with 4G and VoLTE;
- facilitating investment & funding of 5G;
- non-supporting and multiple taxation and regulatory regimes;
- small cell deployment and managing traffic in CBDs/crowded areas;
- 5G Device affordability and availability;
- reliability and energy efficiency of 5G cellular networks;
- vandalism; and
- addressing the widespread misinformation on effects of EMF on public health.

In general, the study focused on providing suitable approaches to securing 5G for Nigeria in such a manner that will guarantee optimal socio-economic benefits derivable from this technology. There are indeed peculiar Nigerian challenges which were assessed and quantified, thereby resulting to informed recommendations and justification for practical and technical steps required to clear obstacles that could delay or impede 5G deployment, or degrade the gains of the technology.

In dealing with anticipated explosion in number of users and devices, key study elements included the following:

- passive network infrastructures such as towers, cell sites, lamp poles, bill boards, street furniture etc;
- backhaul, fiber and fixed line infrastructures, and ROW;
- harmonized, adequate and contiguous frequency spectrum blocks across low, mid and millimeter wave bands including the need for synchronization and common frame structures;
- the suitable spectrum auction methods, re-distribution and re-channelization plans;
- rollout criteria and obligations;
- solid foundation for 5G IoT;
- 5G consumer devices.

1.3. Objectives

The overall objective of the study was to provide an insight into the study of 5G considered as the evolved telecommunication technology of the future. The 5G study was to enable the NCC to achieve the following specific objectives:

1. to investigate and provide possible solutions for some of the key challenges in the deployment of 5G cellular networks;
2. to determine the reliability and energy efficiency of 5G cellular networks;
3. to devise a means by which the 5G cellular network can support more users, more devices, more services without a corresponding impact on cost;

4. to determine what Nigeria needs to do differently or uniquely with regards to global and regional deployment of 5G; and
5. to provide an approach to addressing concerns on 5G EMF and public health.

1.4. Scope

The study was designed to be nationwide with a greater emphasis on areas with high concentration of traffic and business districts. Other areas of focus included:

1. Rapid increase in connected devices;
2. The need to cope with the total volume of traffic;
3. New approach to deal with concentration of traffic in particular areas (CBDs/crowd area services);
4. IoT.

2.0. LITERATURE REVIEW

In order to gain a solid insight to the 5G ecosystem and requirements, an extensive global review on 5G developments and practices was carried out. It focused on 5G policies, regulation and deployments. In addition, the economic importance of 5G to Nigeria was examined, validated and quantified in relation to the socio-economic benefits of telecommunication to Nigeria.

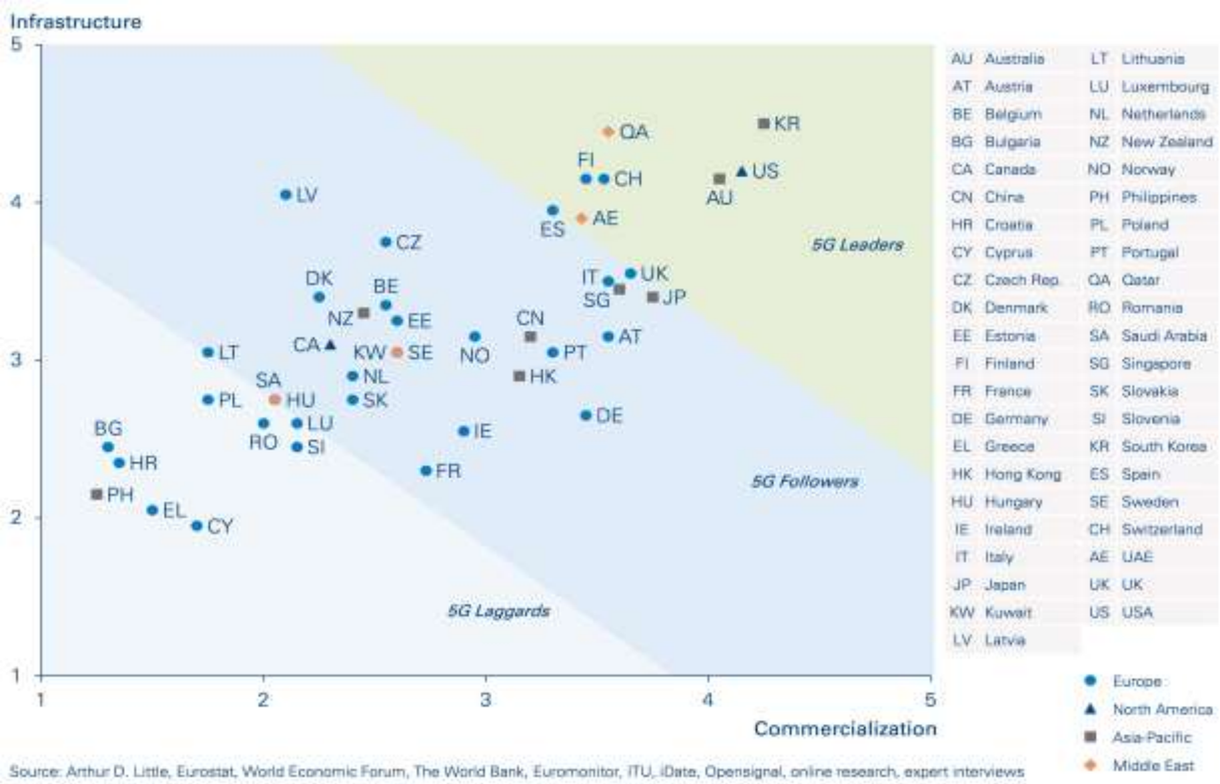
2.1. 5G Deployment in a Global Perspective

As defined by ITU, the IMT-2020 for 5G encompass the systems, components, and related elements that support enhanced capabilities for the next generation of communications technology surpassing IMT-2000 (3G) and IMT-Advanced (4G) systems.

2.1.1. Global Approaches to 5G

Globally, many countries and regions like South Korea, the United States, Japan, China, and the European Union are in a "race" to deploy 5G and to secure country economic benefit – including manufacturing, innovation, and services/applications – from doing so. This has resulted in many Governments enacting a range of supportive policies to encourage 5G, including favorable spectrum policies, infrastructure deployment rules and setting ambitious adoption goals. A comparison of global 5G leadership has been developed by Arthur D Little (see Exhibit 2.1). Nigeria could, with good 5G decision-making, join this leadership index.

Exhibit 2.1: 5G Leadership Index by Arthur D Little (March 2019)[2]



2.1.2. ECOWAS Policy Approaches to 5G

While there is currently an ECOWAS ICT plan to enable 5G deployment,[3] it should be noted that:

- The World Bank is seeking more investment for Africa's telecoms industry through the next phase of its African Regulatory Watch Initiative (RWI). The RWI is intended to tackle the legal, regulatory and competitive challenges that threaten to jeopardize the deployment of digital technologies – including 5G – and provide guidance on things like licensing and spectrum allocation, taxation and tariff-related issues, and access to infrastructure.[4] Phase one was successfully completed in 2017 and focuses on licensing regimes, OTT and International Gateway Liberalization in ECOWAS. The RWI is currently in stage 2 of development with Progressus Corporation, who are conducting a thorough analysis of each

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[2] Arthur D. Little, *The Race for 5G*, March 2019. The 5G Leadership Index is based on detailed analysis of technical infrastructure and tendency for 5G commercialization. 5G Leaders have 5G spectrum allocated, high performance backhaul infrastructure deployed, have announced ambitious goals for 5G launch or launched already, and have successfully trailed multiple use-cases. They demonstrate a willingness to adopt new services and have the right level of competition to foster commercialization. Available at www.adlittle.com/sites/default/files/reports/adl_the_race_to_5g_report_-min.pdf

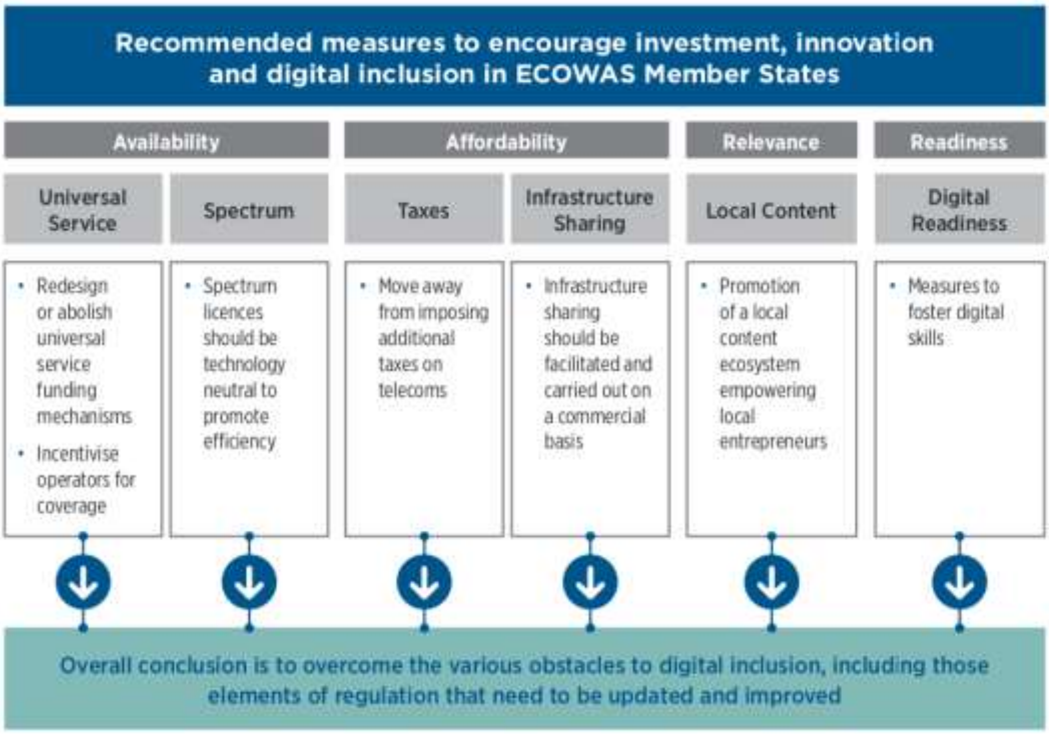
[3] www.cio.com/article/3505937/5g-in-africa-enterprises-to-fuel-uptake-but-network-deployment-lags.html

[4] www.connectingafrica.com/document.asp?doc_id=757289

country's telecoms industry. An RWI Index is to be produced, which will assess countries according to their spectrum management and regulatory governance.[5]

- In 2019, the GSMA identified the factors in Exhibit 2.2 below as being vital to improving the digital industry in ECOWAS.

Exhibit 2.2: GSMA's recommendations in relation to ECOWAS



Source: Digital ECOWAS, GSMA[6]

The GSMA predicts that by 2025, there will be commercial services in at least seven markets, including Kenya, Nigeria, and South Africa, with 28 million 5G connections. Implementation of 5G is unlikely to be imminent in many ECOWAS markets as the existing technologies are capable of supporting current use cases and demand for mobile internet connectivity.[7] In addition, several major African MNOs, including MTN and Vodacom, have already embarked on their journeys towards bringing 5G to the continent.

2.1.3. Nigerian Frameworks for 5G and the Digital Economy

Nigeria's Economic Recovery and Growth Plan 2017–2020 (ERGP)

Nigeria's ERGP recognizes the need for a digital-led strategy to make the Nigerian economy more competitive in the 21st century global economy. At the 5th World Stage Economic Summit held in

[5] https://africabusinesscommunities.com/news/world-bank-appoints-progressus-for-expansion-of-african-regulatory-watch-initiative/
[6] www.gsma.com/publicpolicy/wp-content/uploads/2019/04/GSMA_Digital-ECOWAS_WEB_LowRes.pdf
[7] https://businessday.ng/technology/article/despite-mtns-trial-nigerias-readiness-for-commercial-5g-a-doubt-in-2020/

November 2020. Professor Umar Danbatta, the Executive Vice Chairman and CEO of NCC, emphasized that ICT has the ability to transform development in agriculture, education and healthcare services, and is an enabler for the realisation of the ERGP. The impact of COVID-19 and need for economic diversification from oil and gas are two key drivers of progress in ICT in Nigeria.[8] As part of the plan to invest in national infrastructure, the NCC has recently trialled 5G technology making NCC the first regulator to do so in the West African sub-region.

Vision 2020

Nigeria's Vision 2020 is a strategic document that identifies the long-term developmental objectives with the aim of achieving accelerated and sustained economic development.[9]

The strategic initiatives envisioned to drive implementation of policy within the ICT sector include:

I. Providing the appropriate incentives to drive the development of ICT infrastructure and telecommunications services to rural and underserved urban areas;

II. Mainstreaming ICT into the education curriculum;

III. Encouraging local production of ICT components and subsystems by providing incentives for manufacturers for major ICT projects;

IV. Facilitating the development of a national multi- media superhighway;

V. Establishing a national (spatial) ICT backbone Connectivity and Bandwidth Aggregation Solution;

VI. Implementing the Nigerian National ICT for Development (ICT4D) strategic action plan to foster a competitive environment with ample opportunities and choices;

VII. Establishing a national digital library with access points strategically located in both rural and urban areas;

VIII. Promoting e-learning, e-governance, e-business, e-commerce, e-banking, e-management, etc;

IX. Providing regular and affordable access to Internet resources in all educational and research institutions, with particular focus on basic and post-basic education;

X. Establishing appropriate legal and regulatory frameworks to support e-business and ICT enabled activity—the legal framework will address law enforcement, electronics contracts, consumer protection, intellectual property rights, dispute resolution, privacy, cybercrime and data protection, and other aspects of information security;

8 www.worldstagegroup.com/ncc-commits-to-make-telecoms-an-enabler-of-ergp-2017-2020-as-5g-trial-set-to-identify-security-challenges-to-deployment/

9 http://documents.worldbank.org/curated/en/387871574812599817/pdf/Nigeria-Digital-Economy-Diagnostic-Report.pdf

XI. Providing appropriate incentives, including tax benefits and improved infrastructure, with a view to creating an enabling environment that encourages investment, innovation, and exploitation of ICT-enabled services; and

XII. Mainstreaming ICT policies into the broader development of a knowledge society and ensuring coordination and consistency between ICT policy strategies and national development policies.

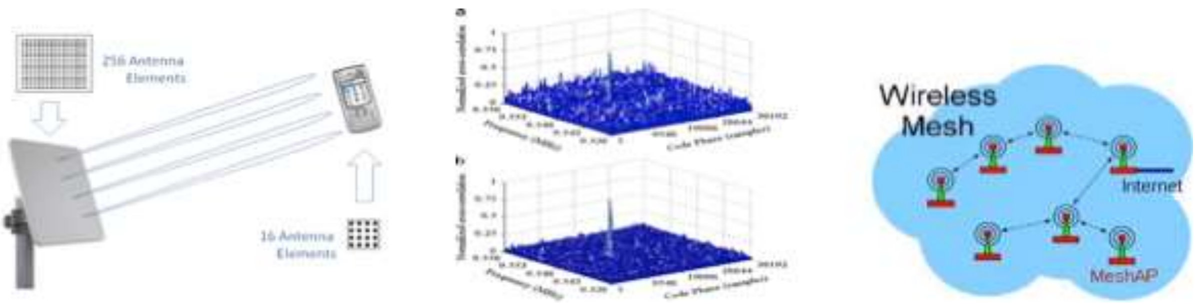
5G is an integral part of the global digital transformation.[10] Making available sufficient and timely IMT Spectrum in Nigeria – especially the pioneer 5G band of 3.5 GHz – is an essential prerequisite to the digital economy.

2.1.4. 5G in the Context of Mobile Technologies

Discussions on 5G commenced in 2008 while 4G/LTE and WiMAX were still vying to become the 4G technology standard. 5G at that time did not describe any particular specification in any official document published by any telecommunication standardization body but it was anticipated to involve many things including (see Exhibit 2.3):

- Spectrum Efficiency and performance, e.g. higher order spectrum aggregation, interference cancellation and scheduling, massive MIMO;
- Radio design and performance optimization, e.g. small cells, Heterogeneous Networks, Mesh, software defined, multi-standard, dynamic spectrum and flexible duplexing, self-optimizing and organizing networks; and
- Network traffic optimization – quality of service (QoS), policy tools, end-to-end, RAN-aware IP and media optimization, and improved codecs.

Exhibit 2.3: Examples of 5G Technologies



10 ITU, White Paper, *Digital Infrastructure Policy and Regulation in the Asia-Pacific Region*, September 2019. Available at www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/SiteAssets/Pages/Events/2019/RRITP2019/ASP/ITU_2019_Digital_Infrastructure_5Sep2019FNL.pdf

There were then three key visions for 5G networks, namely:

I. Super-efficient universal mobile network;
II. Super-fast mobile network with densely clustered small cells for data rates >1 Gbps; and
III. Converged wireless fiber network using mm wave band to allow data rates up to 10 Gbps.

In June 2018, the 3GPP — the international group that governs cellular standards — officially signed off on the standalone 5G New Radio (NR) specification (3GPP Release 15).[11] This followed the December 2017 specification for the non-standalone (NSA) version of 5G NR, which would still be built on top of existing legacy LTE networks. Release 16 was completed in July 2020 after being delayed by three months due to the Coronavirus pandemic.[12] This is the culmination of a program agreed in 2012, by ITU's Radiocommunication sector (ITU-R) to develop IMT standards for 5G by 2020. The evolution of mobile networks is detailed in Exhibit 2.4. Release 17 was delayed, with a new date announced in December 2020.[13]

Exhibit 2.4: Evolution of Mobile Networks

	1G	2G	3G	4G	5G
Approximate deployment date	1980s	1990s	2000s	2010s	2020s
Theoretical download speed	2kbit/s	384kbit/s	56Mbit/s	1Gbit/s	10Gbit/s
Latency	N/A	629 ms	212 ms	60-98 ms	< 1 ms

Source: ITU 5G Paper, 2018

5G is expected to increase data rates dramatically and reduce latency compared to 3G and 4G. The technology is expected to significantly reduce latency to below 1ms, suited to mission-critical services where data are time-sensitive. Its high-speed capability means 5G networks can provide a range of high-speed broadband services and offer an alternative to last-mile access such as fiber-to-the- home or copper connections. The high speeds and low latency promised by 5G are expected to propel societies into a new age of smart cities and the extensive use of the IoT.

2.1.5. 5G Use Cases

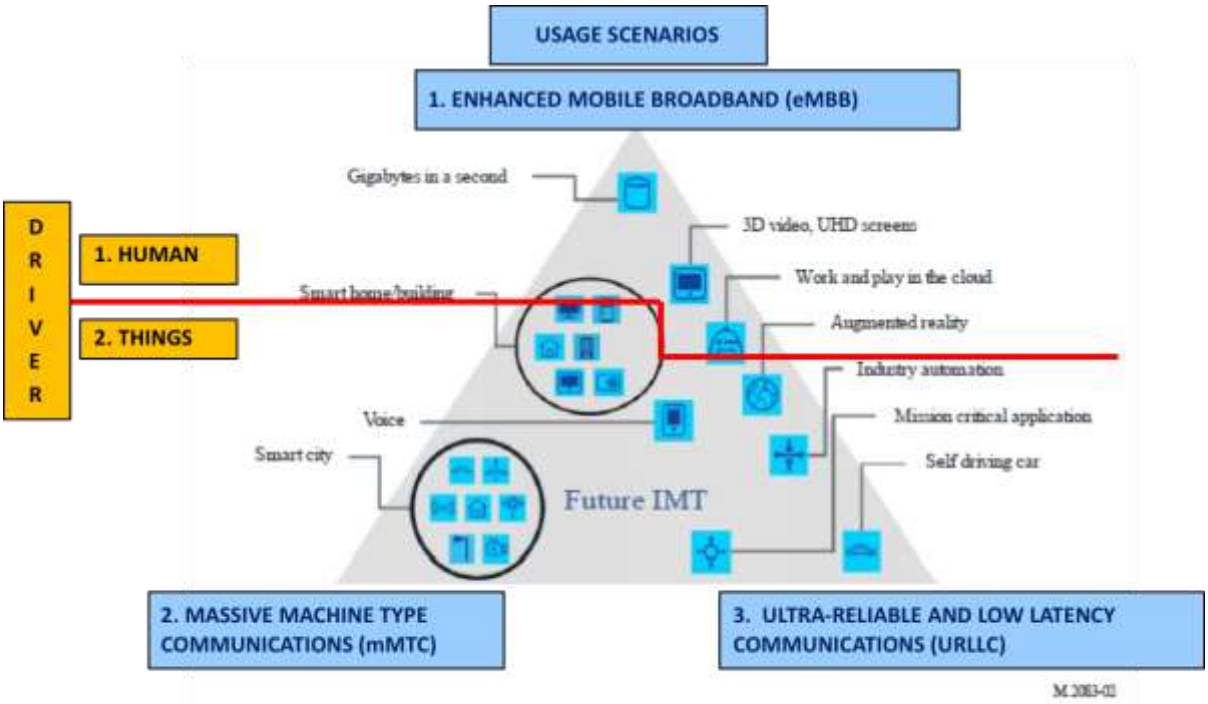
Industry stakeholders have identified several potential use cases for 5G networks, and the ITU-R has defined three important categories of these to be (see Exhibit 2.5):

1. **Enhanced mobile broadband (eMBB)** – enhanced indoor and outdoor broadband, enterprise collaboration, augmented and virtual reality;

[11] www.3gpp.org/release-15
[12] www.3gpp.org/release-16
[13] www.3gpp.org/release-17

2. **Massive machine-type communications (mMTC)** – IoT, asset tracking, smart agriculture, smart cities, energy monitoring, smart home, remote monitoring; and
3. **Ultra-reliable and low-latency communications (URLLC)** – autonomous vehicles, smart grids, remote patient monitoring and telehealth, industrial automation.[14]

Exhibit 2.5: Main 5G Use Cases



Source: Recommendation ITU-R M.2083-02 (09/2015) IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond

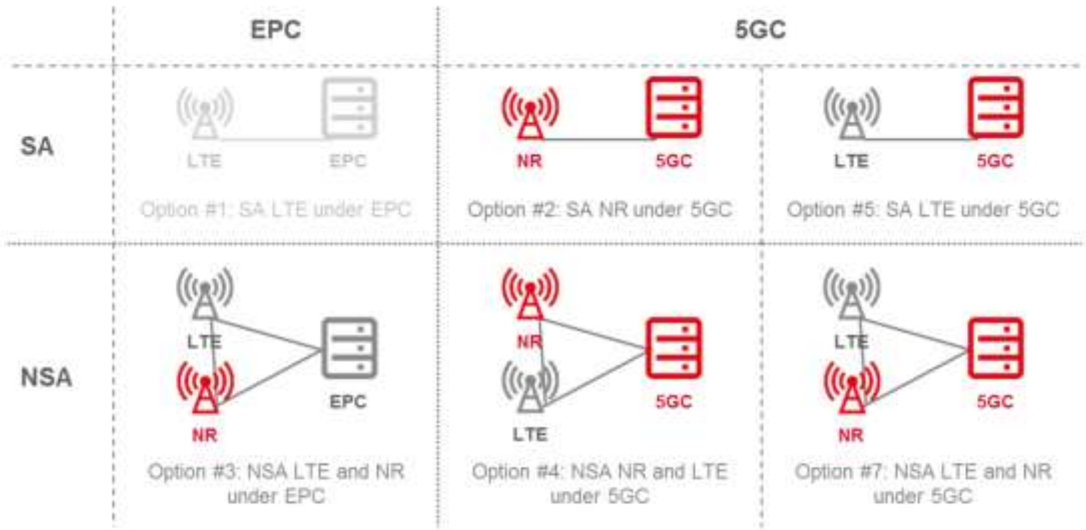
2.1.6. 5G Deployment Scenarios

In terms of 5G deployment scenarios, the 3GPP has defined both a new 5G core network (5GC) as well as a new radio access technology called 5G new radio (5G NR). It is therefore possible to integrate elements of different generations of mobile technology in different configurations with 5G, namely 5G SA (standalone) and 5G NSA (non-standalone).

The SA scenario uses only one radio access technology (5G NR or the evolved LTE radio cells) while the core network is operated alone. In contrast, the NSA scenario combines 5G NR radio cells and LTE radio cells using dual-connectivity to provide radio access while the core network could be either (EPC) or (5GC) as shown in Exhibit 2.6.

14 ITU, *Setting the Scene for 5G Report: Opportunities and Challenges*, 2018

Exhibit 2.6: Main 5G Deployment Scenarios (5G in red)



Source: GSMA, 2018[15]

In practical terms, the 5G deployment cases are their cost implications on MNOs are explored in Exhibit 2.7.

15 GSMA, *Road to 5G*, *Introduction and Migration,* June 2018, page 6. Available at www.gsma.com/futurenetworks/wp-content/uploads/2018/04/Road-to-5G-Introduction-and-Migration_FINAL.pdf

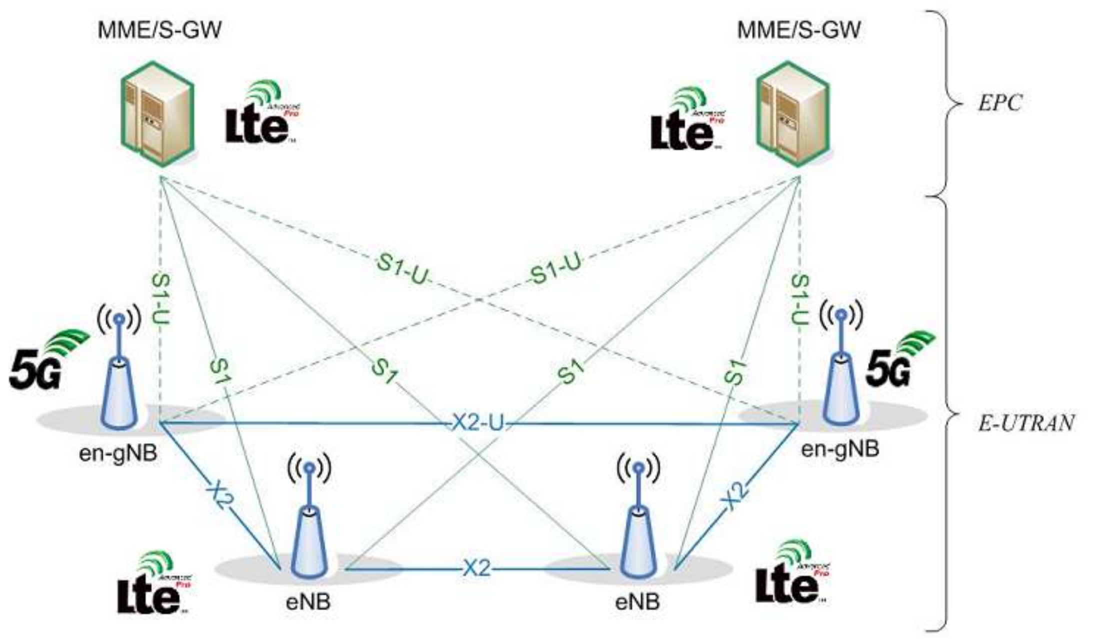
Exhibit 2.7: Case Study: Different 5G deployment strategies and cost implications

With the aim of assessing the implications of 5G deployment on the cost of wholesale services, Network Strategies of New Zealand developed a Bottom-Up Long Run Incremental Cost (BU-LRIC) model of a hypothetical mobile network in a country which is presented here. The model calculates the incremental cost, over the period from 2021 to 2026, which a hypothetical operator would incur by carrying an additional minute of voice call and additional megabyte (MB) of data for two scenarios:

- **4G scenario** – in which the operator deploys a full 4G Radio Access Network (RAN) based on LTE-A technology
- **5G scenario** – a non-stand-alone scenario where 4G RAN is deployed for providing coverage, and 5G RAN for serving additional traffic beyond the 4G RAN coverage capacity.

The model assumes that the hypothetical operator implements a NSA architecture for 5G deployment (see Exhibit 2.8). The 5G standard allows 5G RAN to operate alongside existing LTE RAN infrastructure and EPC. The NSA architecture is an intermediate step towards a full 5G architecture, and may be chosen by MNOs seeking to leverage on existing 4G deployments. It supports LTE services but with added capabilities offered by the 5G RAN.

Exhibit 2.8: 5G NSA Architecture



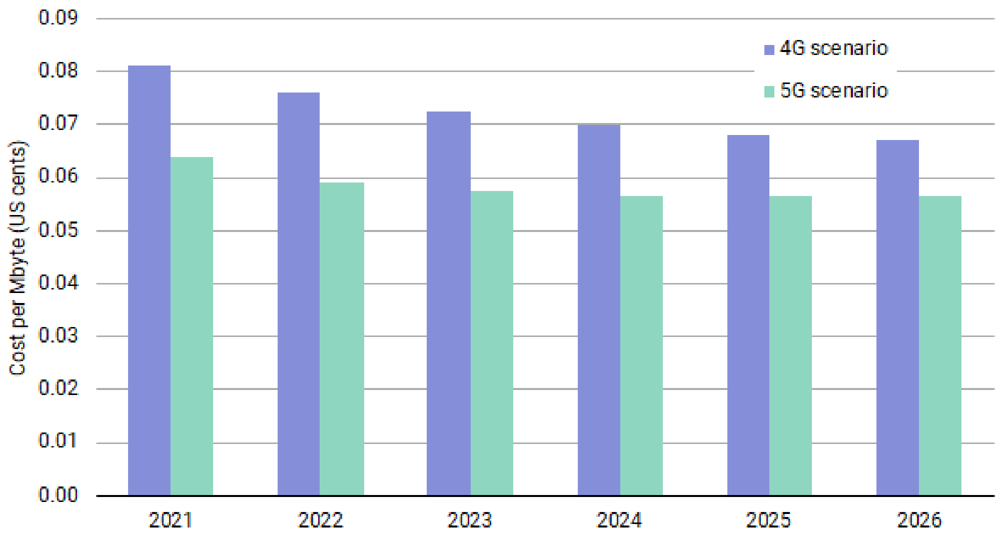
The capacity expansion required to carry the total projected demand and provide service to the coverage area (capacity network) is met by network densification on top of the coverage network, enabled by macro, micro and small cell deployments operating at sub-1GHz and above 1GHz spectrum. In the case of the 4G scenario which was modelled, LTE-A cells operating at 850 MHz and 2600 MHz are deployed. For the 5G NSA scenario, densification is achieved with 5G cells operating at 700MHz and 3.5GHz.

Case Study continued:

The results from the Network Strategies model show that by using 5G technology operators can achieve considerable reductions in the cost of wholesale voice and data services compared with LTE-A. The Total Service Long Run Incremental Cost (TSLRIC) results for the modelled 5G scenario are 15% to 21% lower than the 4G scenario for data services and 8% to 11% for voice services. The difference in service cost is mainly driven by the lower level of investment in RAN and backhaul networks required for the 5G scenario. 5G offers a higher spectral efficiency in comparison to LTE-A, therefore given the same amount of spectrum, 5G capacity per sector is higher than LTE-A.

As a result, fewer base stations are required when deploying 5G rather than LTE-A for capacity expansion. For the modelled network in the case study, the number of base stations required in the 5G scenario is 15% lower than the 4G scenario for the year 2021, with this difference increasing over time.

Exhibit 2.9: Data service – incremental cost per Mbyte (US cents per Mbyte)



In conclusion, the model results from Network Strategies indicate that 5G improvements in spectral efficiency have a significant impact on the cost of wholesale services when compared to LTE-A, therefore MNOs have an economic incentive to deploy 5G. The NSA option not only allows operators to bring to market some of the features of 5G quickly without the need to invest heavily in a completely new network; it also helps operators to cope with increasing mobile traffic in a more cost efficient way than if using LTE-A.

Source: Network Strategies, May 2020[16]

16 Available at http://strategies.nzl.com/industry-comment/5g-what-will-it-cost/

2.1.7. Global Developments in 5G

Globally, 5G is rapidly advancing especially in Asia, Europe and North America. By 2025, the GSMA expects 5G connections to reach 1.2 billion, and 5G networks are expected to cover one-third of the world's population.[17] The GSA reported that as of mid-November 2020, 407 operators in 129 countries are investing in 5G. Following multiple announcements of 5G deployments in 2020, 146 operators have now launched 3GPP compliant commercial 5G services.[18]

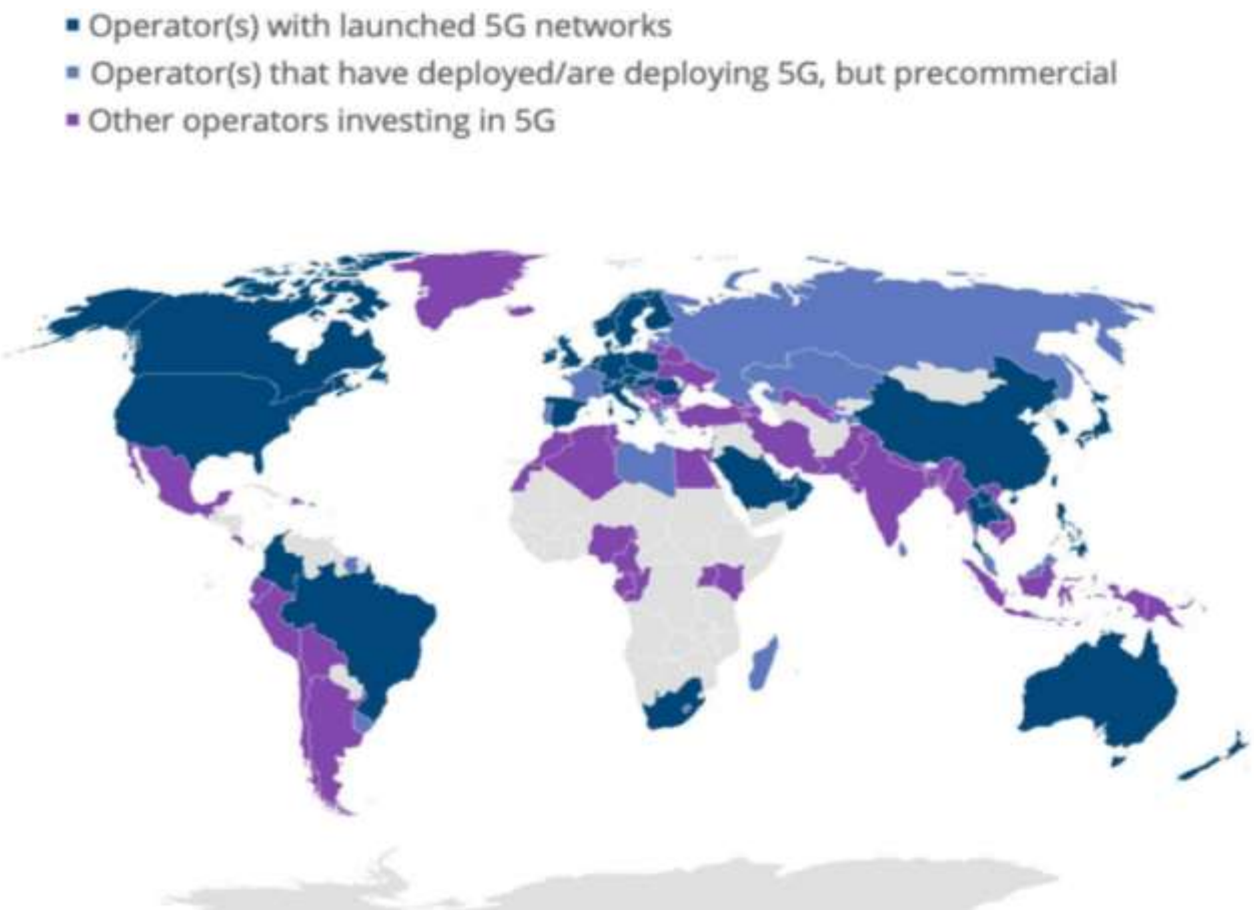
Those MNOs who have launched 5G include those from 49 countries (see Exhibit 2.10) including:

- Americas: Canada (Rogers Communications), Puerto Rico (T-Mobile), Uruguay (Antel), USA (AT&T Mobility, Sprint, T-Mobile US, Verizon Wireless);
- Asia-Pacific: Australia (Optus, Telstra, Vodafone), China (China Mobile, China Telecom, China Unicom), Hong Kong (China Mobile Hong Kong, Hutchison, HKT), Japan, (KDDI, NTTDocomo, Softbank, Rakuten), Maldives (Dhiraagu), New Zealand (Spark, Vodafone), Philippines (Globe), South Korea (SK Telecom, KT Corp, & LG Uplus);
- Europe: Austria (3 Austria, Hutchison, T-Mobile), Bulgaria (Vivacom), Croatia (HT), Czech Republic (Vodafone), Denmark (TDC), Estonia (Elisa), Finland (Elisa, TeliaSonera), Germany (T-Mobile, Vodafone, Telefonica), Ireland (Eir, Vodafone, Three), Italy (TIM, Vodafone), Latvia (Tele2), Netherlands (VodafoneZiggo, T-Mobile) Norway (Telenor), Poland (T-Mobile), Romania (RCS & RDS [Digi Mobil], Vodafone), Slovenia (Telekom Slovenije), Spain (Vodafone, Telefonica, Orang, MASMOVIL), Sweden (Hutchison, Telenor, Telia, Tele2), Switzerland (Sunrise Communications, Swisscom), UK (3 UK, EE, O2, Hutchison, Vodafone);
- Middle East: Bahrain (Batelco, Viva), Kuwait, (Ooredoo, Viva, Zain), Monaco (Monaco Telecom), Oman (Omantel), Qatar (Ooredoo, Vodafone), Saudi Arabia (STC, Zain), United Arab Emirates (Du, Etisalat); and
- Africa: Lesotho (Vodacom), South Africa (MTN, Rain, Vodacom).

Additionally, 44 operators had launched 3GPP-compliant 5G FWA or home broadband services.[19]

17 www.gsma.com/futurenetworks/ip_services/understanding-5g/5g-innovation/
18 GSA, LTE & *5G Market Statistics: Global Snapshot*, 11 November 2020. Available at https://gsacom.com/technology/5g/
19 GSA, LTE & *5G Market Statistics: Global Snapshot*, November 2020. Available at www.gsacom.com

Exhibit 2.10: Map of global operator investments in 5G, November 2020



Source: GSA, November 2020

It should also be noted that 5G itself is likely to be surpassed in the 2030 timeframe by 6G with some work already commencing on it, as summarized in Exhibit 2.11.

Exhibit 2.11: 6G Developments

6G, a term used for the globe's "sixth-generation mobile" wireless internet network, will be the successor to the world's still-forthcoming mobile network, 5G. It is not clear yet what 6G will entail. It will include relevant technologies considered too immature for 5G or which are outside the defined scope of 5G.

The University of Oulu in Finland released a paper based on the views of 70 experts and has its origins in a workshop at the first 6G Wireless Summit in Finnish Lapland that was held in March 2019.The paper, *Key Drivers and Research Challenges for 6G Ubiquitous Wireless Intelligence*, says that research should look at the problem of transmitting up to 1 Tbps per user. The paper claims that this can be possible through the efficient utilization of the spectrum in the THz range.

Artificial intelligence and machine learning will play a major role both in link and system-level solutions of 6G wireless networks, he added. Both AI and machine learning will be used alongside radio sensing and positioning to learn about the static and dynamic components of the radio environment.

6G, however, is not only about moving data around, says the paper. It will become a framework of services, including communication services where all user-specific computation and intelligence may move to the cloud. The integration of sensing, imaging and highly accurate positioning capabilities with mobility will open a range of new applications in 6G.

According to the white paper, the societal and business drivers for 6G will include the United Nations Sustainable Development Goals (UN SDGs). It envisions that new developments will enable ubiquitous services and says one of the key research areas is to make the 2030 vision for Ubiquitous Wireless Intelligence a reality.

Technical success of 5G has relied on new developments in many areas and will deliver a much wider range of data rates to a much broader variety of devices and users, while 6G will require a substantially more holistic approach to identify future communication needs, embracing a much wider community to shape the requirements of 6G.

Nevertheless, there will also be major challenges. The publication says the physical layer and radio hardware needs great improvement in order to cope with faster speeds. It also highlights the issues of increased energy consumption and data processing.

2.1.8. African 5G Developments and Trials

There are ongoing activities in all African countries looking into the release of the 3.5 GHz and other frequency bands to support 5G rollout. The situation in African members is summarized in Exhibit 2.12.

Exhibit 2.12: Selected African 5G updates

Country	Summary of its current 5G initiatives in relation to C-Band/3.5 GHz band
Algeria	In November 2018, Mobilis (subsidiary of Algeria Telecom) successfully tested 5G connection at Oran. The trial, which was carried out in conjunction with Huawei, reached downlink data transmission speeds of up to 1.18Gbps. Mobilis began testing 5G coverage in Algiers in August 2020.[20] However, fines were issued to three of Algeria's operators (including Mobilis) for poor 4G coverage and quality of service in October 2020 by the regulator, ARPCE.[21]
Gabon	Gabon Telecom began trialing a 5G network in November 2019. Frequencies in the 3400MHz to 3500MHz band were used, and the trial was carried out over six months. Although the aim was to see how 5G might be used to develop innovative applications, Gabon Telecom has stated that an actual commercial launch could be some time off.
Kenya	In February 2020, Kenya's biggest telecom operator Safaricom announced that it will partner with Huawei when it rolls out 5G network in 2020. As of March 2020, seven firms have ongoing 5G trials for 5G with the aim of a future rollout, but have not deployed as of October 2020. It is expected that the additional spectrum allocation to mobile services in the frequency bands 24.25-27.5 GHz, 37- 43.5 GHz. 47.2 – 48.2 GHz and 66 – 71 GHz will facilitate implementation of 5G mobile services in Kenya.
Lesotho	In August 2018, Vodacom Group launched Africa's first commercial 5G fixed wireless access (FWA) network in Lesotho. Vodacom was assigned spectrum in the 3.5GHz band, enabling the launch of a commercial 5G service.
Morocco	As of October 2019, the operators and Inwi and Maroc Telecom had begun trialing 5G technologies. Further, in January 2020, Huawei announced that it was ready to collaborate with Moroccan operators in deploying 5G technology. 5G is expected to be rolled out in 2022.[22]
Nigeria	From November 2019 to February 2020, MTN Nigeria implemented 5G network in six cities: Abuja, Lagos, Kano, Abeokuta, Ibadan and Calabar. MTN is Nigeria's largest operator in terms of subscriber base. The demo network architecture was based on 3GPP specifications for SA and NSA 5G network. The 5G trial used the 3500 MHz and 26GHz bands. The PoC demonstrated eMBB, low latency, 5G voice options and some applications such as 5G medicine. No date for a 5G rollout has been given and the NCC has indicated that 5G will not be rolled out until a deployment policy is concluded and approved.[23]
South Africa	In April 2020, ICASA assigned temporary spectrum to Vodacom, MTN, Telkom, Liquid Telecom and Rain. ICASA considered applications for temporary spectrum to November 2020 in the following bands: 700MHz, 800MHz, 2.3 GHz, 2.6 GHz and 3.5 GHz. These temporary spectrum allocations were extended to March 2021.[24] In May 2020, Vodacom launched its 5G network in three major cities in South Africa. The launch encompasses twenty live sites, with a further rollout planned to cover all of South Africa. Vodacom was temporarily given access to 50 MHz of spectrum in the 3.5 GHz spectrum as a measure taken by the South African government to fight the COVID-19 pandemic. Huawei and Rain jointly launched the first standalone 5G network in South Africa in July 2020.[25] The 5G services are currently available in Cape Town. This is the first Standalone 5G network in Africa.

Source: WPC Research, December 2020 from a range of regulator and industry sources

20 www.developingtelecoms.com/telecom-technology/wireless-networks/9797-algeria-and-mexico-plan-5g-trials.html
21 www.developingtelecoms.com/telecom-business/telecom-regulation/10080-algeria-issues-operator-fines-for-weak-4g-coverage.html
22 https://brains.global/5g-mobile-technology-coming-to-morocco-in-2022-2/
23 www.developingtelecoms.com/telecom-business/telecom-regulation/9648-paraguay-and-nigeria-in-no-hurry-to-roll-out-5g.html
24 www.commsupdate.com/articles/2020/12/01/icasa-extends-temporary-spectrum-to-march-2021-levies-fees-on-usage/
25 www.huawei.com/en/news/2020/7/rain-huawei-africa-first-standalone-5g-network.

2.2. The Economic Importance of 5G to Nigeria

2.2.1. The Nigerian Economy and Telecommunication

Economic Challenges and Potentials

Nigeria has Africa's largest population by a significant margin, estimated at 206 million in 2020.[26] It has one of world's highest population growth rates and one of the world's youngest populations with 43% below the age of 15.

Nigeria also has Africa's largest economy with 2019 GDP estimated at $US 448 billion (or $US 1.181 trillion at PPP)[27]. It has been struggling with its dependence on oil in a period of low prices and it is seeking to diversify its economy. The Nigerian government has implemented the Economic Recovery and Growth Plan (2017–2020) which emphasizes economic diversification. The World Bank notes that between 2000 and 2014 Nigeria's economy grew at an average rate of 7% per year but following falls in oil prices between 2014 and 2016 growth dropped to 2.7% in 2015 and in 2016, Nigeria experienced its first recession in 25 years with the economy contracting by 1.6%. The World Bank notes further:

> *Since 2015, economic growth remains muted. Growth averaged 1.9% in 2018 and remained stable at 2% in the first half of 2019. Domestic demand remains constrained by stagnating private consumption in the context of high inflation (11% in the first half of 2019). On the production side, growth in 2019 was primarily driven by services, particularly telecoms.*[28]

Nigeria's GDP per capita, however, is relatively low with the IMF ranking it at 138 out of 186 countries based on 2019 estimates.[29] In terms of its African counterparts, Nigeria ranks 17th out of 54 African nations included in the IMF World Economic Outlook Database[30] (see Exhibit 2.13). The key economic challenge is to encourage productivity and competitiveness in the national economy in order to generate sufficient economic growth to lift the significant proportion of its population living in poverty into higher living standards, and to generate sufficient current and future employment for the enormous younger population. In 2020, Nigeria's GDP contracted by 4.28%, largely as a result of COVID-19.[31]

26 www.statista.com/statistics/1122838/population-of-nigeria/
27 https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=NG
28 World Bank, www.worldbank.org/en/country/nigeria/overview
29 https://en.wikipedia.org/wiki/List_of_countries_by_GDP_(nominal)_per_capita
30 IMF, www.imf.org/en/publications/weo
31 https://data.imf.org/?sk=5778f645-51fb-4f37-a775-b8fecd6bc69b

Exhibit 2.13: Top 20 African nations ranked by GDP per capita

African rank (2017)	World rank (2017)	GDP (PPP) per capita (2017)[1]	Nation	GDP from agriculture (%)	GDP from industry (%)	GDP from services (%)
1	37	34,865	Equatorial Guinea	2.5	56.5	45
2	47	28,712	Seychelles	2.5	13.8	83.7
3	61	21,628	Mauritius	4	21.8	74.2
4	67	19,266	Gabon	4.5	44	51.5
5	71	18,146	Botswana	1.7	29.2	69.1
6	84	15,150	Algeria	13.2	36.1	50.7
7	89	13,403	South Africa	2.8	29.7	74.2
8	92	12,994	Egypt	11.9	33.1	55.7
9	100	11,987	Tunisia	10	25.9	63.5
10	102	11,528	Namibia	6.6	25.8	67.6
11	106	9,882	Eswatini (Swaziland)	6.5	45	48.6
12	108	9,792	Libya	1.3	63.8	34.9
13	115	8,612	Morocco	14.8	29.1	56
14	124	6,942	Cape Verde	7.9	17.9	74.2
15	126	6,813	Angola	10.2	61.4	28.4
16	127	6,707	Republic of the Congo	8.9	50.8	40.3
17	129	5,927	Nigeria	21.6	18.3	60.1
18	137	4,605	Ghana	18.3	24.5	57.2
19	138	4,580	Sudan	39.6	2.6	57.8
20	139	4,474	Mauritania	22.5	37.8	39.7

Source: IMF

ICT, Broadband and Economic Growth

There exists a significant literature on the contribution of telecommunications to economic growth[32]. In recent years, growth in the ICT sector in Nigeria has been rapid with its contribution to Nigeria's GDP at 13.9% as at the end of Q3 2019.

32 see, for example:
Exploring the Relationship Between Broadband and Economic Growth, Michael Minges ictData.orghttp://pubdocs.worldbank.org/en/391452529895999/WDR16-BP-Exploring-the-Relationship-between-Broadband-and-Economic-Growth-Minges.pdf

ITU, *The economic contribution of broadband, digitization and ICT regulation*, https://www.itu.int/dms_pub/itu-d/opb/pref/D-PREF-EF.BDT_AFR-2019-PDF-E.pdf

In 2019, the ITU published *Economic Contribution of Broadband, Digitization and ICT Regulation, Econometric Modelling for Africa* which analyzed the impacts on GDP growth sequel to changes in the adoption and pricing of broadband, the digital maturity of the economy (as measured by the CAF's Digital Ecosystem Development Index[33]) and the quality of telecommunications regulation (as measured by the ITU Regulatory Tracker).

Exhibit 2.14 illustrates the effects that broadband, digitization and regulation on African countries. Research globally has shown that in less developed countries, increases in mobile broadband adoption have a greater impact on GDP growth than increases in fixed broadband adoption while the reverse is true in more developed countries. With Africa's economies being less developed, this effect is apparent with a 10% increase in fixed broadband increasing GDP by 0.3%, and the same increase in mobile broadband adoption increasing GDP by a much larger 2.5%.

Exhibit 2.14: The quantitative impacts of broadband, digitization and regulation on GDP growth

Source: ITU

Also, the Exhibit indicates that a 10% drop in broadband prices increases adoption by 2.3% in the case of fixed broadband but 3.1% in the case of mobile broadband. Increases in digitization also have a substantial impact on GDP growth per capita with a 10% increase in the CAF Digital Ecosystem Development Index generating a 1.9% increase in GDP per capita.

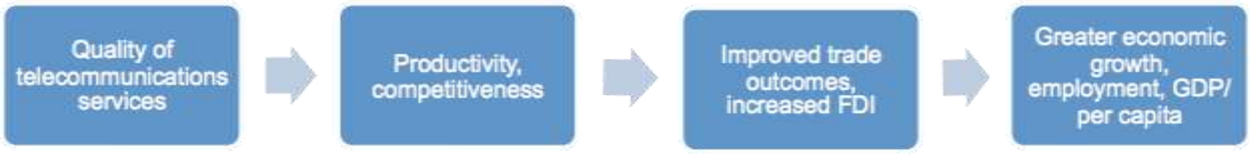
33 www.caf.com/app_tic/#es/home

Increased broadband adoption affects almost all economic activity.

Given that digitization, broadband adoption and pricing have positive impacts on GDP and GDP per capita growth, it is important to understand the mechanisms of operation. Broadband is what economists call a 'general purpose technology'. This means it affects almost all industries in the economy because its potential use is widespread. Broadband and associated digitization processes enable many activities to be automated or semi-automated and enables all costs associated with communication and coordination to be substantially lowered.

This results in increased productivity which makes national economies more competitive by increasing their exports or enabling domestic production and making economies more attractive to foreign direct investment (Exhibit 2.15).

Exhibit 2.15: Communications driving economic development.



Source: Windsor Place Consulting

The broader significance of broadband and digitalization the Nigerian economy is not only its capacity to increase productivity across all industries but also its potential to enable the process of digital disruption to create new business opportunities for Nigerian entrepreneurs and existing Nigerian business.

These digital opportunities do not need to be large-scale digital enterprises or start-ups. Rather, better telecommunications infrastructure and services coupled with better and more widely adopted digital devices, enable individuals and small organizations to create productive opportunities to be self-employed and start small businesses. This might be something as simple as a group of intermediaries been able to better coordinate agricultural production, distribution and sales because they now have access to cheaper more reliable voice telephony services. These capabilities can then quickly evolve using mobile apps and web applications to increase efficiency in particular geographic regions or across sectors nationwide.

The general nature of the economic challenge to the Nigerian economy could be described as how to optimize a range of growth drivers and how to remove impediments to economic growth. Viewing the ICT sector as an important growth driver leads to the more specific question of how telecommunications infrastructure services and skills can be improved in a manner that leads to the greatest growth dividend.

Cost-effective communications infrastructure and services

Optimizing the contribution of telecommunications and ICT generally requires evaluating the cost benefit characteristics of a range of options to improve the quality of Nigeria's telecommunications services. What Nigeria requires is 'bang for buck' in telecommunications infrastructure expenditure. Just as Southeast Asia two decades ago was able to 'leapfrog' the need to invest in fixed voice line infrastructure because of the explosion in mobile telephony, more recently emerging nations especially in Africa are finding that various forms of wireless broadband offer an extremely cost-effective means by which broadband can be made more widely available and affordable.

Most recent generations of mobile technology, 4G LTE and 5G, offer very high performance and speed while spectrum in the 600 to 800 MHz range offers extremely favorable range and coverage characteristics. Together, these drivers offer a rapid and cost-effective pathway to better broad band access.

It should be emphasized that broadband over 5G offers such high-performance that considerable discussion is now occurring about whether this means that various forms of fixed broadband are now, in effect, obsolete. Such discussions tend to position fixed and wireless broadband as substitutes when in fact they are more like complements. In some situations fixed wireless would generate the greatest net economic benefits and in other situations wireless. The dynamic aspects of this decision also need to be considered. In some situations wireless broadband will constitute an excellent intermediate solution while in the longer term fixed broadband solutions would need to be deployed.

In addition, this emphasis on wireless broadband does not mean that fiber infrastructure types can be ignored. Wireless broadband access points are ideally supplied by adequate fiber infrastructure. This combination of fiber backbone and backhaul with wireless access constitutes both a means to deliver broadband quickly and cheaply but it also offers an incremental or evolutionary path to eventual availability of fixed fiber broadband. As regions using wireless broadband develop and become more sophisticated and valuable broadband users, fiber infrastructure can be extended from these points onto less populated areas and more developed areas can be more densely provisioned with fiber connections.

The 5G deployment decision and economic benefits

Governments around the world are currently making decisions on the extent to which they could facilitate 5G deployments. The pace of 5G rollouts is gathering with 320 operators in 103 countries investing in 5G network deployments, trial implementations and license acquisitions by October 2019.[34]

What should inform the decision of Government on the pace of 5G deployment? What approach is best for national interest: support for a fast 5G rollout or more of a 'wait and see' approach?

[34] GSA, 5G Networks and Devices: a Global Snapshot, October 2019

Essentially, these are economic questions which depict a cost benefit problem that involves long analysis periods (at least 10 years) given the commercial life of the investments required, and pervasive economy wide impacts.

Factors such as population size and distribution, rates of economic growth, the quality and extent of existing infrastructure, access to capital for investment, etc, exert important influences on the national economic payoff from deploying new communications technologies. Therefore, it is important that Nigeria prioritizes roll-out of 5G networks as a means to consolidate the economic growth it is currently experiencing, to aid its post COVID-19 recovery and to lay the foundations for ongoing economic development and improvements in living standards for all Nigerians.

The factors influencing economic growth are many, including natural resource endowment, human capital, access to capital markets and cultural factors. In multiple studies[35] the positive influence on economic growth of telecommunications infrastructure, mobile telephony adoption and broadband penetration is described above.

The ITU concludes that for both developed and developing countries and regions, the higher penetration of broadband, the more important is its contribution to economic growth[36]. Various studies cited by ITU reach conclusions such as:

- a 10% increase in broadband penetration is associated with 3.6% increase in efficiency (46 US States during the period 2001-2005);
- a 10% increase in broadband penetration raises per-capita GDP growth by 0.9-1.5 percentage points (25 OECD countries between 1996 and 2007); and
- a 10 % increase in broadband penetration yielded an additional 1.38 percentage points in GDP growth (120 low- and middle-income countries 1980-2002).

These studies, and many others, indicate the significant positive economic impacts of increased broadband penetration. The prospect that 5G networks will generate similar positive economic outcomes is very likely in Nigeria.

2.2.2. Industrial Revolution 4.0 and the Economic Benefits of 5G

The term 'Industrial Revolution 4.0' refers to the enormous potential economic significance of a set of emerging Internet-related technologies, taken together, represent a revolutionary era of rapid productivity improvement, competitiveness and robust economic development. 5G is a centerpiece in the Industrial Revolution 4.0 vision complementing other technologies such as: cloud computing; artificial intelligence and machine learning; IoT; automation and robotics.

35 ITU, *The Impact of Broadband on the Economy: Research to Date and Policy Issues*, *Op cit and ITU,* The economic contribution of broadband, digitization and ICT regulation, 2018. See www.itu.int/en/ITU-D/Regulatory-Market/Documents/FINAL_1d_18-00513_Broadband-and- Digital-Transformation-E.pdf

36 *ibid*

It is important to note that, in the Industrial Revolution 4.0 vision, key applications such as autonomous vehicles and location independent access to data are predicated on wireless rather than fixed connectivity.

In South Korea, KT Economic Management Research of the Government's 5G+ Strategy carried out an analysis on industry verticals in April 2019. It indicates that in 10 industry verticals – namely vehicles, manufacturing, healthcare, transportation, security and safety, media, energy, logistics, financial services – and four surrounding environments – smart city, smart office, smart home, rural areas – will roughly equate to an economic benefit of USD 40.1 billion by 2030 which equates to 2.08 percent of GDP in 2030 (see Exhibit 2.16).[37]

Exhibit 2.16: South Korea 5G economic impact estimation

Year	5G Beneficial Impact (estimated in billion USD)		GDP Ratio (estimated)
2025	Total	25.4	1.51%
	Industry	21.2	
	Environment	4.2	
2030	Total	40.1	2.08%
	Industry	35.6	
	Environment	4.5	

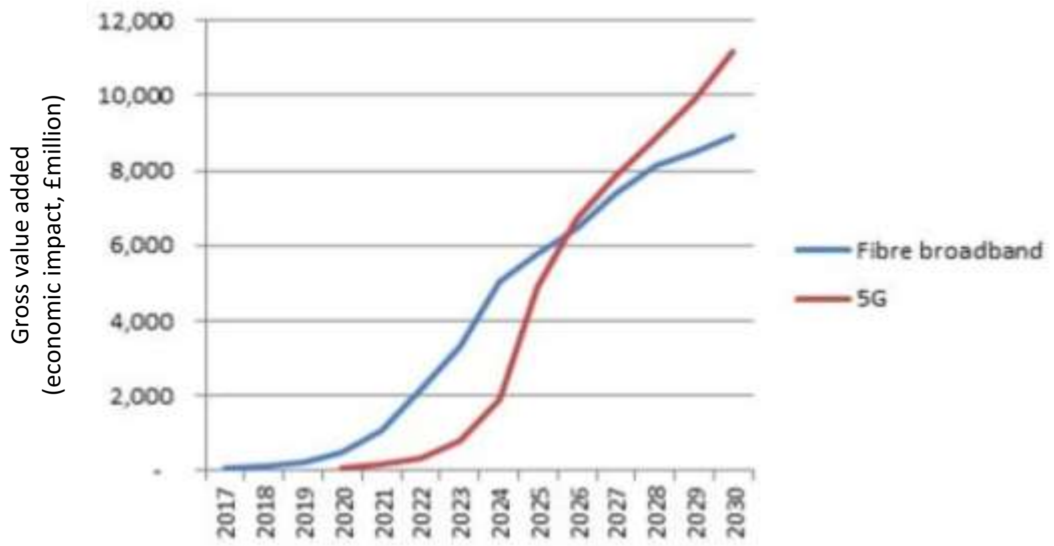
Source: KT Economic Management Research (USD1=KRW1190.5)

A 2017 UK study[38] predicted that the economic benefits created by 5G broadband would overtake those created by fixed line fiber broadband in the UK by 2026 (see Exhibit 2.17) .

[37] Broadband Commission for Sustainable Development, *The State of Broadband: Broadband as a Foundation of Sustainable Development,* September 2019, page 109. Available at www.itu.int/dms_pub/itu-s/opb/pol/S-POL-BROADBAND.20-2019-PDF-E.pdf

[38] *UK 5G infrastructure to outstrip economic benefits of fiber broadband by 2026*. Available at https://news.o2.co.uk/press-release/uk-5g-infrastructure-outstrip-economic-benefits-fibre-broadband-2026/

Exhibit 2.17: 5G and Fibre broadband, forecast gross value added (economic impact, £million)



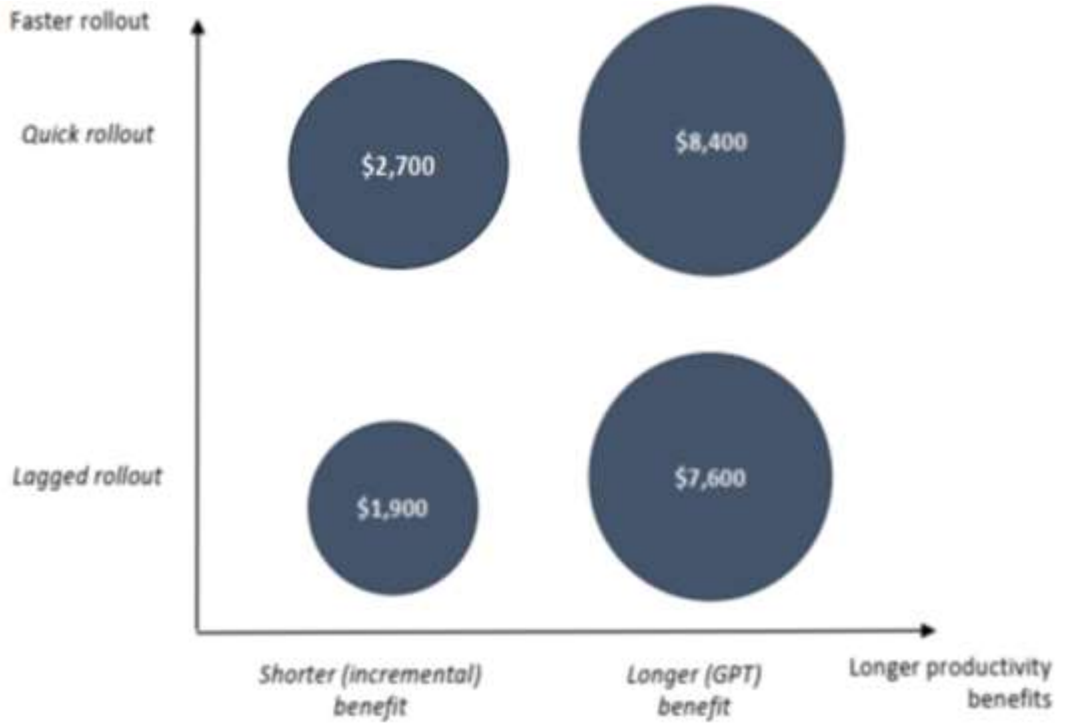
A 2018 paper[39] from the Australian Department of Communications and the Arts focuses on the potential impacts of 5G deployments on productivity economic growth. This paper explicitly explores the medium and long-term impacts on GDP growth of fast and slow 5G deployment. The two hypothetical scenarios that were modelled were 'fast rollout' (all investment in one year) and 'lagged rollout' (rollout over 8 years, at low levels in the initial years building to maximum by year 6). Based on this evidence, it estimated 5G could provide an additional AUD1, 300 to AUD2, 000 in GDP per person after the first decade of the rollout. The study also found that "*The sooner 5G networks are deployed, the sooner these economic opportunities are likely to be realized."*[40]

Exhibit 2.18 illustrates the shorter-term (2030) and longer-term (2050) impact on GDP per capita that arise from faster 5G rollout in Australia.

39 Australian Bureau of Communications and Arts Research, Department of Communications and the Arts, *Impacts of 5G on productivity and economic growth*, April 2018, working paper.

40 Australian Government, Department of Communications and the Arts, House of Representatives Standing Committee on Communications and the Arts: Inquiry into the deployment, adoption and application of 5G in Australia, November 2019, page 4. Available at www.aph.gov.au/Parliamentary_Business/Committees/House/Communications/5G/Submissions

Exhibit 2.18: Impacts of rollout speed of 5G's productivity benefit, real GDP per capita in 2050



At a global level, 2017 report[41] by IHS Economics/IHS Technology argues that 5G will propel mobile communications to the level of a 'General Purpose Technology' (GPT). GPTs are pervasive and revolutionary technologies such as the steam engine and electricity and impact the productivity of every sector. IHS forecast that by 2035 "5G will enable USD12.3 trillion of global economic output". Thus, forecasters agreed that 5G represents a significant if not unprecedented economic opportunity. It is seen by many as the central technology enabling a new generation of high productivity applications associated with the concept of Industrial Revolution 4.0 (see Exhibit 2.19).

41 IHS Economics & IHS Technology (2017), The 5G Economy: How 5G Technology Will Contribute to the Global Economy, January 2017

Exhibit 2.19: 5G use case mapping

	Power Networks and Energy Savings	IoT/ IoMT Sensors	Ultra-High Definition Camera	RFID/ Indoor location	Tactile Internet	Remote Monitoring & Remote Control	Connected Vehicles/ Connected Ambulance	Drone surveillance/ Drone usage	Artificial Intelligence & Data Analytics	Cloud Services/ Blockchain	Robotics & Automation	Augmented Reality/ Virtual Reality
Agriculture	X	X				X	X	O	X		X	X
Banking and Finance		X	X	X					X	O		X
Digital Healthcare		X	X		X	X	O		O			X
Education		X							X	X		O
Manufacturing and Process Industries	X	X	X	X	X	X		X	O	X	X	X
Oil and Gas	X	X	O			X		X	X	X	X	X
Retail and Services	X	X	X	X				X		O		X
Smart City	X	X	O	X		X	X	X	X	X		X
Smart Transportation		X				X	O	X	X			X

Legend:
X: Potential application
O: High potential application – used as example

Source: MCMC, Public Consultation, National 5G Taskforce Findings and Recommendations to Government, 14 August 2019, Page 8-9.

However, these perspectives are generic in nature even if they have been identified within Nigeria. What are the indicators that 5G will create economic benefits in Nigeria specifically?

2.2.3. The Nigerian Context and Economic Benefits of 5G Deployment

Governments and telecommunication operators must make choices on what extent to support 5G deployments based on each unique national context and conditions. Generally speaking, telecommunications carriers will pursue more or less strictly commercial goals, whereas governments will be seeking a balance between economic benefits that contribute to growth in GDP, GDP per capita and social objectives such as improving access to services for the lower class and less privileged groups.

Governments can influence the infrastructure deployment decisions of commercial operators and, in cases where operators are wholly or partially government owned, can directly influence these decisions. Both operators and governments have an interest in deploying types of infrastructure that will lead to better economic and social outcomes because this is in the commercial interest of operators and promotes the national interest.

As we have seen in the discussion above, economic studies from around the globe indicate that the economic benefits of wireless broadband deployments exceed those of fixed deployments in developing countries. Such a conclusion does not, however, mean that it would be optimal for Nigeria to focus on wireless deployment only. In almost all situations, some mixture of wired and wireless deployment will be optimal. The challenge is to determine what the optimal mix of infrastructure is in any particular national context.

Next, we consider economic conditions in Nigeria and how these impact on the potential benefits arising from accelerated 5G deployment.

Strong economic growth and good potential for further growth

Nigeria has significant potential for rapid economic growth. It has very strong demographic drivers in the form of a very young population with large numbers of up-and-coming workers entering the most productive period of their working lives. The benefits of growth are cumulative and compounding, and maximizing current growth rates early implies greater likelihood of improved living standards sooner rather than later. The earlier 5G is deployed, the greater will be the net present value (NPV) of economic benefits.

Attracting direct foreign investment

Foreign firms considering opening offices, manufacturing plants or other investments in Nigeria will be more likely to do so if telecommunication services are of a high quality and reliability. Generally, all foreign investors are sensitive to the quality of technology because they understand that high-quality telecommunications lower costs and improve competitiveness.

Currently congested mobile communications

In Nigeria where mobile services are currently experiencing congestion, material improvements to those services will unleash significant economic benefits. Congestion indicates excess demand and inadequate supply. It also indicates that the quality of telecommunication services are likely limiting business growth and economic development.

Dynamic urban centers driving economic development

In dense urban centers, it is critical to minimize economic losses due to congestion. Sequel to the demonstrated importance of telecommunication services to economic development, it is particularly important that in Nigeria’s urban areas – especially Lagos with a broader metropolitan population of over 20 million persons – businesses and citizens should have access to high-speed reliable broadband services. 5G permits Nigeria’s key urban areas to become smart cities, with smart grids etc. Enterprises within those urban areas and beyond seeking commercial advantage will adopt 5G technologies if they are made available.

Under-developed fixed line infrastructure and significant barriers to rapid deployment of fixed line infrastructure

Nigerian fixed line infrastructure is relatively under-developed and the cost of deploying better fixed line infrastructure is high while the timelines are relatively long. 5G and 4G offer a way to improve overall telecommunication services with FWA rapidly at reasonable cost. Not only does this make Nigerian businesses more competitive, it also offers a way to bring high-speed broadband services to high-rise residential buildings in Nigerian cities.

Suitable 5G spectrum can be accessed in Nigeria

5G works best if harmonized spectrum is allocated in larger contiguous blocks. In some countries spectrum in bands useful for 5G are already committed for satellite services meaning that the costs of making spectrum available for 5G deployments is relatively high. This is not the case in Nigeria as the country has significant blocks of spectrum highly suitable for 5G deployment which can be accessed or re-farmed for use.

2.2.4. The Right Mix of Wireless and Fixed Broadband Infrastructure Deployment

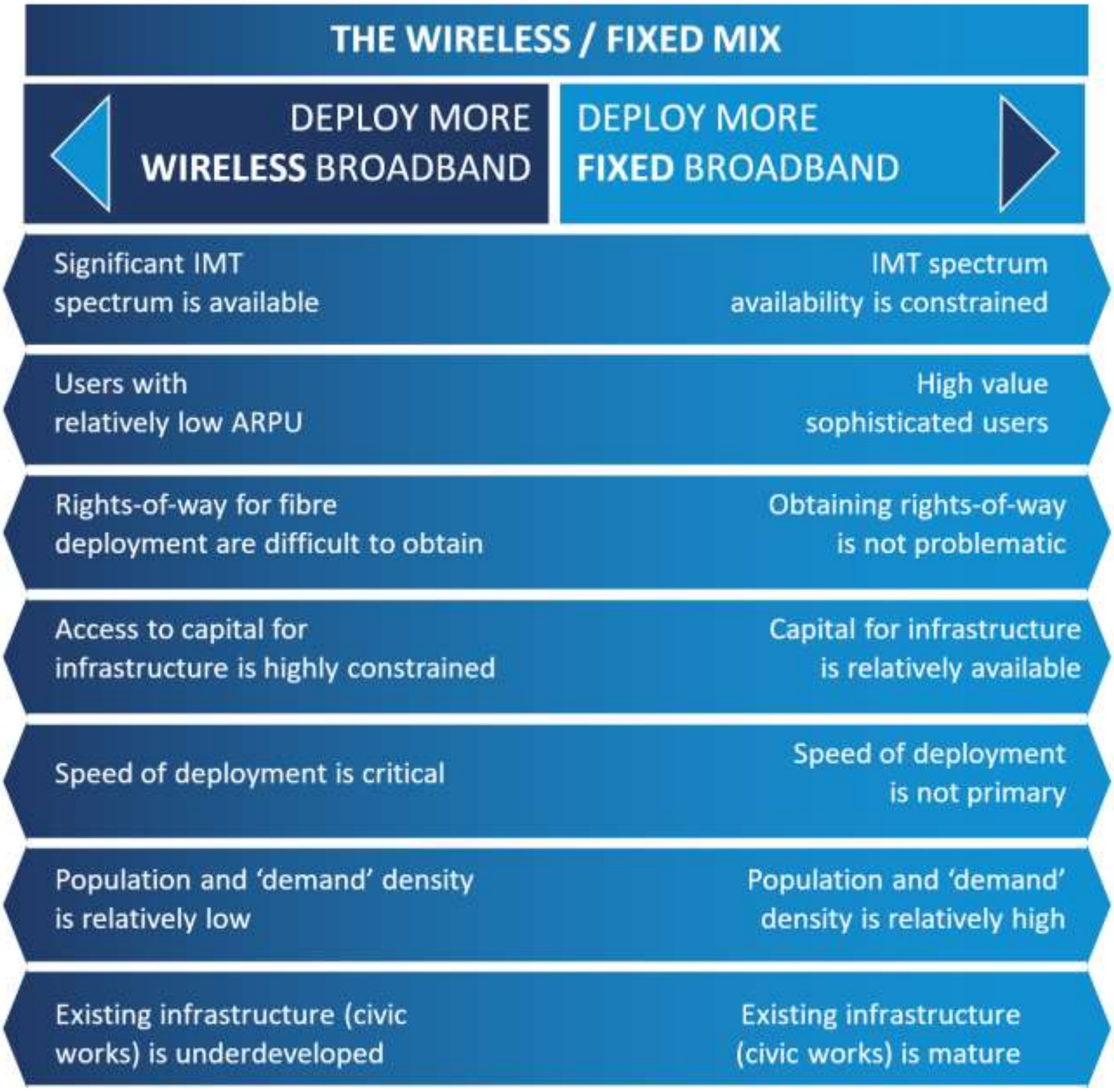
The previous section discussed considerations influencing the decision to deploy fixed or wireless broadband infrastructure. Again, it is emphasized that in every case some mixture of fixed infrastructure and wireless infrastructure will be optimal for the deployment of broadband services. An inescapable reason for this is that fixed infrastructure is required at the backbone level and for access to mobile infrastructure.

Even if fixed access broadband is broadly preferred, there will inevitably be situations at the periphery of the fixed network where economics falls strongly on the side of wireless broadband deployment. Since a mix of fixed and wireless deployment always yields optimal benefits, the key consideration is then to determine what type of broadband infrastructure to deploy where and when.

Exhibit 2.20 illustrates the factors that influence the choice to deploy either wireless or fixed broadband infrastructure. It should be emphasized that none of these considerations are definitive in isolation. Rather, the more a group of factors indicate either wireless or fixed deployment, the more likely it the choice of deployments will be in the interest of the market and the national economy, and will generate the greatest benefits for end telecommunications users.

For example, if we are considering an environment where spectrum was available, ARPUs were low, ROW were difficult to obtain and speed of deployment was critical, then the choice would fairly and obviously be to deploy wireless infrastructure.

Exhibit 2.20: Visualising factors influencing the wireless / fixed broadband access infrastructure deployment decision



Source: Windsor Place Consulting, 2020

2.2.5. Quantifying the Economic Benefits of 5G Deployment in Nigeria

A systematic estimate of the national economic benefits of 5G deployment in Nigeria is beyond the scope of this Report. However, it is possible to provide indicative estimates on the basis of the studies described above in this section. Nigeria's 2019 GDP is estimated at USD447 billion or USD1.181 trillion on a purchasing power parity (PPP) basis.

The South Korean study undertaken by KT Economic Management Research which mentioned earlier, estimated that by 2025, 5G deployments would add 1.51% to South Korean GDP or 2.08% by 2030. This shows the estimated impacts on Nigerian GDP from 5G deployments using the estimated impacts from the South Korean study. By 2025, Nigeria's 5G deployments could add USD6.7 billion per year to nominal GDP or USD17.8 billion at PPP. By 2030, the respective figures are USD9.3 billion nominal or USD24.6 billion PPP.

These increments to GDP are *annual*, implying that in every year following 5G deployment, GDP is higher than it would otherwise be. Furthermore, these increases are *cumulative and compounding*. In the long term, the economic benefits are very substantial.

Obviously, such high-level indicative calculations need to be treated with a significant degree of caution. An important factor is that South Korea has extensive fixed broadband infrastructure. On this basis, it is likely that 5G deployments will have a *greater relative impact* on the Nigerian economy than on that of South Korea. Also, the research findings are in support of the idea that wireless broadband deployments would have a relatively larger impact on Nigeria's economy than that of South Korea because wireless deployments tend to have a large impact on GDP in developing economies than in developed economies. See Exhibit 2.21.

Exhibit 2.21: Applying 5G economic impacts from South Korean figures to Nigeria in estimating impact on GDP and GDP PPP by 2025 and 2030

	US$ billion	INCREASE in GDP by 2025 US$ billion	INCREASE in GDP by 2030 (US$ billion)
2019 GDP nominal	447		
2019 GDP PPP (US$ billion)	1,181		
1.51% increase to GDP by 2025		6.7 (17.8 PPP)	
2.08% increase to GDP by 2030			9.3 (24.6 PPP)

2.2.6. Why 5G is Economically Important to Nigeria

The Nigerian economy exhibits multiple characteristics which strongly suggest that 5G deployment will generate significant economic benefits. It faces ongoing service quality challenges in wireless telephony and broadband services. It has relatively undeveloped fixed line infrastructure, and presently faces significant opportunities for economic growth. All these indices suggest that the benefits from early 5G deployments would be significant.

In addition, it is important to note that 5G deployment offers a stepping-stone in an incremental development path that includes future deployments of fixed line infrastructure. Deployment of 5G will entail additional fiber to 5G base stations and this can provide a solid platform for future fiber-to-the-premises deployments while delivering high quality broadband over 5G using FWA services earlier than would otherwise be possible.

These considerations suggest that Nigeria can harness significant economic benefits from deploying 5G early. In effect, almost all indications are that Nigeria is very well positioned to benefit from 5G deployment and this would have an impact on the Nigerian economy that is likely to be even more positive than similar deployments in regional peer nations.

3.0. METHODOLOGY

The study objectives clearly suggest that an optimal approach is needed in securing 5G for Nigeria. Therefore, the approved study methodology was devised to achieve a quality and realistic approach to 5G deployment taking into account possible Nigerian challenges.

3.1. Research Methodology and Work Plan

Our method focused on establishing peculiar 5G requirements, identifying the gaps in availability of the requirements and proffering means to satisfying these requirements efficiently in Nigeria. These requirements include technical, regulatory, policy and investment demands which will guarantee a timely and successful deployment while ensuring that the key benefits of 5G are optimally harnessed for the various use cases.

Therefore, it was investigative and analytic, and involved the following:

- Obtaining relevant information on 5G policies, regulation and economics including global and regional developments in 5G;
- African and global case studies related to 5G deployments;
- Consultations with selected local 5G stakeholders and field surveys using meetings, visitations, questionnaires and studying press releases/publication from official websites towards identifying and validating possible challenges;
- Identifying best approaches to ensure optimal socio-economic benefits of 5G technology in line with key study objectives;
- Benchmarking and gap analysis of 5G drivers with respect to international best practices and the situation in Nigeria;
- Modelling recommendations to address the identified challenges and deficiencies towards enhancing timely and responsive 5G deployment that would guarantee the scenarios depicted by the study objectives.

The 5G ecosystem[42] comprises of consumer devices and network equipment. Typical 5G consumer devices include 5G smartphones, FWA, MiFi and IoT devices. In the ecosystem, the roles of the OEMs, operators and providers include the provision of 5G radio networks, core and transmission networks, and international capacity requirements. On the other hand, policy and regulatory roles of the government include duties and taxes, harmonized spectrum and EMF best practices, reasonable ROW charges and deployment rules. Government roles also include facilitating access to power, cloud IT infrastructure, submarine cables and high throughput satellites.

Therefore, in order to identify deficiencies and barriers, it was important to engage selected local stakeholders that are connected to the ecosystem.

[42] www.3gpp.org/release-15

Exhibit 3.1 outlines the approved list of relevant stakeholders by the NCC for sampling and consultations within the telecom and vertical sectors. Selection was based on the key study elements and 5G use cases.

Exhibit 3.1: Selected Shareholders for Consultations in Nigeria

Telecommunication Policy and Regulation	
1	Ministry of Communication & Digital Economy (Departments: NFMC; Spectrum Management; Telecom & Postal Services)
2	NCC (Departments: Spectrum Administration; TSNI; Special Duties; PCEA; Licensing & Authorization)
3	National Broadcasting Commission
Network Equipment Vendors	
4	Huawei
5	Nokia
Mobile Network Operators and Associated Stakeholders' Organization	
6	MTN
7	Glo
8	Airtel
9	9 Mobile
10	NATCOM (Ntel)
11	Association of Telecom Companies of Nigeria
Base Stations and Tower Providers (Passive Network Operators)	
11	IHS
12	ATC Nigeria
International Capacity of Cloud Infrastructure Providers	
13	NATCOM (SAT-3)
14	MainOne (Cable; MDX-i)
15	Rack Centre Limited
Fiber (FTTx) Networks	
16	Backbone Connectivity Networks
17	Suburban Limited
Vertical Sector Regulators and Stakeholders	
18	Nigerian Electricity Regulatory Commission
19	Department of Petroleum Resources
20	Exxon Mobil
21	Total E&P
22	Agip
23	Manufacturers Association of Nigeria
24	Defence Headquarters of Nigeria
25	Nigerian Police Force
26	Nigerian Airspace Management Agency
27	Nigerian Communication Satellite

Taxation and Investment	
28	Federal Inland Revenue Service
29	Nigerian Investment Promotion Council
EMF Issues	
30	Ministry of Health
31	Ministry of Environment
32	National Environmental Standards and Regulations Enforcement Agency
33	The Senate
34	The House of Representatives

Procedural tasks were created and grouped into phases that led to the actualization of the deliverables. The phases are outlined as follows in accordance with the stipulated project duration of 6 months:

<u>Phase 1</u>

- Kick off and inception procedures to establish the key elements and working practices
- Timeline: Kick-off+4 weeks
- Deliverable: Inception report

The tasks in this phase included:

Task 1: Familiarization with the Department of Research and Development

Task 2: Preliminary studies, developing a project plan and a draft report structure

Task 3: Inception meeting which discussed working practices and consultant's action plan and confirmed the project scope

Task 4: Preparation and submission of inception report in accordance with project report format

<u>Phase 2</u>

Global aspects of the study which included trends and developments, economics, spectrum and network requirements, and EMF issues associated with 5G technology

- Timeline: Kick-off+12 weeks
- Deliverable: Progress report

The phase involved desk and field researching on a global perspective. It consisted of the following tasks:

Task 5: Investigating and analysing global and African developments in terms of 5G use cases, deployment scenarios and trials

Task 6: Study of the global economy in relation to 5G technology with emphasis on deployment approaches and economic benefits, and quantifying economic values in Nigeria

Task 7: Choosing the right mix of wireless and fixed broadband infrastructure deployment

Task 8: Assessments of key spectrum bands for 5G, suitable licensing options, and scenario development for band re-planning

Task 9: Examining the Nigerian spectrum regulatory framework to determine an optimal approach to 5G spectrum allocation, pricing, trading and infrastructure in Nigeria

Task 10: Investigating and analysing global approaches to 5G EMF regulatory practices

Task 11: Developing questionnaires for engaging the stakeholders in Nigeria towards obtaining relevant information on 5G drivers; and obtaining Departmental approval

Task 12: Preparation and submission of progress report on findings and results from this phase

Phase 3

- Local aspects of the study involving stakeholders' consultation, identifying deficiencies in 5G drivers, and modelling the optimal approaches to 5G deployment
- Timeline: Kick-off+20 weeks
- Deliverable: Draft report

The phase determined how the scenarios depicted by the study objectives could be met, and what needed to be done with regards to the policies, regulation and industrial practices that impact on 5G deployment.

These included optimal spectrum management, accessibility and availability of sites and towers, improving fiber backhaul connectivity and international transmission capacity, and tackling EMF concerns. This phase incorporated the findings from engagement of stakeholders in establishing the best approach to satisfying 5G spectrum, digital transmission and passive infrastructure requirements.

Phase 3 included the following tasks:

Task 13: Consultations with stakeholders on 5G drivers through visitations, meetings, the use of questionnaires and obtaining information from official websites

Task 1: Analysing findings and results of local field research on study elements in relation to international best practices and ITU regulations

Task 15: Modelling and justifying recommendations to addressing deficiencies and regressive practices

Task 16: Developing an executive summary and compiling all findings, analyses, justifications and recommendations arising from the study into a draft report

Task 17: Draft report preparation and submission

<u>Phase 4</u>

- Compilation of the final report including a publishable executive summary
- Timeline: Kick-off +24 weeks
- Deliverable: Final report containing a publishable executive summary

Task 18: The purpose of this task was to respond to observations on the draft report and to compile the work in the required format.

4.0. RESULTS AND FINDINGS

This chapter reports the various results, findings and analyses arising from investigations, examinations and consultations on research elements representing 5G drivers, aimed at devising and ascertaining suitable approaches to achieving the scenarios depicted by the study objectives.

Objective One: to investigate and provide possible solutions to some of the key challenges in the deployment of 5G cellular networks
Key Findings:

4.1. Overview of 5G Spectrum Bands

5G requires contiguous and sufficient spectrum across multiple layers of spectrum which are classified low, mid, mmWave bands to meet demands of the 5G use cases. It also requires timely access to suitable spectrum to address coverage and capacity objectives of MNOs and possibly private enterprises in key sectors such as manufacturing, oil & gas.

The 3GPP has frozen the specification for 5G new radio (NR). Section 4.2 provides the list of bands for 5G NR utilization (see Exhibit 4.1 and Exhibit 4.2). According to 3GPP Release 16, these frequency bands are designated for different frequency ranges (FR) and current specification (Release) defines them as FR1 (450 to 6000 MHz) and FR2 (24,250 to 52,600 MHz). Apart from FR, NR bands can be classified into three into categories: [43]

I. Frequency Division Duplex Bands (FDD);
II. Time Division Duplex Bands (TDD); and
III. Supplementary Bands: Downlink Supplement Bands and Uplink Supplement Bands.

The 3GPP has also agreed on a number of LTE-NR sharing combinations where the UL direction of some low frequency bands (e.g. 700, 800, 900, 1800 and 2100 MHz) are paired with the 3300-3800 MHz band.

Exhibit 4.1: 5G NR Frequency Range below 6 GHz (bands in red are currently in use in Nigeria)

NR FR1 Band	Band Alias	Uplink (UL) Operating Band BS Receive / UE Transmit F_{UL_low} – F_{UL_high}	Downlink (DL) Operating Band BS Transmit / UE Receive F_{DL_low} – F_{DL_high}	Bandwidth	Duplex Mode
n1	2100	1920– 1980 MHz	2110– 2170 MHz	60 MHz	FDD
n2	1900 PCS	1850– 1910 MHz	1930– 1990 MHz	60 MHz	FDD
n3	1800	1710– 1785 MHz	1805– 1880 MHz	75 MHz	FDD

43 Furthermore, it should be noted that depending on the Subcarrier Spacing (SCS) in use, the typical supported channel bandwidths are up to a maximum of 40 MHz for FDD configurations in 5 MHz increments including the 1800 MHz band (n3), 2100 MHz (n1) and 2600 MHz (n7) which have a maximum of 50 MHz while TDD configurations are up to 100 MHz which is more usable for 5G services. For example, the maximum channel bandwidth for 2.3 GHz (n40), 2.6 GHz (n41) and 3.5 GHz (n78) is 100 MHz. For the 1.5 GHz (n50) band, the maximum is 80 MHz.

n5	850	824– 849 MHz	869– 894 MHz	25 MHz	FDD
n7	2600	2500– 2570 MHz	2620– 2690 MHz	70 MHz	FDD
n8	900	880– 915 MHz	925– 960 MHz	35 MHz	FDD
n12	700a	699 - 716 MHz	729 -746 MHz	17 MHz	FDD
n14	700 PS	758 - 768 MHz	788 - 798 MHz	10 MHz	FDD
n20	800	832– 862 MHz	791– 821 MHz	30 MHz	FDD
n25	1900+	1850 - 1915 MHz	1930 -1995 MHz	65 MHz	FDD
n26	850+	859 – 894 MHz	814 – 849 MHz	35 MHz	FDD
n28	700 APT	703– 748 MHz	758– 803 MHz	45 MHz	FDD
n29	700 d	717 – 728 MHz	N/A	11 MHz	SDL
n30	2600 WCS	2350 – 2360 MHz	2305 – 2315 MHz	10 MHz	FDD
n34	TD 2000	N/A	2010 - 2025 MHz	15 MHz	TDD
n38	TD 2600	2570– 2620 MHz	2570– 2620 MHz	50 MHz	TDD
n39	TD 1900+	N/A	1880 – 1920 MHz	40 MHz	TDD
n40	TD 2300	2300 – 2400 MHz	2300 – 2400 MHz	100 MHz	TDD
n41	TD 2600+	2496– 2690 MHz	2496– 2690 MHz	194 MHz	TDD
n50	TD 1500+	1432– 1517 MHz	1432– 1517 MHz	85 MHz	TDD
n51	TD 1500-	1427– 1432 MHz	1427– 1432 MHz	5 MHz	TDD
n53	TD 2500	2483.5 – 2495 MHz	N/A	11.5 MHz	TDD
n65	2100+	2110-2200 MHz	1920-2010 MHz	90 MHz	FDD
n66	AWS-3	1710– 1780 MHz	2110– 2200 MHz	70/90 MHz	FDD
n70	AWS-4	1695– 1710 MHz	1995– 2020 MHz	15/25 MHz	FDD
n71	600	663– 698 MHz	617– 652 MHz	35 MHz	FDD
n74	L-Band	1427– 1470 MHz	1475– 1518 MHz	43 MHz	FDD
n75	DL 1500+	N/A	1432– 1517 MHz	85 MHz	SDL
n76	DL 1500-	N/A	1427– 1432 MHz	5 MHz	SDL
n77	TD 3700	3300– 4200 MHz	3300– 4200 MHz	900 MHz	TDD
n78	TD 3500	3300– 3800 MHz	3300– 3800 MHz	500 MHz	TDD
n79	TD 4500	4400– 5000 MHz	4400– 5000 MHz	600 MHz	TDD
n80	UL 1800	1710– 1785 MHz	N/A	75 MHz	SUL
n81	UL 900	880– 915 MHz	N/A	35 MHz	SUL
n82	UL 800	832– 862 MHz	N/A	30 MHz	SUL
n83	UL 700	703– 748 MHz	N/A	45 MHz	SUL
n84	UL 2100	1920– 1980 MHz	N/A	60 MHz	SUL
n86	UL 1800	1710 – 1780 MHz	N/A	70 MHz	SUL
n89	UL 850	N/A	824 – 849 MHz	25 MHz	SUL
n90	TD 2600+	2496 – 2690 MHz	N/A	194 MHz	TDD
n91	FD1500-	1427 – 1432 MHz	832 – 862 MHz	5/30 MHz	FDD
n92	FD 1500+	1432 – 1517 MHz	832 – 862 MHz	85/30 MHz	FDD
n93	FD1500-	1427 – 1432 MHz	880 – 915 MHz	5/35 MHz	FDD
n94	FD 1500+	1432 – 1517 MHz	880 – 915 MHz	85/35 MHz	FDD
n95	UL 2000	N/A	2010 - 2025 MHz	15 MHz	SUL
n96	TD 6500	5925 – 7125 MHz	N/A	1200 MHz	TDD

Source: 3GPP and www.sqimway.com/nr_band.php . Updated to 24 November 2020.

It should also be noted NR has introduced a new notation for band which starts with “n” e.g. Band 20 is noted as n20 where in LTE it was termed as B20.

Exhibit 4.2: 5G NR Frequency Range above 24 GHz (bands in red are currently in use in Nigeria)

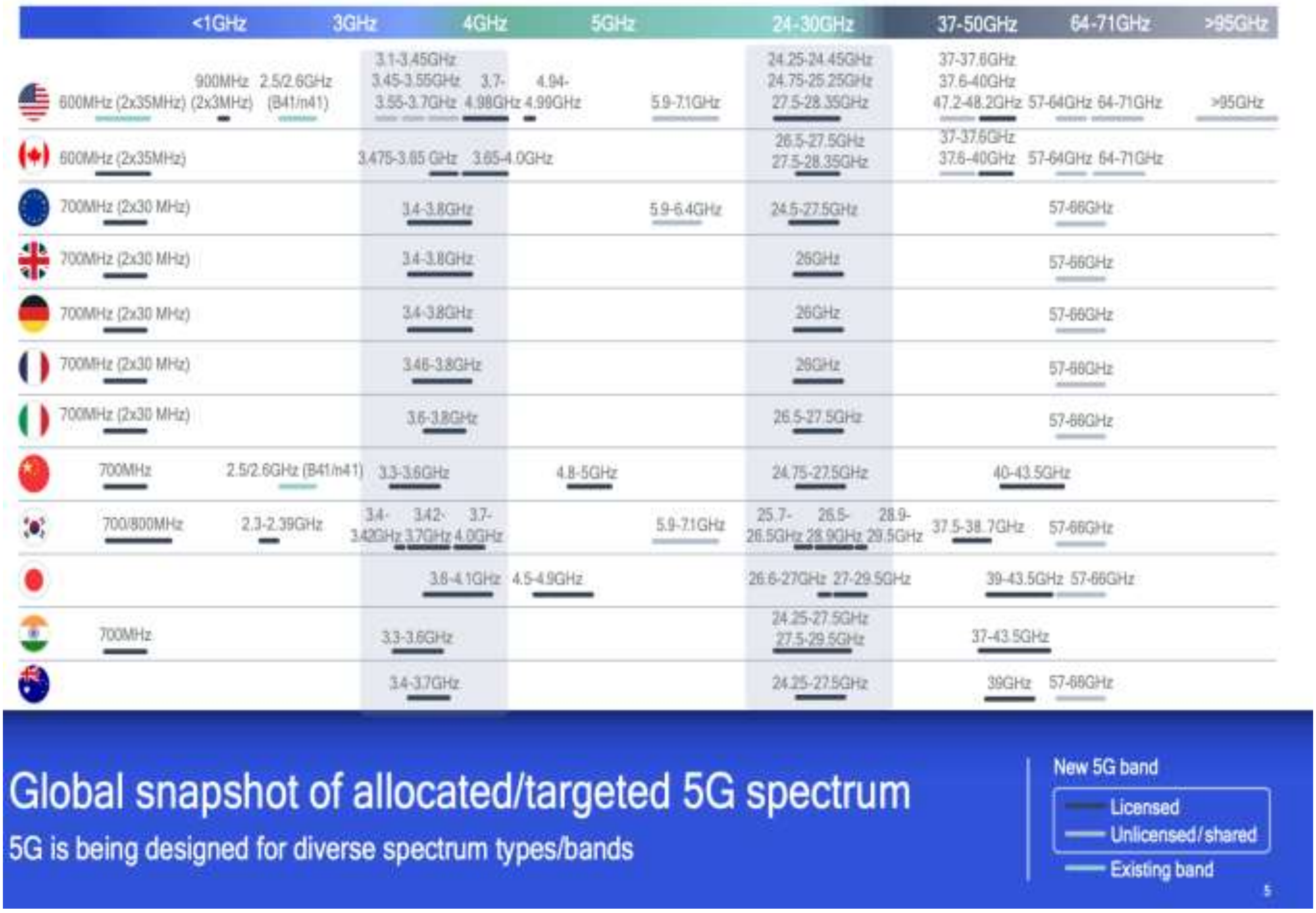
NR FR2 Band	Band Alias	Uplink (UL) Operating Band BS Receive / UE Transmit F_{UL_low} – F_{UL_high}	Downlink (DL) Operating Band BS Transmit / UE Receive F_{DL_low} – F_{DL_high}	Bandwidth	Duplex Mode
n257	28 GHz	26500– 29500 MHz	26500 – 29500 MHz	3000 MHz	TDD
n258	26 GHz	24250– 27500 MHz	24250.1 – 27500 MHz	3249.9 MHz	TDD
n259	41 GHz	39500 – 43500 MHz	39500 – 43500 MHz	4000 MHz	TDD
n260	39 GHz	37000– 40000 MHz	37000 – 40000 MHz	3000 MHz	TDD
n261	28 GHz	27500 – 28350 MHz	27500 – 28350 MHz	850 MHz	TDD

Source: 3GPP. Updated to 24 November 2020

The key global 5G spectrum bands are summarized in Exhibit 4.3. The key pioneer 5G bands are in 3.4 to 3.8 GHz band and 24 to 28 GHz for the mmWave. In time, many legacy IMT bands will be converted to 5G use. It should be noted that in addition to these global spectrum bands, the following observations apply in regional terms:

I. the USA is supporting 600 MHz and 2.6 GHz bands for 5G;
II. the EU supports the lower APT700 duplex and 26 GHz band for 5G;
III. globally the 4.7 GHz band (n79) is gaining considerable support following their allocation in China and Japan; and
IV. while China has endorsed 2.6 GHz with large allocation to China Mobile of 160 MHz, and it's new fourth 5G licensee, China Broadcasting Networks will deploy 5G in the 700 MHz and 4.8 GHz bands.

Exhibit 4.3: Key 5G Bands



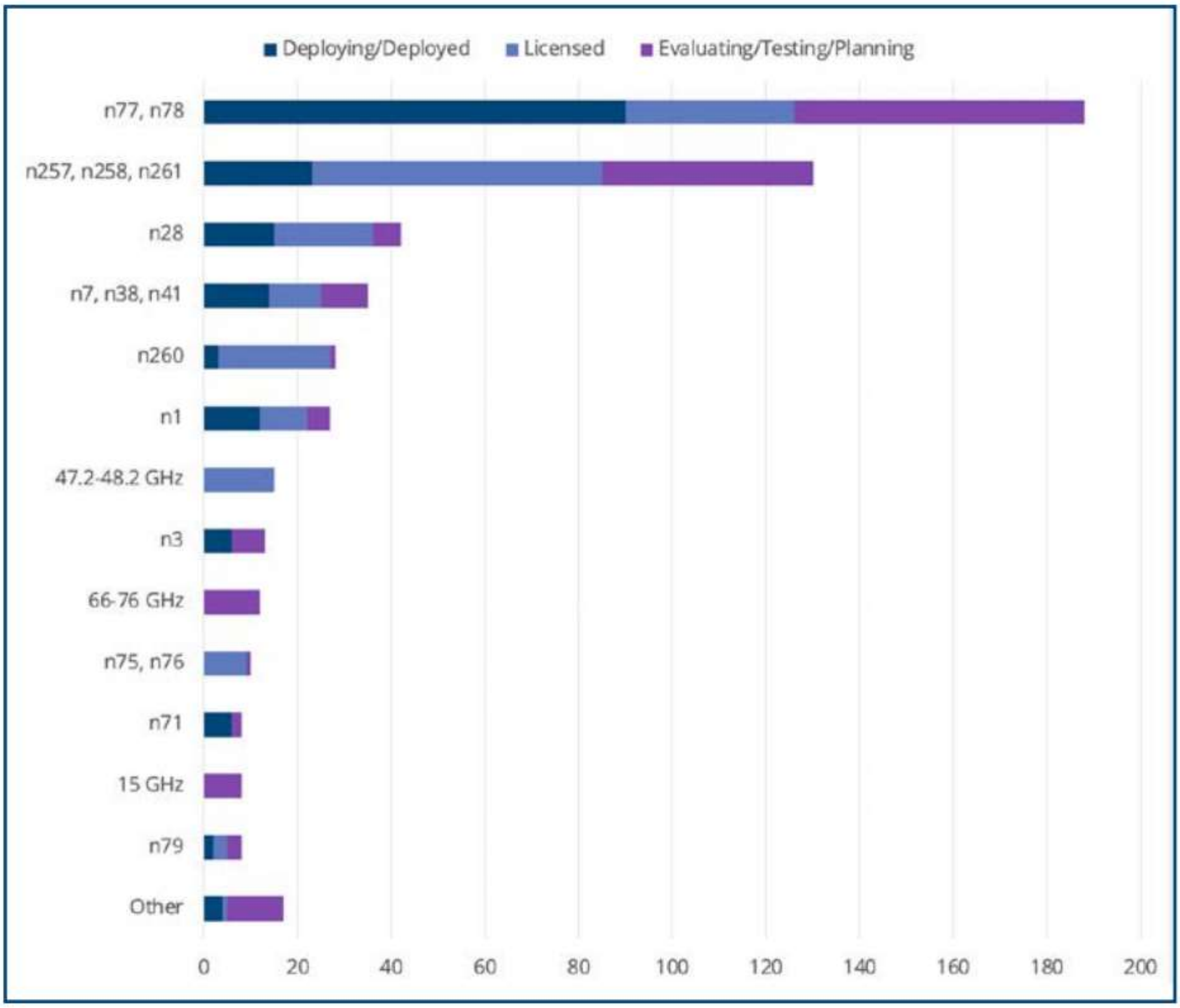
Source: Qualcomm, *Spectrum for 4G and 5G*, September 2020

4.2. Assessment of Key 5G Bands in Nigeria

Presently, global 5G deployments are mainly occurring in a few key spectrum bands. As at October 2020, the GSA had identified 188 operators investing in the C-Band (specifically the overlapping bands n77 and n78).[44] 90 of those operators are identified as deploying networks in the 3.5 GHz band (ie Bands n77 or n78). 130 operators have been identified by the GSA as investing in mmWave 5G deployments within 24.25-29.5 GHz (Bands n257, n258 or n261). The most popular 5G spectrum bands for 5G network deployments are shown in Exhibit 4.4.

[44] GSA, *5G Spectrum Snapshot,* October 2020

Exhibit 4.4: Global 5G deployments by spectrum bands October 2020



Source: GSA, 5G Spectrum Snapshot, October 2020, Page 1

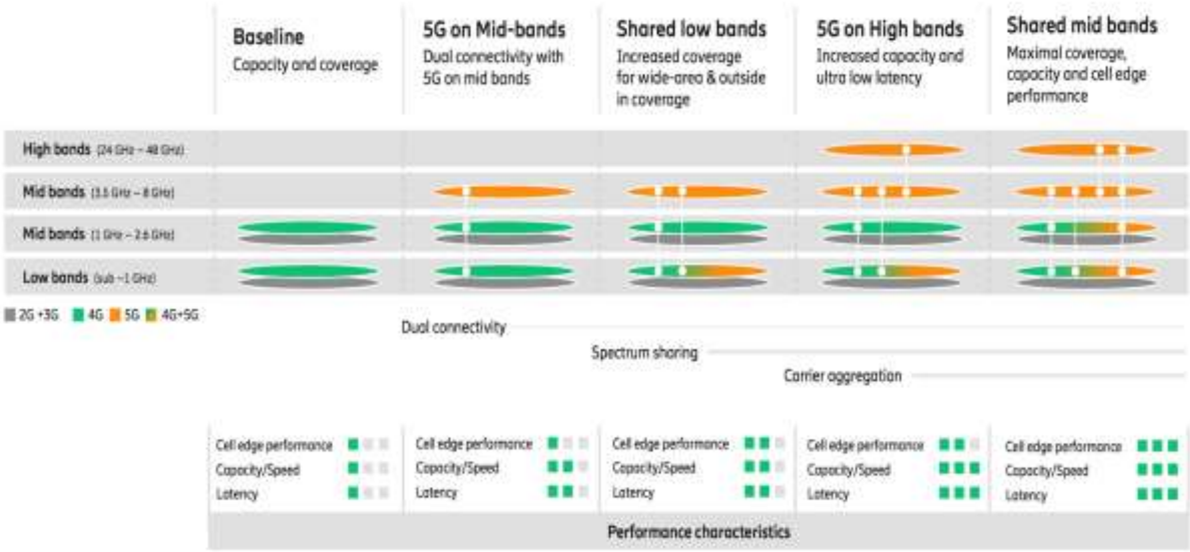
Any assessment of the key bands for 5G in Nigeria also needs to acknowledge the following:

I. that ideally, an MNO will require low band (up to 1 GHz) spectrum, mid-band spectrum (1-6 GHz) and high-band (>6 GHz) IMT spectrum as part of its spectrum portfolio and;

II. that over time, legacy IMT bands including *inter alia* 1800 MHz (n3) 2100 MHz (n1) and 2600 MHz (n7) would be used for 5G services subject to any technical and regulatory considerations.

As shown in Exhibit 4.5, there are a number of different strategies which can be adopted by MNOs depending on their view on demand, current traffic patterns, current IMT spectrum holdings etc. Considering how 5G coverage and capacity can be provided to Nigerian consumers should be a key factor in the NCC's release of additional spectrum bands.

Exhibit 4.5: 5G Spectrum Strategy



Source: Ericsson, 2018[45]

With these considerations, this Report assessed the following spectrum bands for 5G services in Nigeria, namely:

I. 3.5 GHz band (n77/78);
II. mmWave (26/28 GHz) (n257/258/261)
III. 700 MHz (n28);
IV. 2.1 GHz (n1);
V. 2.3 GHz (n40);
VI. 2.6 GHz (n7);
VII. L-band (n75/76); and others.

The identification of these bands also necessitated the investigation on dynamic spectrum sharing (DSS).

4.2.1. 3.5 GHz Band

The mid-band between 1 and 6 GHz is currently the focus of near-term 5G deployments globally with the 3.5 GHz band (namely n77/78) being the most globally supported band. Due to its propagation characteristics and the potential for large contiguous bandwidths, the 3.5 GHz band is an ideal frequency band for 5G as it is able to provide both capacity (data bandwidth) and coverage (propagation distance).

45 Ericsson, *5G Deployment considerations*, 2018. Available at www.ericsson.com/4a5daa/assets/local/networks/documents/5g-deployment-considerations.pdf

High-speed wireless broadband services should be capable of delivering peak download speeds of at least 20 Gbps, a reliable 100 Mbps user experience data rate in urban areas, and 4 ms latency. The 3.5 GHz band is therefore key to delivering eMBB and enabling good 5G service performance. Over the last 36 months, many national regulators globally have either assigned the 3.5 GHz band spectrum for mobile (IMT) services or have started preparations to do so (see Exhibit 4.6). There is also a rapidly growing ecosystem of 5G devices, setting the stage for successful network deployments and consumer adoption globally.

Exhibit 4.6: Global status of 3.5 GHz band allocations (as at December 2020)

Assignment Completed	Planned/Under consultation
Ireland (May 2017)	Greece (end-2020)
Czechia (July 2017)	Ukraine (2020)
Slovakia (October 2017)	Sweden (Nov 2020- delayed)
UK 3.4 GHz (April 2018)	Estonia (2021)
South Korea (June 2018)	India (2021)
Spain (July 2018)	Croatia (H1, 2021)
Latvia (September 2018)	Belgium (2021)
Lesotho (October 2018)	Romania (2021)
Finland (October 2018)	Montenegro (2021)
Italy (October 2018)	UK 3.6-3.8 GHz (January 2021)
UAE (November 2018)	Chile (February 2021)
Oman (December 2018)	Denmark (March 2021)
Australia (December 2018)	Norway 3.6 GHz (from 2021)
Qatar (January 2019)	Brazil (first half-2021)
Switzerland (February 2019)	Canada (June 2021)
Saudi Arabia (March 2019)	Poland (August 2021)
Austria (March 2019)	Myanmar (2021)
Japan (April 2019)	Mexico (2021)
Germany (June 2019)	Uzbekistan (2021)
Mexico 3.5 GHz (October 2019)	Netherlands (2022)
Hong Kong (October 2019)	
Taiwan (December 2019)	
China (February 2020)	
Singapore (April 2020)	
South Africa (April 2020 - temporary)	
New Zealand (May 2020)	
Hungary (March 2020)	
Luxembourg (3.6 GHz only) (July 2020)	
United States (August 2020)	
France (October 2020)	
Croatia (November 2020)	

Source: GSMA, August 2019 as updated by WPC, December 2020

The 3.5 GHz band (3.3 – 3.8 GHz)[46] should therefore be a core spectrum band for 5G deployment in Nigeria. It is also important to highlight that the 3GPP has also agreed on a number of LTE-NR sharing combinations where the upload direction of some low frequency legacy bands (e.g. 700,

46 In 3GPP terms it is n77/78. See 5G NR Band below 6 GHz (Exhibit above).

800, 900, 1800 and 2100 MHz) are paired with the 3.3 – 3.8 GHz band. Deployment of such sharing combinations would be useful in the Nigerian context if existing MNO licensees are able to secure 3.5 GHz spectrum.

In Nigeria, Exhibit 4.7 details the existing 3.5 GHz band allocations which are subject to a 5 MHz channel plan. There are currently allocations from 3403 to 3512.5 MHz, with satellite services utilizing spectrum to 4200 MHz. The state owned C-band satellite transponder downlink is operating within 3540-3660 MHz frequencies.

A guard band of 27.5 MHz between IMT and satellite services in Nigeria is small by comparison to some markets which may have 50 MHz such as Singapore or 100 MHz in Hong Kong, but it is consistent with the approaches of US where 20 MHz is needed and Brazil which uses 25 MHz. It is also consistent with technical Transfinite Systems study[47] for the GSMA in 2019 which concluded that an 18 MHz guard band is sufficient to mitigate co-frequency interference.

In addition, Qualcomm undertook studies that were submitted as input to the APT Wireless Group in July 2019. The studies consider a number of different scenarios and the likely separation distances or separation distances and filtering requirements for a range of different guard bands. The findings were that guard bands of 20 MHz and 41 MHz, based on the assumptions made in the studies, are feasible with minimal separation distances.

What is clear is that there is no one 'correct' answer to this issue and the solution is likely to be dependent on local conditions around the extent and nature of FSS usage in Nigeria. The sufficiency of the current guard band of 27.5 MHz should be confirmed by the NCC.

The band 3300-3400 MHz is not yet allocated in Nigeria although it is available for IMT services, given the applicable Nigerian footnotes as contained in the ITU RR Article 5. The current mobile deployments in this band are small fragments and done on a regional basis. While regional licensing is consistent with the approach in large countries in terms of geography globally (US, Australia etc), the current allocations are arguably too small for them to be useful for 5G.

47 Transfinite Systems, Report for GSMA on the mitigations required for adjacent channel compatibility between IMT and ubiquitous FSS Earth Stations in the 3.4 – 3.8 GHz frequency band, August 2019. Available at https://tslstorage.blob.core.windows.net/papers/Report_for_GSMA_on_3.4-3.8_GHz_Compatibility.pdf

Exhibit 4.7: 3.5 GHz band (3403- 3517.5 GHz) allocations in Nigeria

3500 MHz		CHANNELS CH 21- CH 43	3403- 3512.5	BANDWIDTH 109.5		DUPLEX MODE TDD
Operators		**Assignments**		**Class**	**Application**	**Status**
1	**MTN**	CH 21	3403	National		
		CH 22	3407.5			
		CH 23	3412.5			
		CH 24	3417.5			
		CH 25	3422.5			
		CH 26	3427.5			
		CH 27- 37	3432.5- 3487.5			
2	**Swift Networks**	CH 27	3432.5	Lagos Abuja Rivers		
		CH 28	3437.5			
		CH 29	3442.5			
		CH 30	3447.5			
3	**Horizon Broad-casting**	CH 27	3432.5	Kano		
		CH 28	3437.5			
		CH 29	3442.5			
		CH 30	3447.5			
		CH 31	3452.5			
		CH 22	3457.5			
4	**Wideways**	CH 30	3447.5	Enugu		
		CH 31	3452.5			
		CH 32	3457.5			
		CH 33	3462.5			
5	**Monarch**	CH 31	3452.5	Lagos Abuja Rivers		
		CH 32	3457.5			
		CH 33	3462.5			
6	**Rainbownet**	CH 33	3462.5	Abia, Anambra Ebonyi Gombe		
		CH34	3467.5	Abia, Anambra Ebonyi Enugu Gombe		
		CH 35	3472.5	Abia, Anambra Ebonyi Enugu Gombe		
		CH 36	3477.5	Abia, Anambra Ebonyi Enugu Gombe		
		CH 37	3482.5	Abia, Anambra Ebonyi Enugu Gombe		

		CH 21- CH 43	3403- 3512.5	109.5		TDD
Operators		**Assignments**		**Class**	**Application**	**Status**
7	**Torocomm**	CH 33	3462.5	Akwa Ibom		
		CH 34	3467.5			
		CH 35	3472.5			
		CH 36	3477.5			
		CH 37	3482.5			
8	**Radial Circle**	CH 33	3462.5	Bayelsa		
		CH 34	3467.5			
		CH 35	3472.5			
		CH 36	3477.5			
		CH 37	3482.5			
9	**Odua Investment**	CH 33	3462.5	Oyo		
		CH 34	3467.5			
		CH 35	3472.5			
		CH 36	3477.5			
		CH 37	3482.5			
10	**Cyberspace**	CH 34	3467.5	Lagos		
		CH 35	3472.5	Delta		
		CH 36	3477.5	Abuja		
		CH 37	3482.5			
11	**Tizetti**	CH 34	3467.5	Edo		
		CH 35	3472.5	Ogun		
		CH 36	3477.5	Rivers		
		CH 37	3482.5			
12	**Mobitel**	CH 38	3487.5	Delta		
		CH 39	3492.5			
13	**IPNX**	CH 38	3487.5	Lagos		
		CH 39	3492.5	Abuja		
		CH 40	3497.5	Rivers		
14	**Intercellular**	CH 41	3502.5	Lagos		
		CH 42	3507.5	Abuja		
		CH 43	3515.5	Rivers		

Source: NCC, 2020

As highlighted in a recent GSMA paper,[48] *"At the same time, national competition in the supply of 5G services should be ensured. ...Based on such considerations there should be* ***a minimum bandwidth of 50 – 60 MHz per network operator****. This should help ensure good quality and competitive provision of 5G services in the near term while further work to release more mid-band spectrum continues."*

In Nigeria, a 210 MHz spectrum block can be realized in the 3.5 GHz band within 3300- 3510 MHz, and can be utilized for 5G. As larger contiguous blocks are preferred in the 5G NR environment, three MNOs with 70 MHz each would be an optimal arrangement. Another alternative would be four MNOs being licensed with three of them having 50 MHz and the fourth being allocated 60 MHz. These arrangements should be subject to the synchronization and common frame structure.

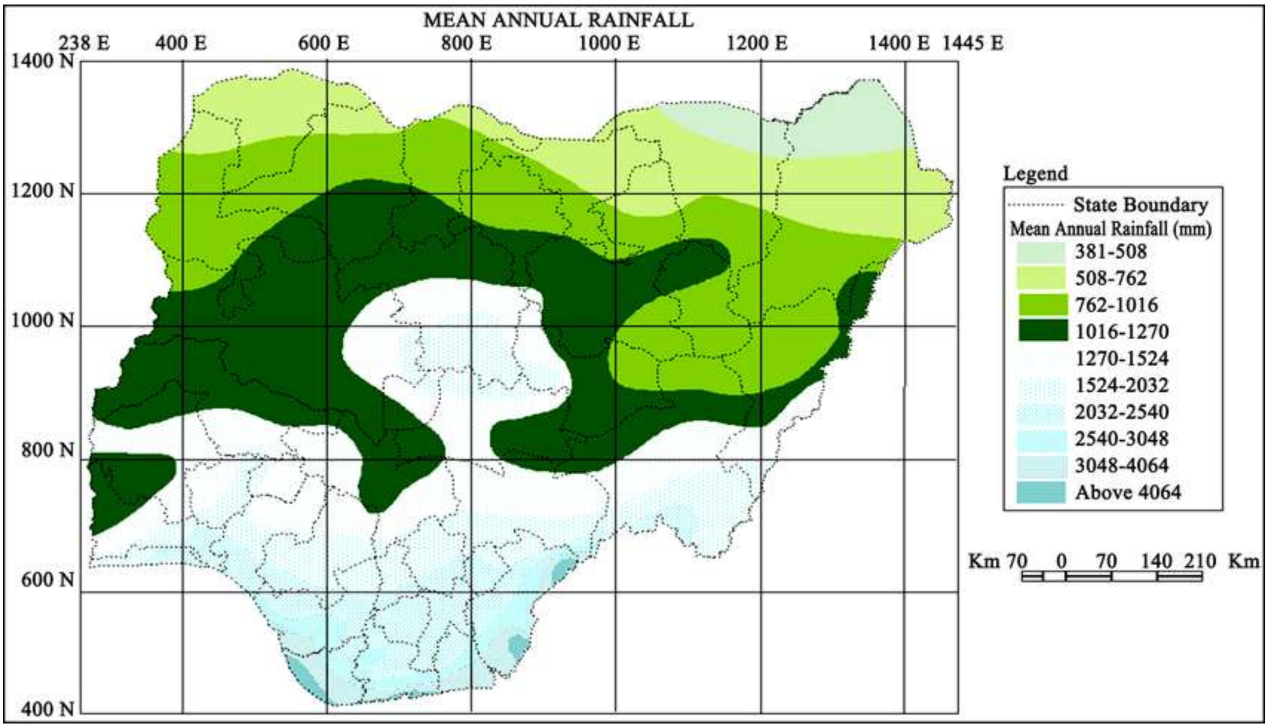
48 GSMA, *Roadmap for C-band spectrum in ASEAN*, August 2019

4.2.2. 26 and 28 GHz Bands

The 26 GHz and the 28 GHz bands, being 24.25-27.5 GHz, and 26.6 -29.5 GHz respectively and known as mmWave[49] are the second most popular bands for the delivery of 5G wireless broadband services globally.

It should be noted in markets with significant rainfall, there are serious doubts about the impact of rain attenuation even for 5G small cell sizes using mmWave spectrum given recent operator experiences and technical studies. In Nigeria, part of the country (the coastal strip) receives more than 4,000 mm of rain a year. More specifically, in the key urban markets where mmWave would be most useful, Lagos receives over 4,000 mm of average rainfall a year, while Benin City, Ibadan, Port Harcourt and Abuja receive over 2,000 mm of rainfall (see Exhibit 4.8). Only the north and western inland parts of the country have low average rainfall including Kano which receives between 500 to 600 mm of average rainfall per year.

Exhibit 4.8: Mean Annual Rainfall in Nigeria



Source: Journal of Water Resource and Protection, 2010[50]

49 mmWaves span 30 to 300 GHz (i.e. a wavelength of 1 cm to 1 mm), however, in the current 5G context, mmWave bands in consideration span from around 24 GHz up to 86 GHz

50 Ishaku and Majid, X-Raying Rainfall Pattern and Variability in Northeastern Nigeria: Impacts to Water Supply, Journal of Water Resource and Protection, 2010, 2, page 956

With this in mind, it is unlikely that mmWave spectrum for 5G will be in high demand in the Nigerian context and/or valued greatly, especially given the considerable costs of deployment (the cell sizes are small) except in relation to enterprise/private networks. Therefore, interest in these bands should be tested with the operators and broader industry with a reservation for private/enterprise use by localized licensing. It should be emphasized that this portion of spectrum has no value until an MNO or an enterprise is willing to substantially invest in it.

The current 26 GHz Band allocations in Nigeria are very limited with two national allocations each of 1008 MHz[51] to MTN Nigeria and used for 4G services. It is unclear why 1008 rather than 1000 MHz was allocated to MTN, perhaps to be consistent with 5G NR, but some adjustments could be made. Given the 3,250 MHz of spectrum which is available in this band, minimum allocations of 400 MHz to 800 MHz would seem reasonable.

From Zest's perspective, there are three broad categories of potential wireless broadband use especially with mmWave spectrum, namely:

- Type 1—traditional subscriber-based wide-area MNO or fixed network operator deployments;
- Type 2—smaller market/local subscriber-based networks; and
- Type 3— uncoordinated ad hoc deployments within the confines of private premises or property.

Globally, private or integrated networks are expected to become more popular with the increased availability of 5G equipment. Currently, in many global markets, there are operational deployments across multiple segments of the critical communications and industrial IoT industries, as well as enterprise buildings, campuses and public venues. Other industries where standalone networks have been used include manufacturing, transportation, airports, utilities, primary industries, and stadiums. The spectrum which is being reserved for such enterprise or vertical use is summarized in Exhibit 4.9.

[51] Namely, 24787-25795 MHz and 24815-25823 MHz.

Exhibit 4.9: Global snapshot of spectrum optimized for private network use (local licensing or Sharing)

Source: Qualcomm, *Transforming enterprise and industry with 5G private networks*, 15 October 2020, Page 19

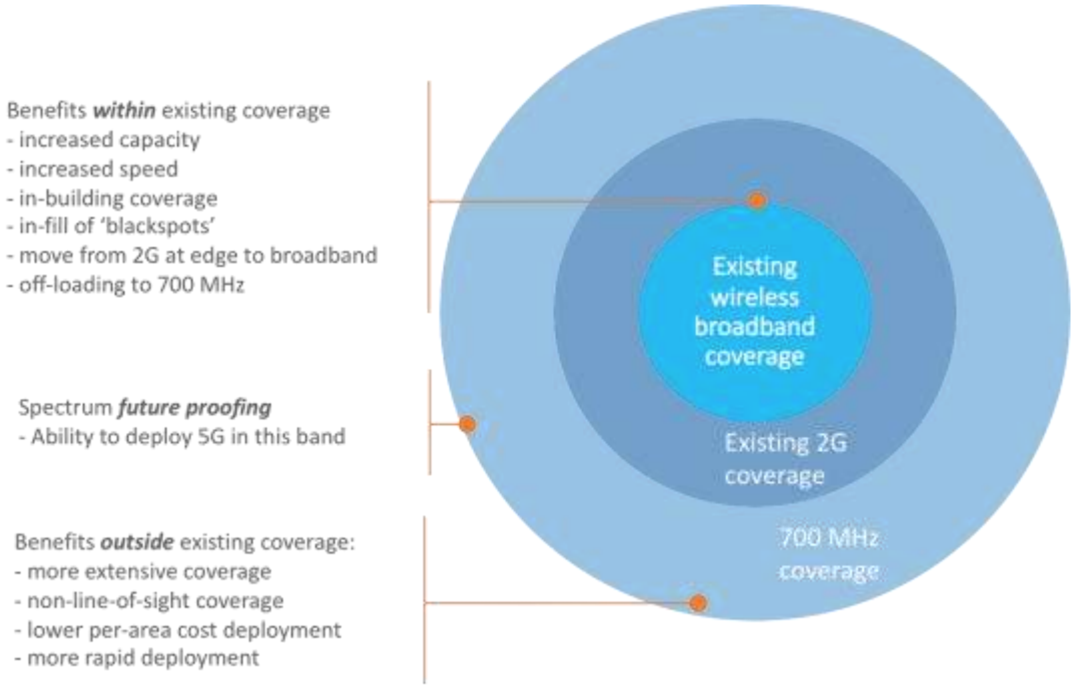
During local consultation with stakeholders, it was observed that there are plans by enterprises especially in the oil and gas sector for private 5G network deployment. Hence, there should be a reservation of some mmWave spectrum for their use (see Section 4.15 of this report for further discussions). It is noted however, that the final level of demand for such spectrum will only be likely estimated once pricing is determined.

4.2.3. 700 MHz Band

Harmonized spectrum below 1 GHz, particularly 700 MHz frequency band, is very useful. This is because the propagation characteristics of this band provide greater geographic reach or coverage and better in-building penetration relative to higher IMT bands. With greater reach, the number of cell sites needed to serve an area is significantly less compared to higher frequencies such as 1800 MHz, 2100 MHz and 3500 MHz or mmWave spectrum. (see Exhibit 4.10).

This fact, which has been well analyzed and modelled, translates to lower deployment (both capital expenditures and operating expenditures) costs for mobile operators, and hence more affordable services to Nigerian consumers. 700 MHz spectrum is particularly attractive in this role because it means that services can be provided to rural and remote communities at significantly lower capital cost, and therefore at lower ongoing operating costs.

Exhibit 4.10: Benefits of 700 MHz deployment over existing IMT spectrum bands



Source: GSMA, 2018 with updated modifications by the Windsor Place Consulting, April 2020

The other advantage is that the 700 MHz band is becoming the affordable coverage layer for future 5G services globally. This follows the December 2016 designation by the European Union (EU) of the 700 MHz as a 5G band.[52] The view from the European Commission's Radio Spectrum Policy Group in relation to 5G services in 2018 was that:

"The 700 MHz band can be used to provide wide area coverage, the 3.6 GHz band can be used to provide high capacity and coverage, using both existing macro cells and small cells. The 26 GHz band is likely to be deployed in areas with very high demand, for example transport hubs, entertainment venues, industrial or retail sites and similar."[53]

While the original plan was for all EU member states to release the 700 MHz for 5G by June 2020, this deadline was postponed in some markets due to the current COVID-19 pandemic and associated lockdowns which made planning and spectrum auctions difficult.[54] In addition to Europe, a range of other markets including China,[55] India, Thailand, and South American markets will utilize the 700 MHz band for 5G as well as 4G services.

52 See http://europa.eu/rapid/press-release_IP-16-4405_en.htm

53 EC, Radio Spectrum Policy Group, *Strategic Spectrum Roadmap towards 5G for Europe: RSPG Second Opinion on 5G networks, RSPG18-005 FINAL*, 30 January 2018.

54 See https://5gobservatory.eu/observatory-overview/5g-scoreboards/

55 2 x 40 MHz of 700 MHz spectrum was allocated by MIIT on 2 April 2020 to China Broadcasting Network (SBN) for 5G services subject to the spectrum clearance. See www.commsupdate.com/articles/2020/04/02/miit-clears-the-way-for-5g-on-700mhz-band/

It should also be noted that based on information from the GSA, the 5G device ecosystem support for the 700 MHz band (APT 700) is strong as it is the fifth most popular band.[56] It is also the most supported sub-1 GHz band, suggesting that it is currently the preferred global 5G coverage band. This emphasizes that permitting the use of 700 MHz spectrum for 5G services in Nigeria is a very progressive approach.

Exhibit 4.11: The 700 MHz band plan in Nigeria

700 MHz		UPLINK MHz	DOWNLINK MHz	BANDWIDTH	CENTRE GAP	DUPLEX MODE
		703- 733	758-788	30	25	FDD
Operators		**Uplink**	**Downlink**	**Class**	**Applications**	**Status**
1	Government	703- 713	758- 768	National	-	Not in use
2	MTN	713- 723	768- 778	National	LTE	In use
3	Glo	723- 733	778- 788	National	LTE	In use

Source: NCC, 2020

As detailed in Exhibit 4.11, only 2 spectrum licenses of 2 x 10 MHz have been currently allocated in Nigeria. Any conversion of the current LTE/4G use of the spectrum by MTN or Glo would necessarily be at the MNO's consideration. Depending on the Government's proposed use of the spectrum of the 2 x 10 MHz reserved for MCDE, this spectrum may also be available for 5G use in the future.

4.2.4. 2.1 GHz Band

2.1 GHz will also support 5G services. Currently, 2.1 GHz (n1) is the third most supported band on 5G devices even though it is only the fifth most popular network currently being deployed. As shown below approximately two-thirds of the 2.1 GHz band has been allocated (see Exhibit 4.12). Going forward, depending on demand by MNO, there would be considerable value in releasing additional 2.1 GHz spectrum for both 4G and 5G services (see the discussion below on DSS). Ideally, any new assignments to MNOs would be done on a contiguous basis (albeit this may result in a need to refarm the band). Consideration should also be made to regularize this band by making changes to current spectrum allocation to Cobranet over time.

Exhibit 4.12: 2.1 GHz band plan

Operator	Block	FDD Frequencies
MTN	A	1920-1930 MHz paired with 2110-2120 MHz (2 x 10 MHz)
Globacom	B	1930-1940 MHz paired with 2120-2130 MHz (2 x 10 MHz)
9mobile	C	1940-1950 MHz paired with 2130-2140 MHz (2 x 10 MHz)
Airtel	D	1950-1960 MHz paired with 2140-2150 MHz (2 x 10 MHz)
Vacant	E	1960-1970 MHz paired with 2150-2160 MHz (2 x 10 MHz)
Vacant (Except Lagos[57])	F	1970-1980 MHz paired with 2160-2170 MHz (2 x 10 MHz)

Source: NCC, 2020

[56] GSA, *5G Device Ecosystem Report, Executive Summary, November 2020*

[57] In Lagos, 20 MHz TDD (from 2160-2180 MHz) has been allocated to Cobranet.

4.2.5. 2.3 GHz Band

The 2.3 GHz band (n40) has recently become a 5G spectrum band and is only the 14th most popular band for 5G network deployments. This is likely to change quickly going forward because it is a large TDD band of 90 MHz with good propagation characteristics and has been be re-farmed in number of global markets for 5G. Early MNOs deploying 5G in this band include STC in Saudi Arabia and Singtel Optus in Australia. In this band, device support for 5G services is also increasing.

In Nigeria, this band is of interest as observed during the local aspect of the study. Presently, the band is not fully utilized as shown in Exhibit 4.13. It is also understood that Bitflux has only deployed its network in Lagos.

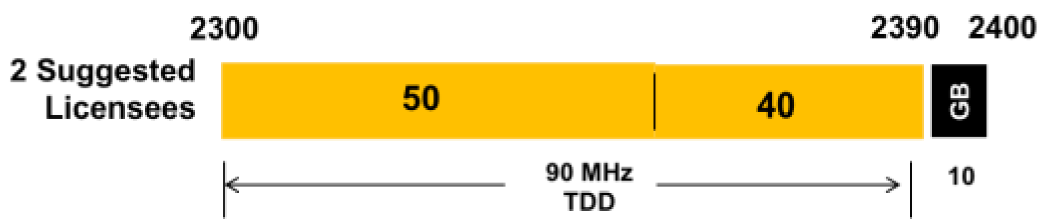
Exhibit 4.13: The 2.3 GHz band plan in Nigeria

2300 MHz		BLOCK		BANDWIDTH		DUPLEX MODE
		2300- 2400		100		TDD
Operators		Channels		Class	Applications	Status
1	Mobitel	1	2300- 2320	National		
2	Sky Broadband	2	2320- 2340	Lagos Rivers Abuja		
3	Spectranet	3	2340- 2360	National		In use
4	Bitflux	4	2360- 2390	National		In use in Lagos only
2390-2400: GUARD BAND						

Source: NCC, 2020

The key challenge with the current channels is that they are too small for a 5G deployment and integrated 4G/5G networks. Consideration should be on how the band could be re-farmed so that at a maximum, there will be two licensees who would have 50 and 40 MHz respectively (see Exhibit 4.14). Though this is not optimal from a spectrum perspective, a larger spectrum allocation will permit higher bandwidth 5G services than trying to deploy 5G say, in a 20 MHz spectrum block. It is recommended that the NCC should be open to consolidation and licensing of additional 2.3 GHz spectrum for realization of the 5G scenario depicted in Exhibit 4.14.

Exhibit 4.14: Suggested 2.3 GHz band plan for 5G services



4.2.6. 2.6 GHz Band

In Nigeria, the 2.6 GHz band has already been allocated for use. It follows European hybrid FDD/TDD band plan (ie n7/38)[58] rather than Asian, US or South African[59] preference for the TDD band plan (ie n41). The current band plan and allocations are set out in Exhibit 4.15. This hybrid band plan is not easily convertible and not as flexible as the TDD band plan (n41) for 5G deployment because it does not readily allow larger contiguous blocks of spectrum to be assigned to MNOs. Band n7 is however, the 8th most supported 5G band from a device perspective and there is growing support to use this legacy band for 5G services as it is already assigned to MNOs.

As the current allocations such as 2 x 20 MHz and smaller allocations of 2 x 10 MHz are more suitable for 4G services, there would be value in considering re-farming this band so that existing licensees could increase their holdings in this spectrum band to better provide 5G services.

Exhibit 4.15: The 2.6 GHz band plan in Nigeria

Operator	Block	FDD Frequencies	TDD Frequencies
Airtel	A1	2500-2520 MHz paired with 2620-2640 MHz (2 x 20 MHz)	n/a
MTN	A2	2520-2550 MHz paired with 2640-2670 MHz (2 x 30 MHz)	
Vacant	A3	2550-2560 MHz paired with 2670-2680 MHz (2 x 10 MHz)	
Open Skys (proposed)	C	2560-2570 MHz paired with 2680-2690 MHz (2 x 10 MHz)	
Megatech	D	n/a	2575-2615 MHz (40 MHz)

Source: NCC, 2020. (NB: There are two 5 MHz guard bands from 2570-2575 MHz and 2615-2620 MHz.)

58 More formally, the channel arrangement adopted by Nigeria (n7/n38) is C1 of the channel arrangement options detailed in ITU-R M.1036-6. The alternative channel arrangement for TDD (n41) is C3 which is adopted in China, US, Ghana, South Africa etc.

59 South Africa converted its 2.6 GHz band plan to TDD n41 in May 2020. See ICASA, *Notice of the Radio Frequency Spectrum Assignment Plan for the Frequency Band 2500 to 2690 MHz (IMT2600),* SA Government Gazette, No. 43341 of 22 May 2020.

4.2.7. L-Band and Others

At WRC-15, the entire 1.5 GHz band (1427–1518 MHz) was harmonized for IMT within ITU Regions 2 and 3, while in ITU Region 1, the 1452–1492 MHz range was identified for African and Arab states. WRC-19 agenda item 9.1.1 considered the compatibility of IMT and broadcasting-satellite service (sound) in the frequency band 1452–1492 MHz in Regions 1 and 3 as detailed in Resolution 761 (WRC-15).

In WRC-19, it was decided to retain and modify Resolution 761 (WRC-19) to define restrictions and coordination triggers on BSS (sound) in order to protect IMT. Limits on IMT emissions from IMT near country borders were also introduced. Recommendation ITU-R M.1036 was updated to include frequency arrangements for implementation of the terrestrial component of IMT in the 1.5 GHz band. This includes a footnote to indicate studies are still being conducted in accordance with Resolution 223 (Rev.WRC-15) to provide possible technical measures to facilitate adjacent band compatibility. This work is underway in Working Party 5D and may result in a revision to the frequency arrangements contained in Recommendation ITU-R M.1036.

Local consultation during the study did not indicate any interest in this band but this may change if the band is supported by device manufacturers in the future.

Due to support from markets like China and Japan, 4.9 GHz band (4.4 to 5.0 GHz; n79) has witnessed rising popularity. This band is available in Nigeria for mobile services. However, the cell sizes will be relatively small implying that the costs of deployment will be high. Going forward, other legacy IMT bands like 800 MHz(n20) and 900 MHz (n8) will also support 5G and maybe useful for 5G coverage layer deployments.

4.3. Dynamic Spectrum Sharing (DSS)

Dynamic spectrum sharing (DSS) allows MNOs to use the same spectrum bands for different radio access technologies. As at December 2020, all the major vendors – Ericsson, Huawei and Nokia - support DSS with some variations. Announced in relation to 5G in late 2019, equipment vendors have positioned it primarily as a way to help MNOs evolve their 4G networks to support 5G in the face of finite or expensive spectrum in a market.

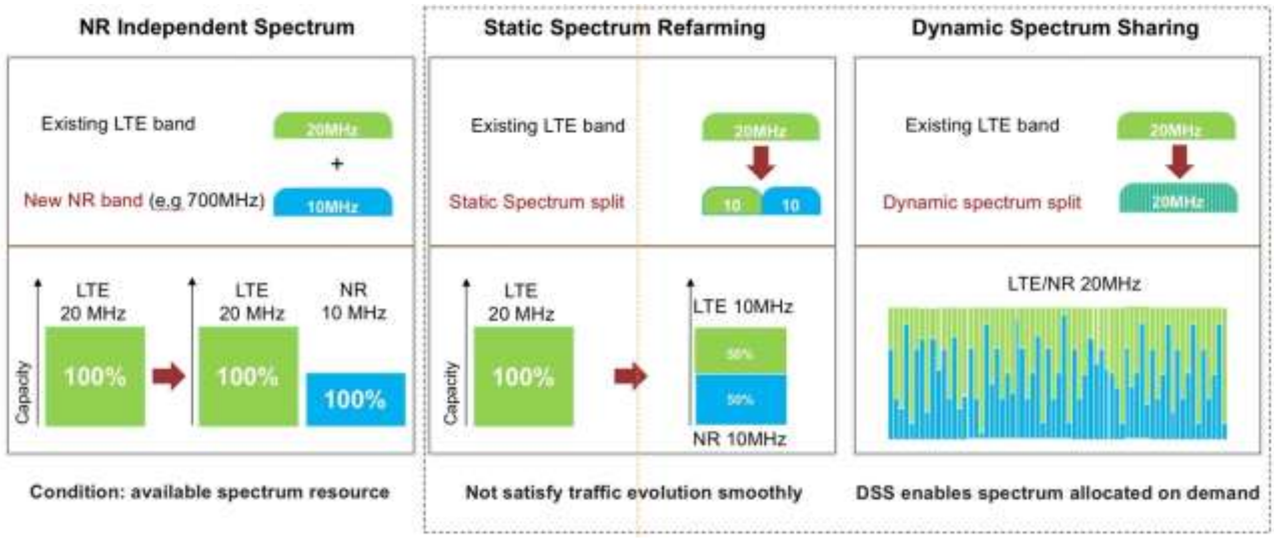
Though some MNOs will prefer from an engineering perspective, to dedicate separate frequency bands to 4G and 5G (or have amble spectrum holdings which allow them to do this), DSS allows them to share the same spectrum assignment and to 'adjust' the amount of spectrum available to each technology based on user needs that are assessed in real time and rapidly changing. [60]

DSS has particular relevance for MNOs that are deploying 5G in existing low- or mid-band spectrum (see Exhibit 4.16) in order to achieve broad coverage with 5G services while making more efficient use of their existing spectrum holdings. Some vendors support DSS for both standalone and non-

[60] Refer to www.mobileworldlive.com/huawei-updates/dynamic-spectrum-sharing-dss-an-update-on-recent-vendor-activity; www.fiercewireless.com/tech/ericsson-china-telecom-test-5g-standalone-dss-call-over-2-1-ghz and www.lightreading.com/5g/nokia-disses-dss-naysayers/d/d-id/758789

standalone networks (SA/NSA) and others for triple mode operations (2G or 3G/4G/5G). At least, Huawei will support non-standard bandwidth allocations.[61]

Exhibit 4.16: Options to deploy 5G NR (Indicative)



Source: Huawei 2020

Depending on age of the network equipment, there are options for MNOs in Nigeria to utilize DSS in order to support the early deployment of 5G services especially when their current spectrum holdings are not fully utilized under current load conditions for the available 5G devices. It is important to note that there are some disadvantages of DSS as well. Primarily, frequent use of sub frames for 5G NR takes away resources from LTE users thereby reducing LTE user throughput.[62]

61 Refer to https://finance.yahoo.com/news/huawei-releases-hybrid-dss-scenario-190000669.html
62 Refer to https://blog.viavisolutions.com/2020/08/12/dss-the-5g-deployment-x-factor/

4.4. Facilitating Synchronization and Common Frame Structure

Inter-operator and cross-border synchronization

With all TDD systems including 5G systems operating in the 3.5 GHz band, two levels of synchronization are needed. These are namely inter-operator synchronization within Nigeria and synchronization across Nigeria's borders with Cameroon, Benin, Niger and Chad.

Firstly, inter-operator synchronization within Nigeria is needed. If 5G macro-cell networks are not synchronised, arguably an additional guard band and improved filtering of transceivers would be required.[63] This would result in additional costs for Nigeria's MNOs and/or result in key 3.5 GHz band spectrum not being optimally used. Thus, synchronization of Nigeria's 5G macro-cell networks becomes the best way to avoid interference. In this way, efficient spectrum usage is ensured – no additional guard band is required – and network equipment costs can be reduced. This will assist in making 5G services more affordable in Nigeria.

This approach has been adopted in Australia, China, France, the European Union,[64] Japan and South Korea. Singapore's regulator has also announced its support for full synchronisation for the 3.5 GHz band.[65]

Secondly, with regards to synchronization across borders, there are three aspects namely clock synchronization, slot synchronization and frame structure synchronization (i.e. the same frame structure).

For clock synchronization, there are two options for the MNOs:

I. Type 1: distributed synchronisation scheme based on satellite (i.e. GPS) which is used in Japan and other countries

II. Type 2: centralised synchronisation scheme based on IEEE 1588V2 system (which is used in Europe)

It is also possible to use a combination of methods in order to improve reliability (e.g. China). If the MNOs use the same frame structure, then frame structure is synchronized.

The most difficult aspect is the slot synchronization which defines the time that each slot begins and ends. Getting neighboring countries across ECOWAS to synchronize their slots could be difficult. Thus, full synchronization across border might not be feasible even though it is the optimal condition. It is recommended that the NCC works with WATRA towards realizing full regional synchronization.

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63 GSMA, Plum Consulting and WPC, *Roadmap for C-Band spectrum in ASEAN*, August 2019, Appendix D

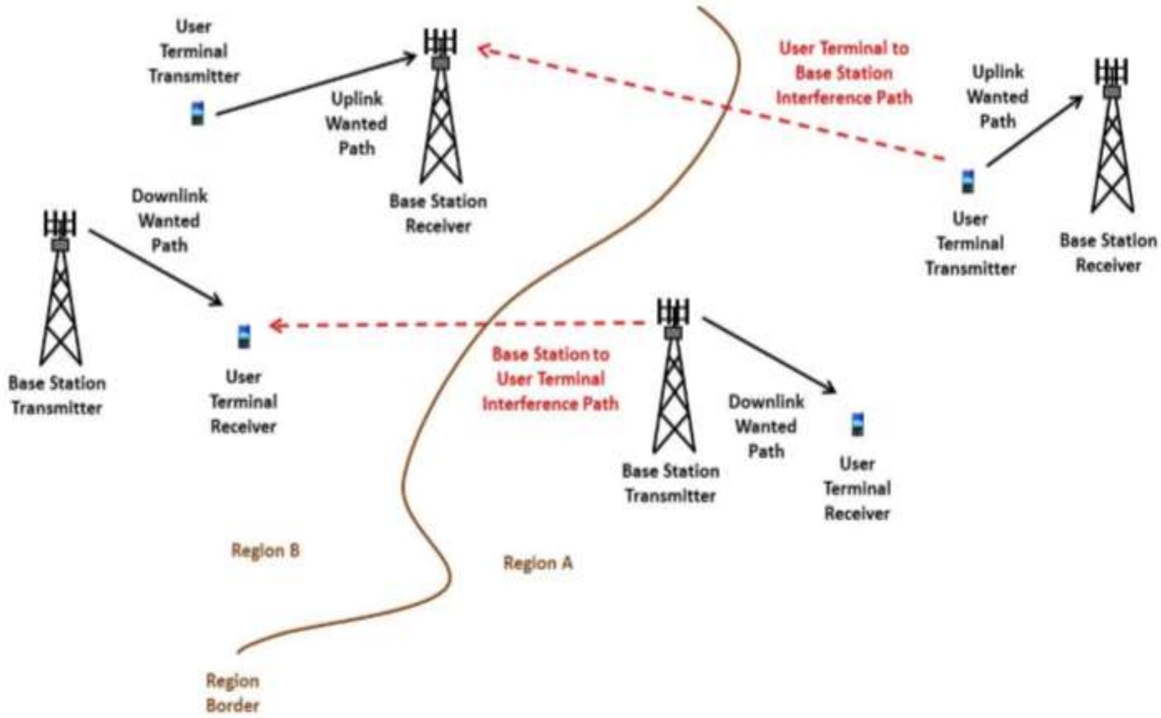
64 See ECC Report 296, *National synchronization regulatory framework options in 3400-3800 MHz: a toolbox for coexistence of MFCNs in synchronized, unsynchronized and semi-synchronized operation in 3400-3800 MHz,* Approved 8 March 2019

65 IMDA *Op cit*, paragraphs 143 and 144.

Adopting the same frame structure results in less interference and hence requires less regional coordination efforts. In Germany, the regulator, Bundesnetzagentur has set different rules including lower transmission limits for base stations for non-synchronized networks.[66]

Another approach involving synchronization of networks on either side of the border that will eliminate base station to base station interference paths and coordination threshold conditions, is driven by interference paths between base stations and user terminals as shown in Exhibit 4.17.

Exhibit 4.17: Interference from Region A (say Nigeria) into Region B when synchronised TDD networks are deployed



Source: GSMA, August 2019

Common frame structure

GSMA expects that download traffic will continue to dominate mobile data traffic in 5G networks in ECOWAS. For eMBB applications, it may go beyond 90 percent of the overall mobile data traffic. Having anticipated this scenario, the GSMA recommends only 5G macro-cell networks with a 2.5 ms

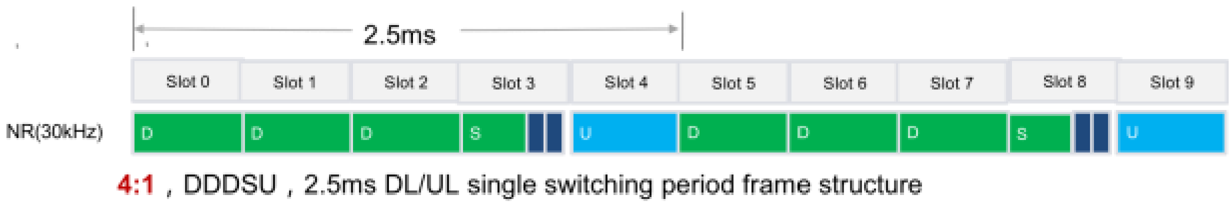
66 Decision of the President's Chamber of the Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen of 26 November 2018 on the determinations and rules in detail (award rules) and on the determinations and rules for conduct of the proceedings (auction rules) to award spectrum in the 2 GHz and 3.6 GHz bands, pages 37 and Annex 3, page 3. Courtesy translation. Available at www.bundesnetzagentur.de/SharedDocs/Downloads/EN/Areas/Telecommunications/Companies/TelecomRegulation/FrequencyManagement/ElectronicCommunicationsServices/FrequencyAward2018/20181214_Decision_III_IV.pdf

single DL/UL switching period frame structure (DDDSU) [67] in C- band for high system capacity and efficiency as shown in Exhibit 4.18.[68]

The other advantage of the 3.5 GHz spectrum band is that it facilitates future evolution of URLLC scenarios as it has a lower reduced round trip time (RTT). This view on the overwhelming direction of traffic is also strongly supported by Zest.

If further flexibility is needed, then Nigeria could do what the Swedish regulator has done provided that the frame structure will be reviewed every 5 years in order to follow technology developments.[69]

Exhibit 4.18: Recommended National Frame Structure for 3.5 GHz spectrum



The South Korean Ministry of Science, ICT and Future Planning (MSIP) in June 2018 auction of 5G spectrum, observed that synchronisation in the bands 3.5GHz and 28GHz will use the same frame structure of DDDSU as recommended here. Japan's Ministry of Internal Affairs and Communications (MIC) in relation to the 3.4-3.6 GHz band requires synchronisation between all of Japan's domestic MNOs and a 3:1 DL: UL ratio. China's MIIT is actively organising MNOs and relevant stake holders to negotiate a single frame structure for synchronisation of 5G networks in 3.5 GHz band.

In Australia, following industry consultation on 17 June 2018, [70]the then Minister of Communications on advice from ACMA, issued the *Australian Communications and Media Authority (Radiocommunications Licence Conditions—3.4 and 3.6 GHz Bands Interference Management Direction 2018*.[71] The direction also specified the adoption of a common frame structure (or equivalent in terms of duration and timing of downlink and uplink segments) if and when required to support the synchronization fall-back solution. The frame structure specified supports a 3:1 DL: UL ratio, with the arrangements taking affect from 30 March 2020.

67 Down link dominant special slot.
68 Note for 2.3 and TDD 2.6 2.6 GHz networks where there is 5G coexistence with LTE TDD network. In such circumstances, a 5 ms frame structure of 8:2 (DDDDDDDSUU) should be adopted in order to be compatible with LTE TDD network
69 See www.pts.se and http://5gobservatory.eu/wp-content/uploads/2019/10/90013-5G-Observatory-Quarterly-report-5_final.pdf
70 Refer to ACMA, 3.4 GHz and 3.6 GHz band spectrum license technical framework— Outcomes and response to submissions, August 2018
71 Available at www.legislation.gov.au/Details/F2018L01045

Similarly, in France, ARCEP published Decision n° 2019-0862 on 1 August 2019 on synchronization of terrestrial networks in the 3.4-3.8 GHz band in the country. This decision requires that terrestrial networks operating in the 3.4 to 3.8 GHz band will have to use the same synchronization frame structure from 1 July 2020.[72] Furthermore, the Singapore regulator, the IMDA announced on 17 October 2019 that it was also supportive of full synchronization stating that:[73]

> *"143. …. IMDA is inclined for the 3.5 GHz band to be fully synchronised while affording operators the flexibility on the choice of synchronization for the mmWave band. ….*
>
> *144. On the issue of synchronisation, as a start, IMDA will not mandate the synchronization approach for both the 3.5 GHz and mmWave bands. IMDA will allow operators to coordinate amongst themselves in the first instance. In the event of disputes amongst operators, IMDA may require operators to synchronise and comply with certain parameters in order to minimise interference between the networks on a case-by-case basis. Similarly, for cross-border coordination, IMDA will also facilitate coordination with our neighbouring countries on the TDD synchronization in order to avoid cross- border interference."*

In conclusion, these synchronization and frame structure issues are best addressed in the licence terms and conditions included in any 3.5 GHz spectrum licence issued by the NCC.

72 EC, 5G Observatory Quarterly Report 5, Op cit
73 IMDA Singapore, *Op cit*

4.5. Overview and International Exemplars of Policy and Regulatory Approaches to 5G Infrastructures

In addition to making key 5G spectrum available in the Nigeria, there is also a need for the NCC to enact supportive polices and regulatory approaches to facilitate the efficient and timely deployment of 5G network infrastructure and services across the country. The ITU recently identified a number of various 5G deployment challenges as shown in Exhibit 4.19.

Exhibit 4.19: 5G Deployment Challenges

Summary	For consideration
Investment case	Policymakers may consider undertaking their own independent economic case assessment of the commercial viability of deploying 5G networks
Harmonize spectrum	Regulators should allocate/assign globally harmonized 5G spectrum eg 3.5, 2.6 TDD GHz, 700 MHz
Spectrum roadmap	Regulators should adopt a spectrum roadmap and a predictable roadmap renewal process
Spectrum sharing	Regulators may consider allowing sharing to maximize efficient use of available sharing spectrum, particularly to benefit rural areas
Spectrum pricing	Regulators may consider selecting spectrum award procedures that favour investment
Sub-1 GHz spectrum	Policymakers should consider supporting the use of affordable wireless coverage (eg through the 700 bands) to reduce the risk of digital divide
Fibre investment incentives	Policymakers, where the market has failed, may consider stimulating fibre investment and passive assets through PPPs, investment funds and the offering of grant funding, etc.
Fibre tax	Policymakers may consider removing any tax burdens associated with deploying fibre networks to reduce the associated costs
Copper to fibre	Policymakers may consider adopting policies/financial incentives to to encourage migration from copper to fibre & stimulate deployment of fibre
Wireless backhaul	Wireless Operators may consider a portfolio of wireless technologies for 5G backhaul backhaul in addition to fibre, including point-to-multipoint (PMP), microwave and mmWave radio relays, satellites etc
Access/ sharing of passive infra-structure	Policymakers may consider allowing access to government-owned infrastructure such as utility poles, traffic lights and lampposts to give wireless operators the appropriate rights to deploy electronic small cell apparatus to street furniture. Regulators may consider continuing to elaborate existing duct access regimes to encompass 5G networks allowing affordable fibre deployments
Access costs	Policymakers/Regulators may consider ensuring reasonable fees are charged to operators to deploy small-cell radio equipment on street furniture
Asset database	Policymakers may consider holding a central database identifying key contacts, showing assets such as utility ducts, fibre networks, CCTV posts, lampposts, etc. This will help MNOs cost & plan their infrastructure deployment more accurately
Wayleaves (ROW) Agreements	Policymakers may agree upon standardized wayleave agreements to (rights of way) reduce cost and time to deploy fibre and wireless networks
5G test beds	Policymakers to encourage 5G pilots and test beds to test 5G technologies, & use cases, and to stimulate market engagement

Source: ITU, Setting the Scene for 5G: Opportunities & Challenges, 2018

Likewise, the GSMA released a paper in March 2020 on realizing 5G's full potential. It is summarized in Exhibit 4.20.

Exhibit 4.20: Key Challenges in implementing 5G

Recommendations for MNO's	
Strengthen the consumer proposition	○ ***Fixed Wireless Access (FWA).*** Operators have an opportunity to strengthen the core business by extending their connectivity offerings. ○ ***Smart Connectivity & Content Partnerships.*** These provide opportunities for operators to accelerate 5G adoption and increase the value proposition.
Vertical partnership	Operators have multiple opportunities to identify promising verticals and find partners that can help deliver high-value, data-centric products or services to be distributed over the 5G network.
Optimize network costs	○ **Value-Based Deployment Strategies.** Operators should make careful assessments on the value of infrastructure deployments. ○ **Network-Sharing Agreements.** Infrastructure sharing with other operators has the potential to reduce network costs significantly. ○ ***Network Virtualisation and Centralisation.*** Virtualisation of networks allows the development of new, more cost- efficient network architectures ○ ***Automation and Self-Organising Networks.*** There is substantial potential to automate configuration, management, and operation of mobile networks.
Recommendations for Policy Makers and Regulators	
Additional, affordable, spectrum	Making additional spectrum available in a timely and affordable fashion is a top priority for accelerating advanced network deployment.
Facilitate access to site locations	Ensuring that local regulations allow for easy access to sites.
Enable small cell deployments	Facilitate next-generation infrastructure investments by streamlining approval processes for small cells.
Facilitate deployment of backhaul	Policy changes that facilitate the rollout of new fibre backhaul and other backhaul technologies, and encourage sharing of facilities and costs, can help to reduce the overall costs of backhaul. Governments are looking at the arrival of 5G as an opportunity to promote fibre infrastructure.
Freedom to establish network sharing agreements	Allowing operators to share networks. It is vital for the wider success of 5G that regulators permit, or even encourage, shared deployment, especially for small cells, recognising that network operators need the flexibility, to share infrastructure assets.
Harmonize power density limits	Overly strict power density limits for radio signals transmitted by network antennas undermines the ability of MNOs to speed up deployment of next-generation infrastructure.
Provide financial support for deployments	To unlock the full value of 5G for the entire country. Governments should consider providing financial support to achieve the widest coverage.
Provide regulatory flexibility for B2B partnerships	Regulatory authorities should acknowledge the dynamic nature of 5G networks and services and that optimised connectivity built on network slicing is compatible with the open internet principle.

Source: GSMA, Realizing 5G's full potential: Setting policies for success, March 2020

In meeting with the objectives of the study, Zest has identified five key recommendations necessary for the success of 5G in Nigeria. These are namely:

- Improving ROW to facilitate 5G deployment treated under Objective 1;
- Need for improved access to towers and sites for 5G deployment treated under Objective 1;
- Need to accelerate the fiber connectivity to base stations to support traffic loads treated under Objective 3;
- International transmission capacity and cloud infrastructure treated under Objective3; and
- Internet of Things (IoT) treated under Objective 3.

4.6. Improving ROW to Facilitate 5G Deployment

In order to efficiently deploy 5G infrastructure in Nigeria (including the needed fiber backhaul), a regulatory regime that facilitates accelerated infrastructure deployment is critical. Deploying telecommunications infrastructure is generally complex, expensive and risky. Nigerian operators must forecast the likely demand for network services in the face of uncertain future consumer behavior, unknown behavior of competitors and rapid technological change. The rapid pace of technological change accelerates obsolescence and makes long-term planning inherently more difficult.

Small cells (used for 5G) generate less power, collect and transmit signals in a short range from one cell to another and require collocating cells on other infrastructures. This means that there will be many more installations per unit area than were necessary for 4G rollout. To make it economically feasible for operators to deploy 5G, small cell wireless facility deployment will preferably require streamlined approval and permit processes for rights of way and relatively low application fees.

In order to accelerate the rate of infrastructure deployment in the face of these challenges, the NCC needs to ensure that there is a supportive structure within the next 12 to 24 months. This would require removing unnecessary obstructions and other barriers such as delayed approval processes that negatively impact on investment and rollout. The key laws and regulations that impact the deployment of 5G infrastructure in Nigeria are identified and discussed below.

4.6.1. The Applicable Plans, Rules and Regulations

Constitution

The Constitution of the Federal Republic of Nigeria (1999 Constitution) is the supreme law of the *Federal Republic of Nigeria* from which all Nigerian laws derive their validity. As such, the Constitution establishes the fundamental legal framework for the regulation of Nigeria's telecommunications industry.[74] Notably, Section 44 of the Constitution infers that jurisdiction over immovable or moveable property lies with the local Court of law, tribunal or body where the property is located.

74 Uchenna Jerome Orji 2018, *Telecommunications Law and Regulation in Nigeria*, page 9

The Nigerian Communications Act 2003

The *Nigerian Communications Act 2003* (NCA 2003) sets out the general legal framework for telecommunications in Nigeria. The Act's key objectives include promoting modern, universal, efficient, reliable, affordable and easily accessible communications services, as well as protecting the rights and interests of service providers and consumers within Nigeria.[75]

The NCA 2003 includes provisions for, *inter alia*:

- licensing;
- competition policy;
- quality of service;
- interconnection;
- scarce resources management;
- infrastructure sharing;
- universal service;
- tariff regulation;
- penalties and sanctions; and
- dispute resolution.

The NCA 2003 also established the NCC, which is responsible for regulating the communications sector, facilitating private sector participation in communication services delivery, as well as coordinating and regulating the activities of operators to ensure consistency in availability of service delivery and fair pricing.[76]Section 137(1) of the NCA 2003 provides that notwithstanding the provisions of any other written law, a licensee shall provide another licensee with non-discriminatory access to any ROW owned or controlled by the licensee. However, a licensee may deny access to another licensee on a non-discriminatory basis on the following grounds:

- where there is insufficient capacity; or
- for reasons of safety, security, reliability, or
- if there is difficulty of a technical or engineering nature.[77]

The NCC may regulate the rates, terms and conditions for ROW access and provide that such rates, terms and conditions are just and reasonable. The NCC may also adopt procedures necessary and appropriate to hear and resolve disputes in accordance with Part VII of Chapter V.[78] In addition, the NCA 2003 gives the NCC the power to resolve disputes between licensees. Under Section 137(3), in the event of a dispute between licensees in respect of ROW access, the NCC shall intervene and make a binding ruling. Despite NCC's significant powers over regulating ROW access, the NCA 2003

[75] NCA 2003, Chapter 1
[76] Marcus Ayodeji Araromi, '*Regulatory Framework of Telecommunication Sector: A Comparative Analysis between Nigeria and South Africa'*
[77] Section 137(2) of The National Communication Act 2003
[78] Section 137(4) of the National Communication Act 2003

stipulates that the NCC does not have jurisdiction with respect to ROW access where a State Government, local authority or other authority regulates such matters.[79]

The Land Use Act Cap L5 LFN 2004

The *Land Use Act Cap L5 LFN 2004* (LUA) vests land in each State on the Governor of the State, who is then responsible for allocating the use of land to individual residents, as well as to organizations for residential, agriculture, commercial and other purposes. This means that telecommunication operators are subject to the State Governor's power to grant easements and other rights appurtenant to land in respect of ROW.[80]

According to Section 28(4), it is lawful for the Governor of the State to revoke a right of occupancy in the event of issue of a notice by/or on behalf of the Head of State if such a notice declares such land to be required by the Government. With the exception of the NCA 2003 and the National ICT Policy, some other laws, Acts, legislations etc, derive their powers from this section of LUA and institute the granting of ROW permits to other interested entities at a fee.[81] The NCA 2003 has no such provision like Section 28(4), but rather stipulates that licensees should negotiate with statutory owners of ROW for access.[82] This scenario is partly responsible for the multiple charges for acquiring ROW permits.

Nigerian National Broadband Plan 2020 – 2025

The Nigerian National Broadband Plan 2020 – 2025 (NBP) was introduced to facilitate Nigeria's roadmap to digital economy. In particular, it was designed to deliver ambitious targets such as increasing coverage in the country to at least 90% of the population by 2025 at an affordable price. The NBP recognizes that effective regulation of ROW is critical to achieving its objectives, stating that harmonized ROW policies can contribute to accelerating the rollout of broadband services.

The NBP made the following recommendations:

- **Implementing National Standardized ROW Fees**: It is expected that developing a framework to encourage operators to collaborate and stay within the proposed ROW fee of N145N per linear meter will contribute to unimpeded fiber roll out in the states.
- **Incentivize ROW with Universal Service Provision Funds (USPF):** It is thought that providing incentives for states to adopt N145 per linear meter for ROW will facilitate fiber roll out. For example, rewarding states with USPF social intervention projects around security, health and education are possible incentives.

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79 Section 137(5) of the National Communication Act 2003

80 Akintunde Kabir Otubu 2012, '*The Regulator and the Regulated: An Examination of the Legal Framework for Telecommunication in Nigeria*'.

81 Federal Ministry of Communications, '*Report of the Ministerial Committee on Harmonization of Right of Way Charges and implementation Strategies*', June 2016.

82 Section 137 of The National Communication Act 2003

Non-compliant states should also be denied government interventions. This will result in cost reduction and encourage the deployment of shared broadband fiber infrastructure.

- **Harmonize the processes for issuance of ROW relevant permits:** Broadband penetration can be increased through stakeholder collaboration and financial incentives using harmonized processes for the issuance of ROW permits.

<u>National ICT Policy</u>

The National ICT Policy aims to provide a "framework for streamlining the ICT sector and enhancing its ability to catalyze and sustain socio-economic development critical to Nigeria's vision of becoming a top 20 economy by the year 2020".[83] It is anticipated that by using this Policy to develop action plans, sub-sectoral policies and specific implementation guidelines, ICT could be integrated into the socio-economic development of Nigeria and help transform it into a knowledge-based economy.

The Policy discusses ROW in the context of managing scarce resources to facilitate the effective and efficient deployment of ICT. Importantly, one of the Policy's objectives is to devise a national plan for allocating of ROW for all tiers of Government. The Government is also tasked with ensuring coordination between the States, Local Governments and Federal agencies that are involved in issuing ROW for ICT infrastructure deployment.

4.6.2. Assessment of Key Issues

<u>High Right of Way Fees</u>

The involvement of Nigeria's three-tier governance structure (comprising of Federal, State and Local Governments) give rise to multiple charges. For example, Section 135 of the NCA 2003 recognizes that operators may require State and/or Local government approvals in erecting or maintaining network facilities, even though ROW fees may also have already been paid to the Federal Government for access to federal highways.[84] In addition, as discussed in (5.2.1), the inconsistencies between the provisions of the NCA 2003 and the LUA with respect to obtaining ROW access have also resulted in excessive fees, which is to the detriment of operators and ultimately the consumers of these services.

These scenarios demonstrate why granting ROW permits are considered a huge revenue opportunity by the various government authorities in Nigeria.[85] According to operators during the local aspect of the study, the cost for producing ROW permits has been prohibitively expensive, with local government authorities usually charging disproportionately high amounts.[86] Indeed, the cost of obtaining ROW could account for up to 50 to 70% of the total cost of deploying fiber in various states.[87]

83 Refer to *National ICT Policy*, page 8.
84 www.mondaq.com/Nigeria/Tax/751100/Multiple-Taxes-Levies-And-Regulations-In-The-Nigerian-Telecommunications-Industry
85 Uchenna Jerome Orji 2018, *Telecommunications Law and Regulation in Nigeria*, Chapter 5
86 Ibid.
87 Ibid.

As such, and consistent with the NBP's proposed standardization of ROW fees, a committee set up by the National Economic Council (NEC) in 2013 resolved to harmonize taxes applicable to broadband related activities and streamline the taxation management processes across Nigeria. Ultimately, NEC agreed to a uniform ROW charge of N145.00 per linear meter of fiber.[88] The proposal to introduce a standard fee of N145.00 per linear meter was also agreed upon by the Honorable Minister of Communications and Digital Economy and the Nigerian Governors Forum (NGF) in order to address the prevailing non-uniform fee regimes.[89]

However, despite this recommendation, States have continued to charge high and inconsistent rates since 2013. Indeed, the absence of harmonized ROW charges has been identified by commentators as one of the reasons why Nigeria's NBP 2013-2018 failed to deliver.[90] States such as Abia, Delta, Lagos, Ogun and Rivers, charged arbitrary ROW ranging from N1500 to N6000 per linear meter on state roads, while the Federal Government charged N145 on federal roads.[91] Consequently, in 2018, last mile broadband penetration is still deficient in the country even though it was the primary aim of the NBP Plan of 2013- 2018.[92]

Most recently, in early January 2020, agencies and ministries of some Nigerian States further increased the cost of ROW from the initial fee of between N300 to N500 per linear meter to between N3000 and N6000 per linear meter. In response, the Minister of Communications and Digital Economy called on all Governors to reconsider this move in the interest of Nigerians as well as for the socio-economic growth and development of the country. [93]

On 22 January 2020, all 36 State Governors finally agreed to adopt the NEC's ROW fee recommendations which include dropping the maximum ROW charge to N145 per linear meter.[94] It is envisaged that this agreement will finally help resolve the recurring problem of ROW charges in Nigeria. On 23 May 2020, the Minister of Communications and Digital Economy, Dr. Isa Ali Ibrahim, commended Governors El-Rufai (Kaduna), Uzodimma (Imo), Masari (Katsina) and Lalong (Plateau) for implementing ROW Resolution.[95] The ROW charges in Kaduna State have been completely waived, while the charges in Katsina, Plateau and Imo State have been pegged at a maximum N145 per linear meter.

Administration of Right of Way Permits

Broadband penetration in Nigeria has also been plagued by inconsistencies in administrative procedures regarding ROW permits by authorities at different tiers of government.

88 www.sunnewsonline.com/fg-rues-states-disregard-of-row-charge-agreement/
89 Nigerian National Broadband Plan 2020 – 2025
90 www.vanguardngr.com/2018/05/nigerias-5-year-broadband-plan-failing/
91 www.vanguardngr.com/2018/05/nigerias-5-year-broadband-plan-failing/; www.benjamindada.com/broadband-right-of-way-ng/
92 Ibid.
93 www.vanguardngr.com/2020/01/broadband-penetration-state-governors-agree-to-address-row-challenges/; https://nextbillion.net/digital-finance-right-of-way-nigeria/
94 Ibid.
95 www.vanguardngr.com/2020/05/pantami-lauds-kaduna-imo-katsina-plateau-govs-for-complying-with-right-of-way-resolution/

The practice of federalism entitles all three government tiers to exercise a level of jurisdiction over land in accordance with the relevant laws. This requires operators to obtain ROW permits from authorities either at federal, state or local tier of government before deploying infrastructure along public roads within the jurisdiction of any of these tiers of government.[96]

Consequently, such inconsistencies have slowed down investments in the deployment of fiber optic cable infrastructure which would be needed for 5G backhaul. They have also increased the regulatory difficulties involved with obtaining such permits. Lengthy approval times have greatly contributed to delays and escalation of cost in rollout of broadband networks. The inconsistencies have also hindered the efforts of operators to build backbone infrastructure that will facilitate widespread and affordable access to broadband in Nigeria.[97]

Harmonizing Right of Way Regulation

The high ROW charges and inconsistent administration of ROW are both to a large extent caused by multiple regulations at the state and local levels of government in Nigeria. As such, in order to address these ROW issues, there ought to be a national harmonization of regulations governing telecommunications ROW in Nigeria.

In this regard, the various guidelines and advice published by the Nigerian Federal government should be implemented. The NBP as analyzed contains useful recommendations for effective regulation of ROW. In addition, the 2016 report by the Federal Ministry of Communications on ROW issues remains relevant.[98] The report made a number of recommendations, including the following:

- the establishment of a centralized agency comprising officials from the Ministries, Departments and Agencies in charge of road construction in the Federal, States and Local Government Areas to manage all ROW issues;
- enterprises are to obtain ROW permits from the centralized agency regardless of any laws, Acts, legislations, legal and institutional framework, guidelines, on ROW in Nigeria; and
- the review, update and amendment of the National ICT Policy and the NCA 2003 to incorporate or insert a section on ROW to harmonize the charges and draw up the implementation strategy.[99]

This centralization of authority and harmonization of ROW regulation would be in line with international best practice. Countries such Australia, Germany and Singapore operate a centralized regime for the management of ROW issues. For instance, in Australia, the power to manage ROW issues is vested in the Australian Communications and Media Authority in accordance with the *Telecommunications Act 1997.* In Germany, enterprises are legally entitled to use public roads at no fee upon receipt of a permit from the Federal Network Agency in charge of road construction. In Singapore, the same set of ROW rules apply throughout the country under the central government.

96 Uchenna Jerome Orji 2018, Telecommunications Law and Regulation in Nigeria, Chapter 5
97 Ibid.
98 Federal Ministry of Communications, '*Report of the Ministerial Committee on Harmonization of Right of Way Charges and implementation Strategies'*
99 Ibid.

‘Dig Once’ Approach

The adoption of the ‘dig once’ approach may also effectively address the challenges arising from the ROW issues in Nigeria. This approach entails constructing a specially designed underground conduit along public roads that would allow operators to simply pass their fiber cables through the conduit without going through the process of excavating the ground. This would then reduce the need to obtain a ROW permit. The ‘dig once’ approach has been applied in the United States through the Presidential Executive Order 13616 of 2012.[100]

The Executive Order establishes measures to minimize excavations that characterize broadband deployment including:

- directing the US Department of Transportation to work with State and Local Governments to help them develop and implement best practices on dig once requirements;[101]
- directing the US Department of Interior and other relevant agencies to encourage the deployment of broadband infrastructure in conjunction with deferral highway construction;[102] and
- directing the US Department of Transportation in consultation with the American Association of State Highway and Transportation Officials to create an online platform where States and Local governments can publicly publish their ROW laws.[103]

The implementation of these measures has brought significant improvements to broadband development in the US. For instance, it has fostered the deployment of conduit for broadband facilities in conjunction with federal or federal-assisted highway construction. It has also promoted the establishment of ‘dig once’ best practices by State and Local Governments in the US.[104]

4.7. Need for Improved Access to Towers and Sites for 5G Deployment

Two case studies are presented and analyzed detailing how this 5G requirement was satisfied in Australia and China.

4.7.1. Case Studies of Interest

Exhibit 4.21 details the challenges of 5G deployment in Australia with the number of tower sites increasing by almost 4 times.

100 Uchenna Jerome Orji, *Telecommunications Law and Regulation in Nigeria*, Chapter 5
101 Section 5(a) (ii) of the Executive Order 13616
102 Section 5(a) (iii) of the Executive Order 13616
103 Section 5(a) (v) of the Executive Order 13616
104 Uchenna Jerome Orji, Telecommunications Law and Regulation in Nigeria, Chapter 5

Exhibit 4.21: Australian 5G Deployment Case Study

The transition to 5G networks in New South Wales (NSW) Australia has resulted in a fundamental change in radio access network design and a significant growth in the number of sites, as demonstrated here. This example covers the Local Government Areas (LGAs) around Sydney – namely, Sydney, Woollahra, Waverley, Randwick, Bayside, Inner West, Canada Bay, Ryde, Hunters Hill, Lane Cove, Willoughby, North Sydney and Mosman. These LGAs have a combined landmass of 295 square kilometers and a residential population of around 1.5 million.

Map of proposed Local Government Area in Sydney

Source: Singtel Optus, Unlocking the Potential of 5G; Deployment Reform, March 2019

3G and 4G radio design provide services in this area mainly through a layer of macro and micro towers on buildings. These sites primarily utilize low and mid band spectrum to provide mobile wireless services. Under this model of radio design, the landmass of the LGAs are covered by around 400 sites.

However, the deployment of a 5G network fundamentally alters this design. 5G radio design is based primarily on small cells integrated onto existing fixtures such as light posts, street signs, and utility poles. The features of 5G such as low latency and very high throughput require a dense radio network, utilizing low to high bandwidth spectrum.

Australia is currently deploying 5G networks in the 3.4-3.6 GHz band, with 26-28 GHz spectrum to be made available soon. 5G will require many more sites than current networks. For example, Ericsson has shown that to offer 1 Gbps speeds, cells would have a coverage area of around 200 to 300 meters. This implies that to provide 5G services to the limited number of dense metro LGAs listed above, ***a MNO would need to deploy up to 1,500 small cells to cover an area of less than 300 square kilometers. This is a fundamental re-design of current radio networks, which provides services in these LGAs with around 400 sites***.

In light of the above, Singtel Optus argues that costs in relation to rental arrangements for mobile towers should be kept at a reasonable rate. Under the proposed rates (and assuming that the rates apply to all sites), annual rental charges for just these small number of LGAs would increase from AUD15.2 to AUD57 million. Singtel Optus cautions that such an increase in the cost to deploy sites is prohibitive and likely to delay or prevent the deployment of 5G in NSW. In more general terms, Singtel Optus is calling for significant changes to the regulatory regime to facilitate 5G network deployment.

Exhibit 4.22 summarizes China's approach to facilitate 5G deployment.

Exhibit 4.22: Summary of China's MIIT Guidelines on Telecom Passive Site Sharing

- Local telecom regulators are to promote access to state-owned public areas free of cost, and to coordinate road, railway, metro, airport etc, to provide site infrastructure at a reasonable cost.
- Encourage telecom operators to consult with municipal government, police offices, road transport bureau and railways for the opening of public sites. Encourage telecom and tower operators to trans-sector cooperation with power and railways for bilateral resource sharing
- The respective passive infrastructure for 5G including telecom pipes, fiber & cable, equipment room in newly built residential or commercial building, must follow engineering guidelines.
- Open and reuse existing fixed broadband cabinets in residential areas, commercial buildings and campuses. Fixed and mobile operators are encouraged to share the passive site infrastructure
- Unified site information system: consolidate public site passive information into a government database including macro site, micro/pole site and indoor sites.
- Consolidate public assets including light, monitoring and traffic pole for 5G site readiness.
- Share indoor passive infrastructure in public places (metro, railway, express way, airport, bus station, etc.), public infrastructures (stadium, business building, government office building)

Source: Translation of MIIT Guideline, 2019[105]

4.7.2. National Infrastructure Database

To avoid costly damage to infrastructure, disruption of service and possibly personal injury, it is important to ensure that underground infrastructure such as fiber optic cable and ducts are protected from subsequent construction projects.

International best practice demand the creation a national infrastructure database so that before any new project commences, the location of existing infrastructure can be identified. Such databases require creating a 'dial before you dig' organization. These organizations are supported by electricity, gas, communications and water companies as well as many other private enterprises. They provide an 'on call' service which provides very detailed information of the location of underground infrastructure in a given area. In order to establish these organizations, operators in

105 Ministry of Industry and Information Technology (MIIT) of the People's Republic of China, Implementation Guideline of Ministry of Industry and Information Technology and State-Owned Assets Supervision and Administration Commission of the State Council on Promoting Joint Construction and Sharing of Telecom Infrastructure, MIIT Letter [2019] 123, 6 June 2019

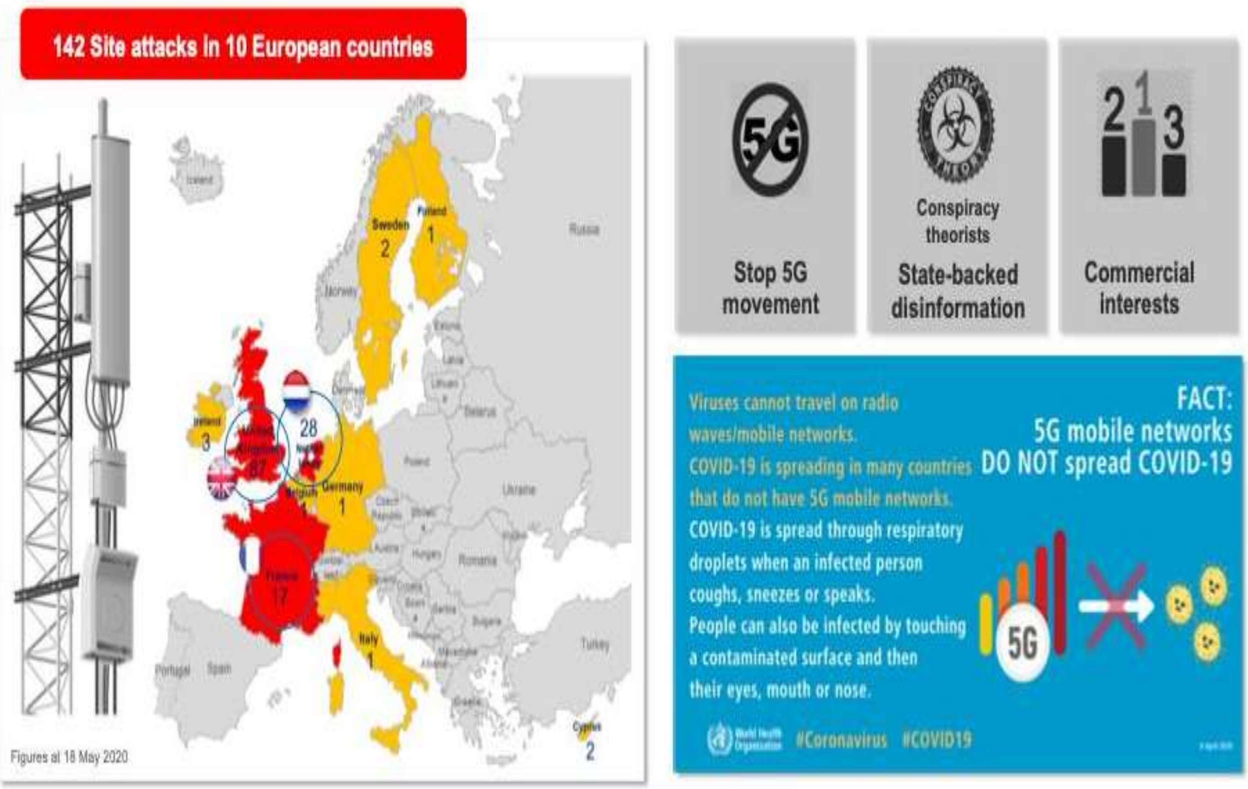
Nigeria would essentially need to share their existing records and agree on common practices in recording infrastructure-related data.

4.8. Vandalism

Regarding 5G and health concerns, in a number of global markets particularly in the UK and Europe and also markets like Australia and New Zealand, there have been a number of cases of vandalism including tower burning due to conspiracy theory which is propagating on the Internet that 5G and the corona virus are linked. See Exhibit 4.23.

While the theories that there is a link between 5G and coronavirus are utterly baseless, these theories have gained popularity in several climes including Nigeria. It is important for the Government and NCC to engage in public enlightenment campaign to assure the citizens that 5G does not cause the coronavirus and does not spread the coronavirus. This may be necessary before any 5G deployments in Nigeria that such concerns take hold as the public cannot distinguish between 5G and early generations of mobile technology or indeed between mobile and fixed telecommunications facilities.[106] The ITU has also issued a strong statement making clear that there is no scientific basis between 5G and COVID-19.[107]

Exhibit 4.23: 5G site vandalism and site attacks linking 5G with COVID-19



Source: GSMA, May 2020

106 www.theverge.com/2020/6/3/21276912/5g-conspiracy-theories-coronavirus-uk-telecoms-engineers-attacks-abuse

107 www.itu.int/en/Pages/COVID-19/5g-covid-19-statement.aspx

In Nigeria, cases of vandalism so far reported by service providers and vendors are attributed to theft. Local consultation with stakeholders indicated that there are certain technologically driven initiatives aimed at countering vandalism associated with theft.

It is expected that the presidential declaration of telecommunication infrastructures as critical national infrastructures on 2 June 2020 and signing an Executive Order to this effect will strengthen the protection of network resources. It is important that the NCC initiates a collaborative partnership with the institutions listed in the declaration towards safeguarding telecom networks across the country.

Objective Two: to determine the reliability and energy efficiency of 5G cellular networks
Key Findings:

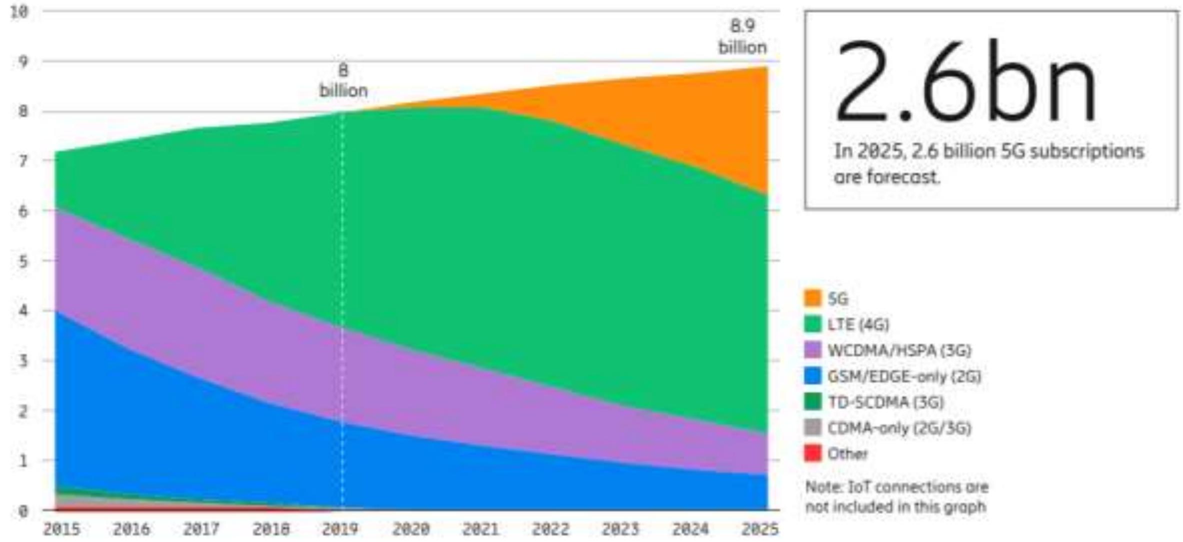
4.9. Reliability and Energy Efficiency of the 5G Cellular Networks

The 5G regime of networks will face some challenges in delivering greener and more energy efficient operational outcomes, at least in the short-term. At present, the telecommunications industry consumes about 3% of global energy.[108] The rising adoption of 5G by countries is expected to further increase these levels of energy consumption.

For example, a 2019 Ericsson Mobility Report projects that by the end of 2025, 5G will attract 2.6 billion subscriptions, generating 45% of the world's total mobile traffic data (Exhibit 4.24).[109] The potential increase in data traffic of up to 1,000 times more, as well as the building 5G infrastructure to cope with this traffic, could make 5G consume up to two to three times as much energy.[110] This potential energy increase may also be caused by an increased number of base stations, maintenance of legacy and 5G networks, and the greater cost of energy supply.[111] Until older networks are shut down, operators are likely to witness an energy increase in maintaining legacy networks in 2G, 3G and 4G networks in addition to new requirements in deploying 5G.[112]

108 https://millgens.com/innovation/owning-the-green-revolution-can-5g-be-sustainable/
109 https://wcm.ericsson.net/4acd7e/assets/local/mobility-report/documents/2019/emr-november-2019.pdf
110 www.gsma.com/wp-content/uploads/2019/04/The-5G-Guide_GSMA_2019_04_29_compressed.pdf
111 *Ibid.*
112 *Ibid.*

Exhibit 4.24: Mobile subscriptions by technology (billion)



Source: Ericsson Mobility Report, June 2019

As such, the 5G era raises the need for increased reliability and energy efficiency in order to optimize the overall power consumption of networks. One important dimension of 5G technology in terms of addressing such concerns is the Massive Multiple-Input Multiple-Output (MIMO) which involves the use of a large-scale antenna system or base station antennas that control the transmission and reception of radio signals.[113] Although the increased number of hardware components per base station will likely increase the total energy consumption of 5G base stations, its energy efficiency is expected to improve in the long-term.[114] With the refinements to massive MIMO hardware over time, a system of multiple antennas working together have the following advantages:

- more paths to the 5G client, providing stronger signal strength;
- more parallel antennas can serve a larger number of users; and
- antenna arrays can track mobile clients and direct the transmission beam at the client.[115]

Since the massive MIMO antenna and base station systems can direct radio transmission signals using a focused beam, 5G networks using beamforming utilize about four times less power than comparable 4G networks.[116]

In addition, MNOs have also taken action in formulating solutions to enhance network energy efficiency in part due to energy being the highest of all operating expenses for telecom businesses.[117] Solutions by operators fall in two major categories:

113 www.a10networks.com/blog/5g-energy-efficiency-explained/
114 https://spectrum.ieee.org/energywise/telecom/wireless/will-increased-energy-consumption-be-the-achilles-heel-of-5g-networks
115 www.a10networks.com/blog/5g-energy-efficiency-explained/
116 *Ibid*.
117 www.gsma.com/membership/resources/the-green-power-opportunity-for-5g-operators/

I. increasing the use of alternative energy sources to reduce dependence on the main power grid; and

II. network load optimization to reduce the energy consumption.[118]

4.9.1. Alternative Energy Sources

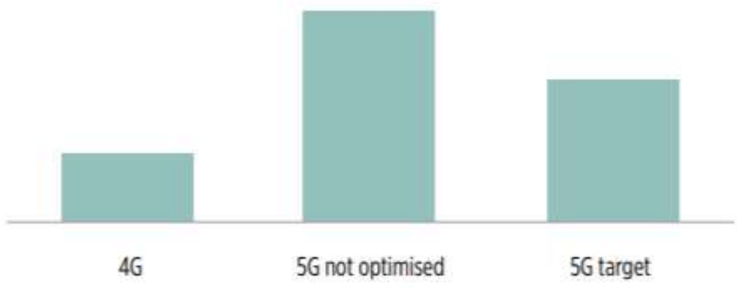
Operators have a number of options for sourcing alternative energy. First, MNOs may purchase green energy directly from their utility provider (not available in Nigeria). They may also use a third-party power purchase agreement to shift supply to renewables without the initial capex investment. Finally, MNOs can also self-generate energy at the base station with standalone or hybrid solar based solutions, or with larger scale solar and wind farms, which requires capex investment.[119]

T-Mobile and Vodafone in the USA are examples of operators exploring green power alternatives to address the challenge of maintaining reliable and energy-efficient 5G networks. T-Mobile has committed to using 100% renewable energy across its business by 2021. Vodafone also announced that it would do the same by 2025. [120]

4.9.2. Network Load Optimization

Network load optimization is likewise crucial to ensuring that total energy consumption in the 5G era is reduced (Exhibit 4.25). Improving energy efficiency to consume less energy can be achieved through solutions including smart building, virtualizing the core, and improving RAN efficiency through modernization of legacy equipment.

Exhibit 4.25: Projected Impact of Energy Optimization in 5G Networks



Source: GSMA, The 5G Guide: A Reference for Operators, April 2019

118 www.gsma.com/wp-content/uploads/2019/04/The-5G-Guide_GSMA_2019_04_29_compressed.pdf
119 *Ibid.*
120 www.gsma.com/membership/resources/the-green-power-opportunity-for-5g-operators/

Objective Three: to devise a means through which the 5G cellular network can support more users, more devices, and more services without a corresponding impact on cost

Key Findings:

4.10: Infrastructure Sharing

Sharing of network resources promotes network deployment and competition, and also reduces cost of investments. Thus, MNOs are able to save cost thereby enhancing the affordability of services by users.

4.10.1. NCC Guidelines on Infrastructure Sharing

The Guidelines on Collocation and Infrastructure Sharing 'The Guidelines' were first issued by the NCC in 2011. The Guidelines were developed to encourage collocation and infrastructure sharing, and promote fair competition in the communications industry.[121] The Guidelines also outline the role of NCC: to resolve disputes and 'impose facility sharing or collocation arrangements between operators after consultation with the parties'.[122] This aligns with the ITU guidelines on infrastructure sharing, which recommend that regulators publish guidelines and resolve disputes on infrastructure sharing.[123] The Guidelines have clear policy goals and are explicit on the types of sharing allowed, in conformity with the ITU's Guidelines.[124]

The Guidelines encourage and promote the sharing of the following infrastructure:

a. Rights of Way
b. Masts
c. Poles
d. Antenna mast and tower structures
e. Ducts
f. Trenches
g. Space in buildings
h. Electric power (public or private source).[125]

However, the following infrastructure is not permitted to be part of a sharing agreement under the Guidelines:

a. Complete network structures;
b. Switching centers;

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121 NCC, *Guidelines on Collocation and Infrastructure Sharing* 2011. www.ncc.gov.ng/accessible/documents/54-guidelines-on-collocation-and-infrastructure-sharing/file
122 Ibid s 16(1).
123I TU, *Digital Regulation Handbook: Conference Edition,* August 2020.
124 ITU, *Digital Regulation Handbook: Conference Edition,* August 2020 page 36-7.
125 NCC, *Guidelines on Collocation and Infrastructure Sharing* 2011 s 4(2).

c. Radio network controllers;

d. Base stations.[126]

Also, national roaming is not to be included in an infrastructure sharing agreement.[127]

Therefore, the NCC Guidelines only permit passive infrastructure sharing. Passive sharing raises fewer competition issues than sharing active network elements, but it is less cost-efficient. With the rollout of 5G, and the transition to a digital economy, greater infrastructure sharing is critical to making investments in new technologies economically viable.[128]

4.10.2. 2020 Infrastructure Sharing Guidelines- Proposed Amendments

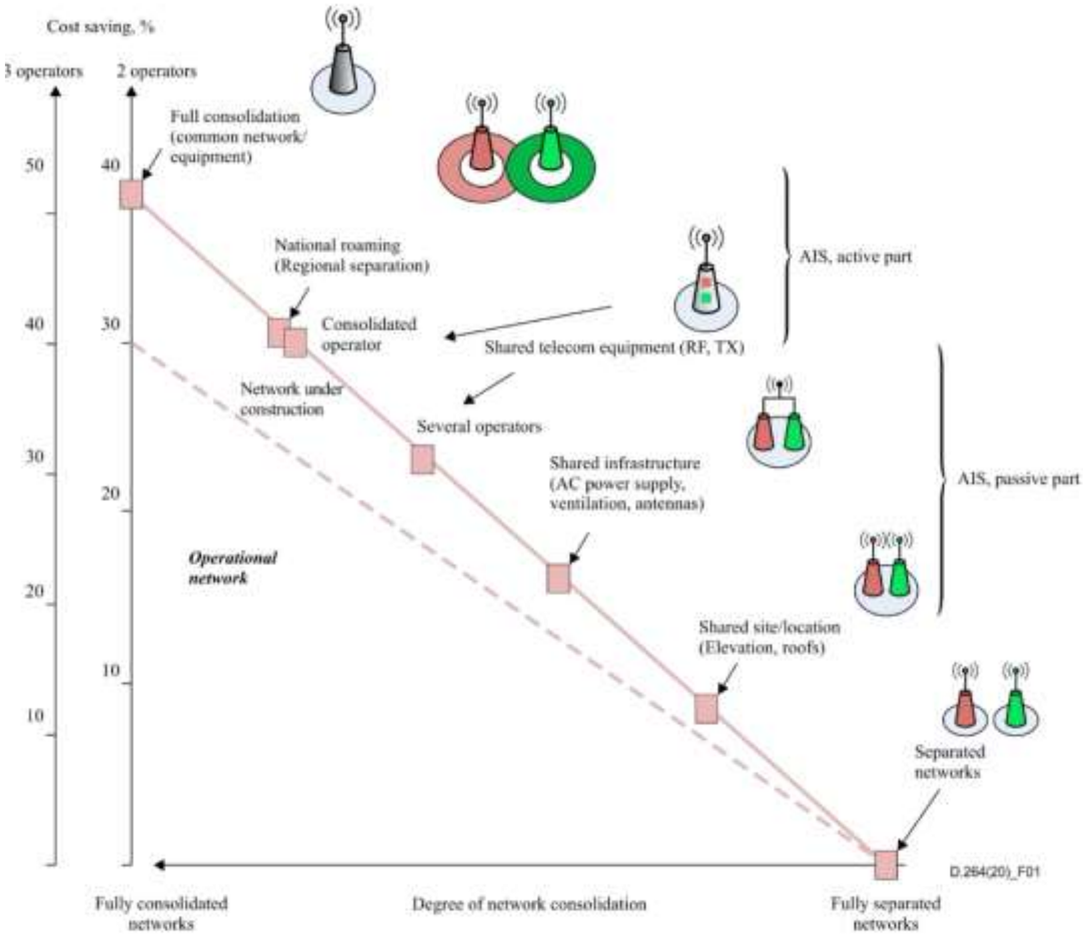
In November 2020, the NCC issued proposed amendments to the Guidelines that would permit the infrastructure listed from [(i)-(l)] to be shared.[129] The provision regarding national roaming is also to be amended to indicate that national roaming will not form part of any infrastructure sharing arrangements made pursuant to the Guidelines, but shall be negotiated under the relevant regulatory framework specific to National Roaming.[130] By permitting active infrastructure sharing, the NCC Guidelines align with ITU best practice.[131]

Additionally, the NCC have published a draft of their Active Infrastructure Sharing Business Rules ('The Rules').[132] The Rules aim to maximize the use of active network infrastructure and 'enhance sharing and reduce duplication of investment for network facilitates were adequate provision has been made'.[133] The Rules permit Multi-Operator Radio-Access Network (MORAN), Multi Operator Core Network (MOCN) and Gateway Core Network Operator (GCN) agreements. A MORAN model allows for shared RAN, but separate spectrum. MOCN is the same as MORAN, but the spectrum is also shared. GCN takes MOCN sharing a step further as MNOs share elements of their core network, thereby allowing even greater cost savings.[134]

The NCC's decision to amend the Guidelines and allow active sharing will bring number of benefits to the Nigerian Telecommunications Sector. Exhibit 4.26 demonstrates the potential for increased cost savings by allowing active infrastructure sharing. However, it is important to note that active sharing, while more cost-efficient, requires more rigorous market and competition analysis than passive sharing.[135]

126 Ibid s 5(1).
127 Ibid s 5(2).
128 ITU, *Digital Regulation Handbook: Conference Edition,* August 2020.
129 NCC, *Guidelines on Collocation and Infrastructure Sharing* November 2020. www.ncc.gov.ng/accessible/documents/922-draft-collocation-and-active-infrastructure-sharing-guidelines/file.
130 Ibid s 5(1).
131 Ibid.
132 www.ncc.gov.ng/accessible/documents/923-draft-active-infrastructure-sharing-business-rules/file
133 NCC, *Guidelines on Collocation and Infrastructure Sharing* November 2020 s 1(iv).
134 www.commscope.com/globalassets/digizuite/2015-antenna-sharing-wp-109680-en.pdf?r=1
135 A4AI, *Affordability Report 2019* page 6. Available at www.A4AI.org

Exhibit 4.26: ITU Estimates of Potential Scenario for Cost Savings



Source: ITU, 2020[136]

4.10.3. 5G and Infrastructure Sharing

Internet users in Nigeria's rural areas often experience digital exclusion through limited coverage and much slower internet speeds. Investments in telecommunications and most of the existing terrestrial fiber are centered in Lagos, Abuja and other major cities. This has resulted in uneven development and an infrastructural deficit in many areas in Nigeria. Since there are limited infrastructure-sharing arrangements throughout the country, many Nigerians must rely on expensive technologies in order to remain connected. As such, the NCC should promote collaboration on network infrastructure, particularly for 5G.

Infrastructure sharing is critical to facilitating accessible and reliable internet access in Nigeria, particularly in regional and remote locations. As global infrastructure-sharing experiences have shown, developing countries can save billions and accelerate universal broadband access by sharing infrastructure.

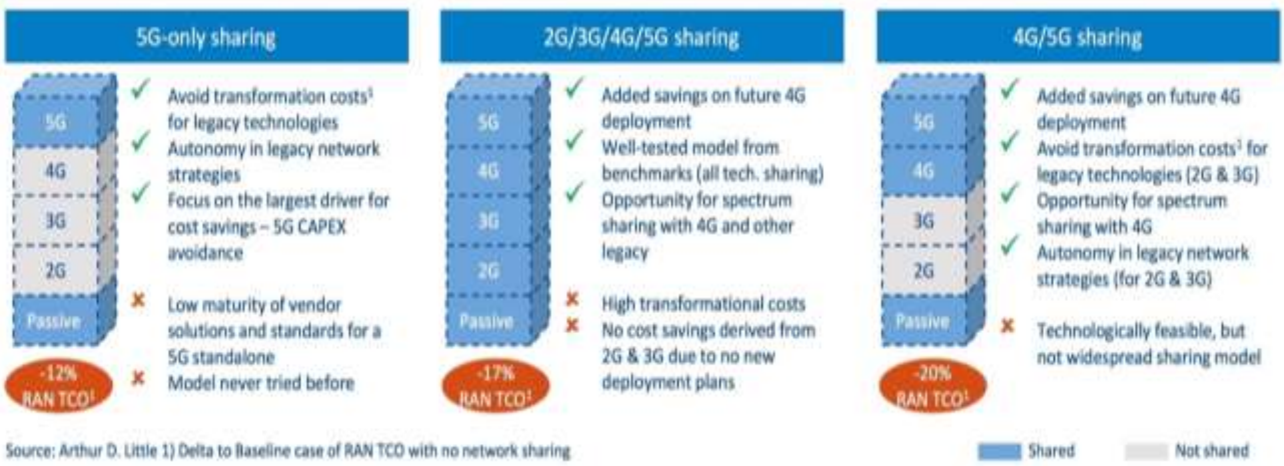
It is therefore a pertinent time for Nigeria to consider what sort of networking sharing agreements would be most cost efficient and prevent redundant future CAPEX.

136 ITU, *Shared uses of telecommunication infrastructure as possible methods for enhancing the efficiency of telecommunications*, D.264, 04/2020, page 3

5G deployment requires significant investment, so network sharing and partnerships with other MNOs is an attractive option. In urban areas, where there will be a large number of small cells/street furniture to deploy, network sharing makes particular financial sense. It would also be the most cost-efficient strategy in rural/less economic areas (with low band spectrum).

When entering into agreements on 5G infrastructure sharing and in addition to determining pricing and bundling schemes, MNOs need to determine the scope of the sharing arrangements. Globally, MNOs have often chosen to exclude legacy technologies like 2G and 3G from an active sharing arrangement to avoid transformation costs of the legacy technologies or asymmetries in existing legacy technology between operators.[137] The advantages and disadvantages of sharing different technologies in an infrastructure sharing agreement are considered in Exhibit 4.27.

Exhibit 4.27: 5G Active Network Sharing Technology Options, 2019[138]



The regulatory challenges of a 5G rollout are substantial. There are many considerations to be taken into account when considering how 5G infrastructure could be optimally deployed. Selecting the most appropriate network-sharing model requires a balance between the strategic considerations of the future 5G network and competitive positioning while ensuring favorable financial outcomes. Arguably, 5G deployment in Nigeria would benefit from active network sharing under an MCON or GCN agreement, and while prohibited under the current Guidelines, they are to be permitted in accordance with the proposed amendments.[139]

It should be noted that globally, other jurisdictions have adopted spectrum sharing models to counter the scarcity and high cost of spectrum:[140] Hong Kong has implemented high traffic demand priority areas, so that the 26/28 GHz band is subdivided into shared and non-shared spectrum. 400 MHz is allocated for the provision of wireless broadband services in locations with high traffic

137 Arthur D Little, *Network Sharing in the 5G era: Choosing the Right Sharing Model to Maximize Efficiently of 5G Rollout,* November 2020.

138 Ibid page 6.

139 Ibid.

140 www.itu.int/en/ITU-D/Regional-Presence/Europe/Documents/Events/2020/Spectrum_EUR_CIS/Pavel%20Mamchenkov%20%281%29.pdf

demand. Italy has implemented club sharing, which allows multiple MNOs to use spectrum if there are more than one 5G provider in the area. Spectrum sharing should certainly be part of the NCC's regulatory strategy for infrastructure sharing as it may help alleviate cost and resource issues with 5G rollout in Nigeria.

4.11. Accelerating Fiber Connectivity to Base Stations

Massive fiber connectivity to base stations guarantees the support of more users and more devices in a cellular network. From the field study conducted, it is clear that the vast majority of Nigeria's mobile towers are not connected to terrestrial transmission or backhaul networks. Ideally, such backhaul networks should be fiber optic cable networks given their superior capacity and reliability compared to microwave backhaul networks. Fiber connectivity of Nigeria's mobile networks is likely to be necessary for 5G and will drive future business activity for the country's transmission infrastructure providers.

Based on our consultation with the local stakeholders, this is an area of concern as further substantial investment will be required. FTTX providers, MNOs and tower companies indicated their 5G business plans include massive deployment of fiber to connect base stations in major cities to facilitate 5G deployment but ROW challenges are obvious impediments.

4.12. 5G Internet of Things (IoT)

The current global view is that IoT is rapidly transforming the way individuals, enterprises and governments communicate and work. There will be a fundamental shift in lifestyles on the back of a large number of devices communicating with one another. In turn, this will collaboratively result in increased optimization of resources and enhanced productivity.[141]

The IoT ecosystem involves interaction of telecommunications services with a range of new services and machine to machine (M2M) communications. The IoT will be felt in all aspects of living and will support all industries. According to the GSMA, the global IoT market will be worth $1.1 trillion in revenue by 2025.[142] By that time, the GSMA estimates that there will be more than 25 billion IoT connections driven largely by growth in the industrial IoT market.

The IoT first emerged in the 2G/3G network environment. However, the development of 4G LTE networks featuring advantages in spectral efficiency, latency and data throughput provided the initial stimulus for widespread IoT deployment. 5G provides superior transmission speed and lower latency enabling greater capacity for connected devices. The capacity of 5G networks to carry more data faster will push significant growth in IoT applications. 5G provides a range of benefits to IoT, which are not available with 4G or other technologies. These include 5G's ability to support a massive number of static and mobile IoT devices, which have a diverse range of speed, bandwidth and quality of service requirements.

As Nigeria prepares for 5G adoption, it must ensure that its policy and regulatory settings are conducive for capturing the benefits that IoT applications provide. This section discusses IoT and

[141] See www.gsma.com/iot/
[142] See GSMA, 'IoT: the $1 trillion revenue opportunity (May 2018)'

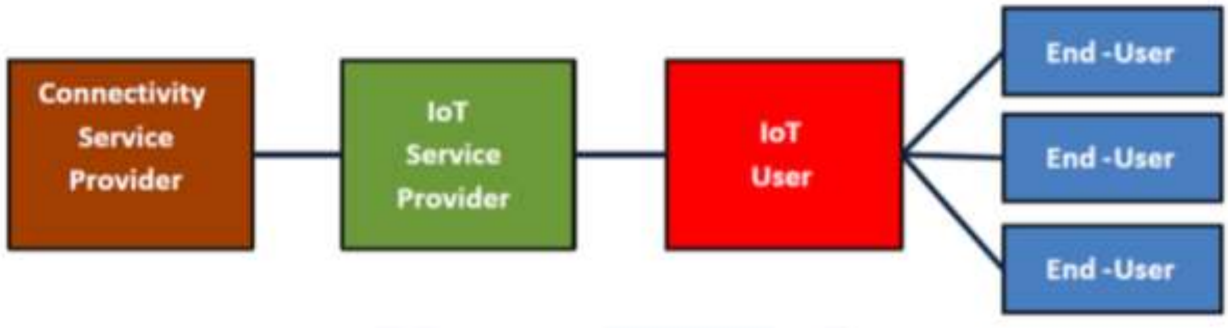
the opportunities that it offers and proposes recommendations to ensuring that IoT applications are allowed to flourish in the 5G environment.

4.12.1. Defining IoT and Technology Status

IoT refers to the interconnection via the Internet of billions of computing devices embedded in everyday objects enabling them to send and receive data. IoT includes devices and sensors that connect, communicate or transmit information with or between each other through the Internet. Each device has a unique identifier and communicates real-time data without involving a human being.

According to BEREC, IoT services are created and delivered through relationships that are formed among Internet connectivity providers, IoT service providers, IoT users and end users. Exhibit 4.28 illustrates the delivery chain for IoT services.

Exhibit 4.28: Delivery chain for IoT services



Source: BEREC Report, Enabling the Internet of Things, 12 February 2016

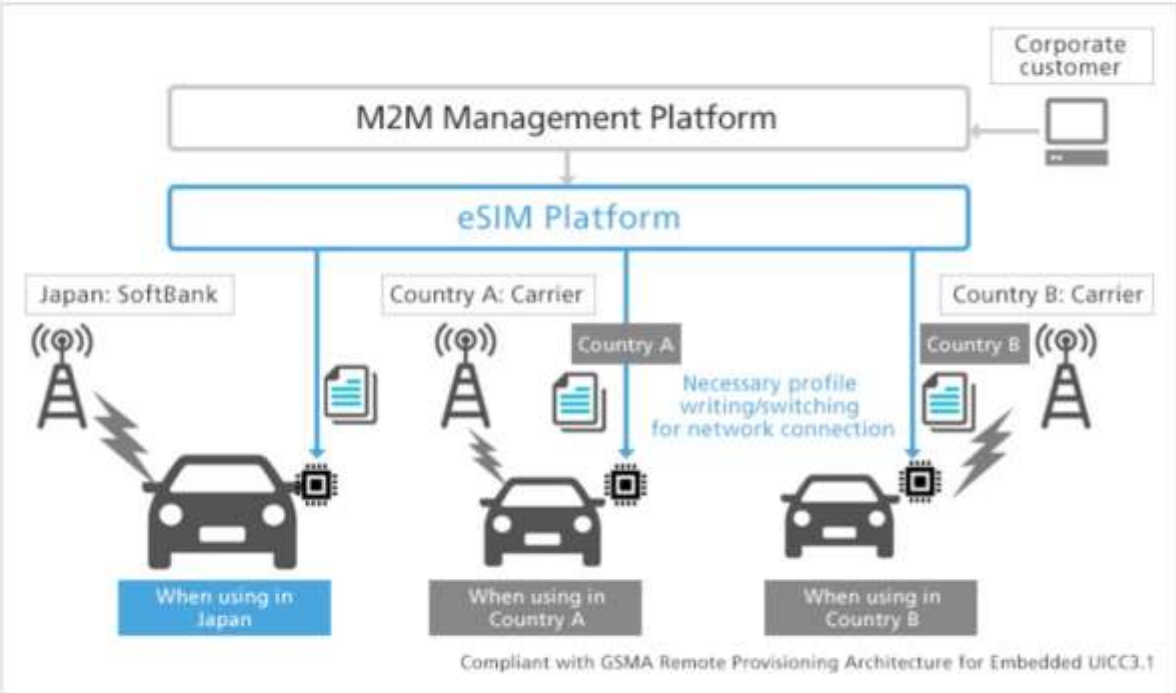
Typically, the IoT user purchases the IoT service from an IoT service provider who, in turn, purchases the Internet connectivity from a connectivity service provider. The customers of connectivity service providers are the IoT device makers, the IoT service providers or the IoT users but not the end-users. Often, the connectivity service providers have no relationship with the IoT service providers, and run their business with the hardware manufacturers. The end-user, on the other hand, buys an interconnected device and is not necessarily interested in the communication service as such. The service of the connectivity service provider to the IoT device maker, IoT service provider or IoT user is a wholesale-type arrangement.

With mobile IoT technologies like Narrow Band IoT (NB-IoT) and LTE-M rising in popularity, the IoT is moving towards a mobile-first world. NB-IoT and LTE-M are technologies developed by the global standards organization 3GPP and are the two main offerings which are set to become the global dominant Low-Power Wide-Area (LPWA) technologies. The two protocols were launched in 2017 as part of the 3GPP's Release 13.[143]

[143] See https://www.3gpp.org/release-13

NB-IoT focuses specifically on indoor coverage, low cost, long battery life, and high connection density. NB-IoT uses a subset of the LTE standard, but limits the bandwidth to a single narrow-band of 200 kHz. On the other hand, LTE-M is the abbreviation for LTE Cat-M1 or Long Term Evolution (4G), category M1. This technology enables devices to connect directly to a 4G network, without a gateway and with the use of batteries. It should be noted that typically, an eSIM platform is necessary for the MNO to manage IoT/M2M services. This would be similar to that launched by Softbank in 2017[144] and a number of other major global operators. See Exhibit 4.29.

Exhibit 4.29: eSIM Platform for IoT/M2M Services



Source: Softbank, 2017

NB-IoT and LTE-M have different characteristics making each more suitable for particular use cases. NB-IoT can be deployed within an LTE carrier, in the guard band, or in a stand- alone carrier in other (non-LTE) spectrum. In contrast, LTE-M is deployed solely within an LTE carrier. In the IoT network deployments, MNO's typically deploy within an LTE carrier. Exhibit 4.30 shows the key differences between NB IoT and LTE-M.

[144] See www.thefastmode.com/technology-solutions/10516-softbank-to-launch-new-esim-platform-for-iot-this-year

Exhibit 4.30: Differences between NB IoT and LTE-M

	NB-IoT	LTE-M
Peak Data Rate	<100 kbps	>384 kbps, up to 1Mbps
Latency	1.5-10 s	50-100 ms
Power Consumption	Best at very low data rates	Best at medium to high data rates
Mobility	No for Cat-NB1, limited for Cat-NB2	Yes
Voice (VoLTE)	No	Yes
Antennas	1	1

Source: Ubidots, "Here's What the Cellular IoT Buzz Is All about", March 2020

NB-IoT is optimized for:

- Low data rate connections;
- Stationary use (with Cat-NB2 allowing for limited mobility); and
- Extremely low cost per device applications.

On the other hand, LTE-M is suitable for:

- High bandwidth data rates;
- Mobility (asset tracking, vehicles, etc.); and
- Voice connectivity through VoLTE technology.

Based on sourced GSA data, MNO commitment to the range of 3GPP standards based LPWA technologies has been characterized by the dramatic growth in the number of networks supporting NB-IoT and LTE-M standards. Globally, as at May 2020, 157 operators have invested in NB-IoT with 106 having deployed or launched networks. This compares to 44 operators two years earlier. By contrast, as at May 2020, 68 operators have invested in LTE-M with 45 having deployed or launched networks. This compares to 13 MNOs two years earlier.

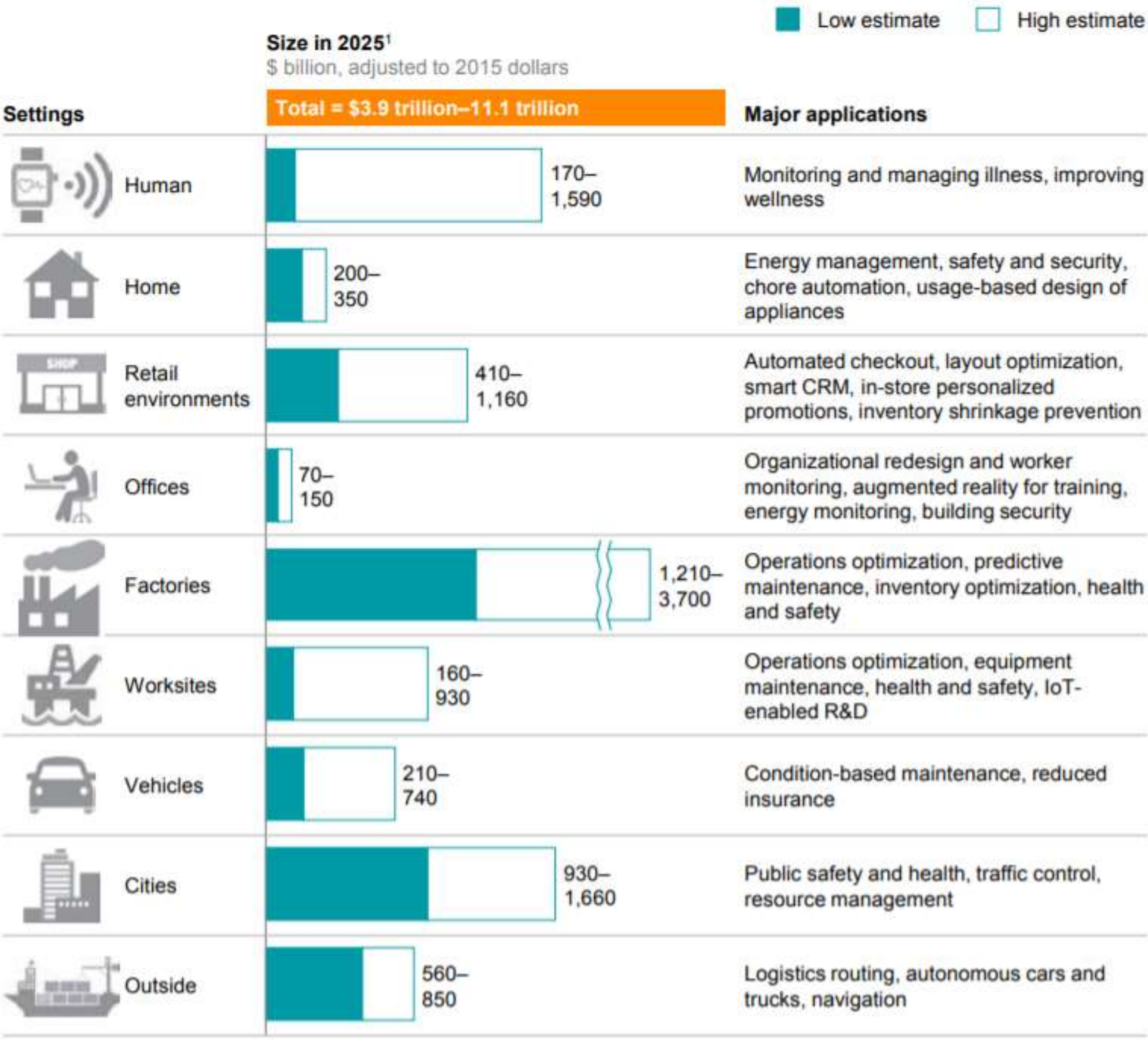
Across the globe, two countries (Argentina and Mexico) have launched LTE-M networks only while a wide range of markets (including India, Russia, United Kingdom and Italy) have launched NB IoT networks only. A range of other countries (including Australia, Canada and Spain) have launched both NB IoT and LTE-M networks.

It should be noted that both NB IoT and LTE-M continue to be developed and enhanced by 3GPP. Release 14 (2017) and Release 15 (2019) have made a wide range of enhancements to the IoT specifications. Release 15 is the first full set of 5G standards. It expands to cover 'standalone' 5G, with a new radio system complemented by a next-generation core network. It also embraces enhancements to LTE and, implicitly, the Evolved Packet Core (EPC). Release 16 will be "5G Phase 2", and is scheduled for June 2020. It will address 5G satellite access, LAN support in 5G, wireless and wireline convergence for 5G. Release 17 is scheduled for September 2021.

4.12.2. Use Cases: Industrial IoT

IoT applications are anticipated to increase globally as economies continue to be driven by cost reduction, energy savings, value added services and automation of equipment and infrastructure. A recent study by McKinsey estimated the potential impact of IoT across different sectors of the economy. As shown in Exhibit 4.31, the manufacturing sector is poised to see the biggest gains from IoT.

Exhibit 4.31: Potential economic impact of IoT in 2025, including consumer surplus, is USD3.9 trillion to USD11.1 trillion.



1 Includes sized applications only.
NOTE: Numbers may not sum due to rounding.

SOURCE: McKinsey Global Institute analysis

The use of IoT in manufacturing is creating 'smarter' factories that can deliver on-demand manufacturing, reliable and ubiquitous communication, and zero-defect manufacturing. A further study by Juniper Research[145] also identified the industrial sector as a key driver of growth in the

145 See Juniper Research, *The Internet of Things: Consumer, Industrial and Public Services 2020:2024*, April 2020

number of IoT connections. The study found that the industrial sector, including manufacturing, retail and agriculture, will account for over 70 percent of all IoT connections by 2024. The industrial sector is expected to account for 60 billion IoT connections.

Juniper Research anticipates that the emergence of cost-efficient private cellular networks would be a key driver of growth over the next four years, and expects that the recent increase in demand for private LTE networks will carry forward to private 5G networks as the cost of the technology decreases over the next two years. Oil and Gas are also poised to gain from the use of IoT technology (see Exhibit 4.32).

Exhibit 4.32: IoT in the Oil and Gas Industry

Demand for oil and gas has dropped due to Coronavirus and the associated reductions in travel and reduced economic activities. Additionally, oil prices are not expected to recover to their pre-pandemic levels until 2022, slower than other industries such as metal and agriculture.[146] For this reason, it is crucial that oil and gas companies find ways to reduce production, refining and distribution costs.

IoT is one possible solution as it can be utilized to create more time and cost-efficient practices. IoT enables an unprecedented amount of data to be exchanged with other devices through a central platform via software, sensors and network connectivity. Inexpensive IoT sensors can be implemented in oil fields to analyze data, monitor performance of tanks or explore drilling sites.[147]

The positive impact of IoT on the oil and gas industry has already been demonstrated in Nigeria. In 2016, Shell Nigeria was able to save $1 million using IoT sensors to monitor remote oil fields, replacing site visits and manual data collection. The system combined IT automation and technologies to access remote field data, which it analyzed and managed to provide insight into safer and more efficient oilfield operations. The savings came from deploying a system that was lighter on infrastructure, as opposed to satellite or general packet radio service (GPRS) which required significant infrastructure investment.

Deploying a 5G network will maximize the potential benefits of IoT to oil and gas companies. Connection to 5G bandwidth will ensure that future IoT investments are affordable. Moreover, adopting a wireless connectivity approach over a wired network approach will allow African oil and gas producers to stay competitive and promote operational efficiency.[148]

4.12.3. IoT Technologies and 5G

5G can significantly support IoT by offering an optimal platform to realize IoT's benefits (see Exhibit 4.33).[149] For example, 5G can support new high speed IoT applications such as 4K cameras and control of drones.[150] At the same time, 5G enables IoT applications requiring reliability and

146 www.worldbank.org/en/news/press-release/2020/10/22/impact-of-covid-19-on-commodity-markets-heaviest-on-energy-prices-lower-oil-demand-likely-to-persist-beyond-2021

147 www2.deloitte.com/us/en/pages/consulting/articles/iot-digital-oil-and-gas.html

148 https://blog.softwareag.com/5g-and-iot-helping-solve-energy-woes

149 https://home.kpmg/xx/en/home/campaigns/2019/06/converging-5g-and-iot.html

150 GSMA, 5G, the Internet of Things (IoT) and Wearable Devices: What do the new uses of wireless technologies mean for radio frequency exposure?, October 2019.

extremely low latency (1 ms minimum), such as connected vehicles, health equipment and remote control of machines.[151]

Where wireless technologies have played a limited role in manufacturing due to vibration, sound and heat, 5G is also expected to eliminate these issues.[152] Together, IoT and 5G can improve manufacturing processes by enabling businesses to connect all stages of the planning-to-sales process in a continuous loop, as opposed to data flowing in a straight line.[153] This allows producers to respond quickly to potential problems, as well as provides manufacturers with predictive analytics to undertake preventive maintenance.

Exhibit 4.33: Telstra's 5G IoT networks

In June 2020, Telstra (Australia's largest MNO) announced that both its LTE-M and NB-IoT are now recognized as 5G technologies. This will assist the operator in delivering IoT through the fifth generation of mobile network development, beyond the lifespan of 4G. It is also expected that adopting LTE-M and NB-IoT into the 5G family of technologies will continue to drive the expansion of connected things.

What does this mean for consumers? 5G delivers greater speeds and network capacity, and via LTE-M and NB-IoT, can potentially connect billions of things globally. Though leveraging the capabilities of 5G for IoT, connected devices can enable new advances both in nationwide and localized settings. Such massive IoT deployments can impact many industries, with connected transport, healthcare and infrastructure communicating with centralized dashboards to help the nation move smoothly. At the same time, if IoT is deployed in industrial settings like factories, collaborative robotics could receive almost instantaneous responses from surrounding machines to enable faster and smarter manufacturing.[154]

4.12.4. IoT Regulatory Approaches

Policy makers around the globe are faced with a choice between making specific regulatory interventions in support of IoT or to refrain from specific intervention and allow market forces to run their course. Some advocate for regulatory intervention to build public confidence, promote public safety and to ensure a competitive market. Others argue that regulation should be avoided fearing that too many rules may hinder technology development and innovation.

The key regulatory issue arising with respect to IoT primarily concerns spectrum allocation, i.e., whether a specific allocation of spectrum should be made for IoT. There are a range of other key factors to examine and optimal approaches that need to be determined in relation to IoT services which are wider than spectrum management issues. Other such issues and possible areas of regulatory intervention of concern are data privacy and security, numbering, and type approval / certification.

151 *Ibid.*
152 https://home.kpmg/xx/en/home/campaigns/2019/06/converging-5g-and-iot.html
153 *Ibid.*
154 https://exchange.telstra.com.au/our-iot-networks-are-joining-the-5g-family-future-proofing-for-years-to-come/

IoT Spectrum

Europe's Radio Spectrum Policy Group's (RSPG) has developed a spectrum policy strategy known as the Spectrum Roadmap for Internet of Things (IoT) including M2M[155] as part of the RSPG's '*Work Programme for 2016 and beyond'*.

The paper recognises that the continued growth of IoT applications creates an increased demand for access to spectrum, although the quantity and type of spectrum access required will depend on the operational requirements and use cases. In contrast, there is very little IoT-specific regulation currently in the US.

The RSPG paper concluded that *inter alia*:

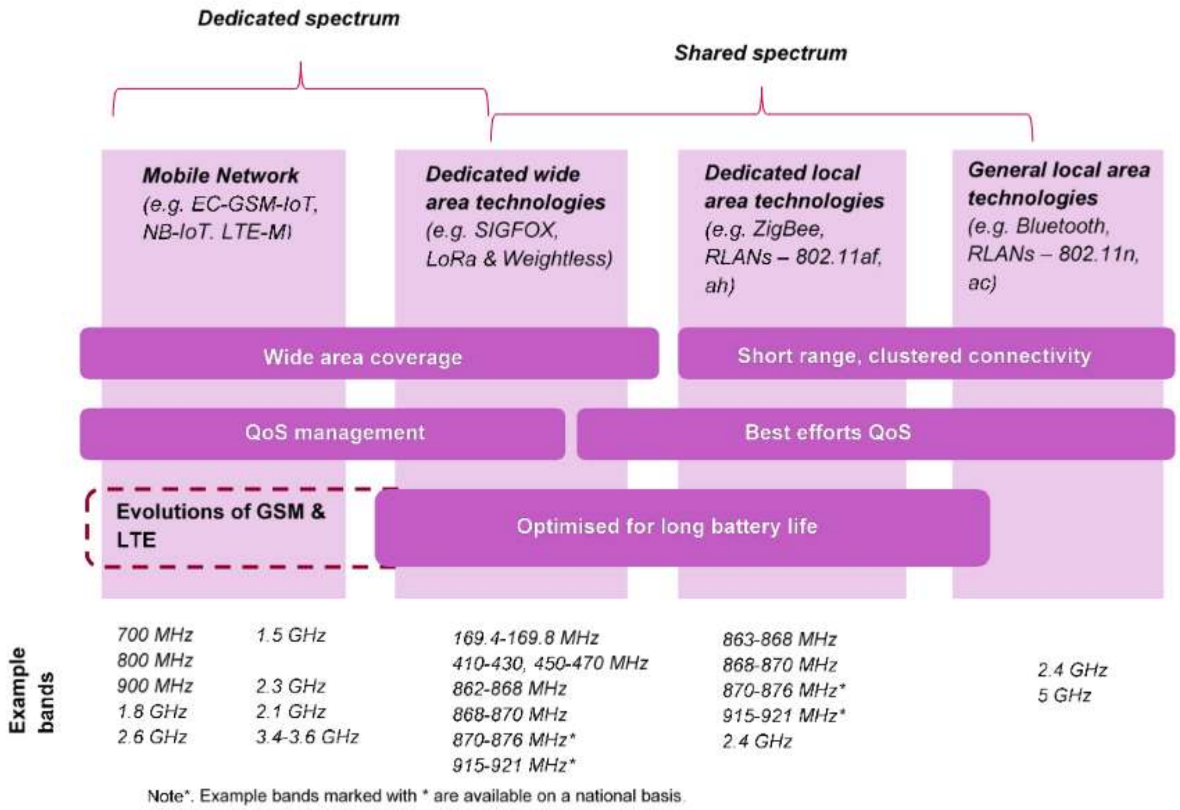
- As IoT is heterogeneous - there is no single solution for access to spectrum that fits all these possible use cases since their technical requirements differ dramatically;
- Allocating and designating bands solely for IoT is not needed; and
- Frequencies allocated or identified for electronic communication services (mobile networks) may be used for emerging IoT applications and services – including the 700, 800, 900, 2100 and 2600 MHz bands.[156]

The RSPG will continue to review the evolution of spectrum demand for IoT, in particular bands below 1GHz. Exhibit 4.34 below details the RSPG's Roadmap for IoT Spectrum Access.

155 See https://circabc.europa.eu/sd/a/a0faa1a5-ca41-42c3-83d5-561b197419b0/RSPG17-006-Final_IoT_Opinion.pdf

156 This is a view shared by vendors such as Ericsson who have said No single band will provide a complete solution for 5G IoT requirements. Therefore spectrum will be need in low, medium and high band ranges. See Ericsson, *Developing Policy Frameworks for Successful Industrial Transformation*: *IoT Policies*, 2017, page 36

Exhibit 4.34: RSPG Roadmap for IoT Spectrum Access



The use of low bands (below 1GHz) should be the basic goal for mobile operators when offering NB-IoT solutions. For example, the NB-IoT chipset is fully supported in APT700, along with other IMT bands below 1 GHz, and there are considerable and compelling benefits in deploying APT 700 including enhanced indoor coverage, wider coverage that extends to suburban and rural areas, higher speeds and improved IoT deployments.

Data Privacy and Security

IoT networks collect large amounts of personal and commercially sensitive data, raising concern among regulators and end-users about data privacy and security. It is already evident that cyberattacks on IoT devices have grown at an unprecedented rate.[157] Moreover, data is then often sent across national borders and stored and processed largely at the discretion of service providers. Some jurisdictions have recently introduced laws to protect data privacy and security. For example, the US State of California passed a cybersecurity law covering IoT devices. SB-327 came into law in January 2020. This law requires that manufacturers of a device that connects directly or indirectly to the Internet must be equipped with "reasonable" security features that are designed to prevent unauthorized access, modification or information disclosure. A similar law has also been adopted in the US State of Oregon. In addition, the UK government has recently announced plans to

157 See https://blog.f-secure.com/attack-landscape-h1-2019-iot-smb-traffic-abound/

introduce new IoT security laws for manufacturers of connected devices.[158] This follows the apparent failure of a voluntary code of practice.

In addition to legislation, other regulatory measures to protect data privacy and security include:

- incentives for companies to develop new mechanisms to improve transparency of IoT personal data use, for example, companies should follow a security and privacy “by design” approach, building security and privacy functionality into the device from the outset of the development process;
- the development of further guidance from global privacy regulators on application of the principles of data minimization and purpose limitation in IoT systems which reduce the risk of data breaches and/or use of the data for other than its intended purpose; and
- co-operation between telecoms and other regulators such as privacy/data protection agencies with regard to agreed minimum privacy and security related business practices.

The issue facing policy makers is whether some form of intervention, such as regulations, guidelines or voluntary code of practice should be taken to protect data privacy and security.

Numbering

Currently mobile network code (MNC) and numbers are only allocated to domestic licensed operators. The approach by service providers and IoT service providers has been the use of existing ranges of national E.164 numbers (especially mobile numbers). This is because of their relative ease of implementation into existing network infrastructures. It is very likely that in the medium term or long term, extra-territorial E.212 identifiers will be used for addressing IoT/M2M devices, or alternatively there will be increased use of IPv6 addresses.[159]

In Europe, BEREC considers that from a cost-benefit perspective the introduction of a European numbering scheme for IoT/M2M does not seem to carry any significant benefits which would justify the deployment costs of setting up such a solution. It found that no special treatment of IoT or M2M communication appears necessary or appropriate except for roaming, switching and portability. Roaming is very important in the IoT context because many M2M services, which use mobile connectivity, are currently based on permanent roaming.[160]

The other challenge on numbering is that IoT/M2M applications give rise to the use of eSIMs.
For MNOs, the eSIM can give rise to new market opportunities in areas such as wearable devices, M2M, IoT and the connected car (see Exhibit 4.35). It can also lead to the reduction of SIM handling, integration and handling costs.

158 See https://www.forbes.com/sites/charlestowersclark/2019/05/02/uk-to-introduce-new-law-for-iot-device-security/#4b6de291579d

159 For further analysis see BEREC, *EWG NGN Project Advanced connectivity of devices, systems and services (M2M) Draft Report on Enabling the Internet of Things*, BoR (15) 141, page 9*ff*

160 See http://apps.ero.dk/eccnews/april-2016/numbering_resources_in_support_of_m2m.html

Type Approval / Certification

In broad terms, the purpose of type approval process is to avoid harmful radio frequency interference, reduce electromagnetic incompatibility issues and exposure to radiation levels which are beyond acceptable safety norms. In other words, type approval protects public safety and physical network infrastructure.

According to a recent report by the GSMA[161], there are two organizations involved in the IoT certification process:

- Global Certification Forum (GCF)
- PCS Type Certification Review Board (PTCRB)

GCF is independent organization which defines the certification framework for devices that are based on cellular technologies such as GSM, UMTS, LTE, NB-IoT and 5G from 3GPP. GCF operates based on vendor and operator membership, and has a number of working groups. GCF certification is widely used in many regions and can be considered as a global certification body.

North American network operators established PTCRB as an independent organization to provide the framework for cellular mobile devices and communication modules to obtain certification for use on PTCRB operator networks. PTCRB certification is considered regional, covering mainly North America. The PTCRB membership includes network operators, device manufacturers and test labs. A PTCRB working group of authorized test labs own the test cases for PTCRB certification, which are based on the cellular technology specification such as 3GPP's UMTS and LTE. Both GCF and PTCRB publish a list of IoT certified products.

Certification practices for IoT equipment at the level of individual countries, such as Nigeria, even if it was fully operational would have a limited positive effect because many of the IoT devices are imported. As such, Nigeria should support the quick adoption and enforcement of international security standards for IoT devices by all countries through its interaction at the ITU and other related fora.

As Nigeria prepares itself for the deployment of 5G networks, Nigeria's policy makers must carefully balance implementing new specific IoT regulation with creating an environment that allows IoT innovation to thrive. Overstepping regulatory intervention is capable of stifling industry initiatives and eroding consumer benefits. On the other hand "do nothing" or a "wait and see" approach have the potential to create risks for public safety.

[161] GSMA, 'IoT Device Certification Report', September, 2019

In relation to the spectrum needs and the spectrum road-map for 5G IoT in Nigeria, the following are apt regulatory approaches:

I. Align regulatory framework with global and regional development
II. Utilize sub 1 GHz bands for IoT

Align regulatory framework with global and regional development

Given the global nature of 5G IoT device availability, it is in Nigeria's interest to align itself, where possible, with global and regional developments. A unique Nigerian approach to 5G IoT spectrum allocations and regulation is not workable and could be costly. An optimal approach would be a regulatory framework that facilitates the development and growth of IoT, and does not impose service or technological restrictions that could hold back innovation.

The European approach to IoT as articulated by the RSPG has merit given the above argument. Specifically, the RSPG concluded that *inter alia*:

- As IoT is heterogeneous - there is no single solution for access to spectrum that fits all these possible use cases since their technical requirements differ dramatically;
- Allocating and designating bands (solely) for IoT is not needed; and
- Frequencies allocated or identified for electronic communication services (mobile networks) may be used for emerging IoT applications and services – including the 700, 800, 900, 2100 and 2600 MHz bands.

These views are arguably different from those of the GSMA which are advocating for the following:

- Regulators should adopt a service/technology neutral framework to support cellular IoT services;
- Licensed spectrum has the capacity and coverage capabilities to support IoT growth.[162]

Nigeria should not restrict IoT spectrum and hence deployments solely to the MNOs. The MNOs already have significant advantages; it seems that if they make the requisite investments in the necessary systems, then they will stake a strong if not unassailable market position.

Utilize sub 1 GHz bands for IoT

It is recommended that Nigeria utilizes the 700 MHz band for NB-IoT. The wide and deep coverage it can provide and the fact that NB-IoT chipset fully supported, make this band a viable candidate.
In Australia the 700 MHz band has been instrumental in extending 4G coverage to regional and remote areas of Australia that would have been economically problematic to do otherwise. Prior to the deployment of 700 MHz, Australia's leading provider Telstra had networks covering approximately 85 percent of population and 100,000 sq. km.[163] The use of this band in conjunction

162 See GSMA, *Spectrum for the Internet of Things, GSMA Public Policy Position,* August 2016.
163 See GSMA, *Securing the Digital dividend across the entire ASEAN*, August 2018, page 11

with existing and new 4G sites helped push Telstra's 4G coverage to over 99% of the population and more than 1.6M sq. km of Australia including NB-IoT coverage.[164]

In emerging markets such as the Philippines, the ability of 700 MHz to support NB-IoT/LTE-M services is excellent given the improved coverage and lower costs.[165] It is also important to emphasize that IoT encompasses a broader set of applications and use cases than those enabled by today's mobile cellular networks. New IoT use cases will be enabled by 5G since some specific IoT functionality will be designed into 5G from the start, with features including network slicing, low energy consumption and scalability. As previously discussed, such factors may be addressed by including a requirement to support MNOs in relation to 5G spectrum, including the 700 MHz band.

4.13. International Transmission Capacity and Cloud Infrastructure to Support 5G

The advent of 5G mobile services will create significant new demands on international and domestic network infrastructure. Data traffic is anticipated to increase between 10 and 100 times in the period 2020 – 2030.[166] Growth in the number of end-user devices and services, as well as the demand for enhanced user experience will mean that there will be significantly greater volumes of data being created in the 5G environment. In turn, network infrastructure will face huge pressures to transmit, store and access this data at ever-higher service levels demanded by end users.

The discussion in this section focuses on two key aspects of network infrastructure, namely international transmission capacity and cloud infrastructure. International transmission capacity refers to network platforms which enable data to be transmitted across Nigeria's international borders. Essentially, this refers to submarine cable systems, satellite systems and terrestrial cable systems. Cloud infrastructure refers to data centers which are secure facilities where computing and networking equipment are concentrated for the purpose of collecting, storing, processing, distributing or allowing access to large amounts of data. The discussion aims to assess the key requirements of these infrastructures that Nigeria will need to have in place to cope with the demands of the 5G environment.

4.13.1. International Transmission Capacity

Nigeria's international data transmission is primarily handled by a number of undersea or submarine cable systems and through satellite systems. There is no evident international data transmission through terrestrial cable systems. Nigeria's terrestrial cable systems appear to be confined to domestic data transmission. The transmission services provided by these systems include the following:

- DWDM and SDH;
- Cross Connect;
- IP Transit and DDoS;
- MPLS;

164 *Ibid*
165 *Ibid*
166 ITU www.itu.int/en/mediacentre/backgrounders/Pages/5G-fifth-generation-of-mobile-technologies.aspx

- DIA and BIA;
- Dark Fiber; and
- Co-location.

Nigeria currently has six submarine cable systems landing on its shore delivering over 40 terabytes of internet traffic capacity. [167] These cable systems and their respective operators are as follows:

- SAT3 landed by Natcom;
- MainOne Cable landed by MainOne;
- Glo1 Cable landed by Globacom;
- ACE Cable landed by Dolphin Telecom;
- WACs Cable landed by MTN; and
- Nigeria Cameroon Submarine Cable System (NCSCS) landed by Camtel.

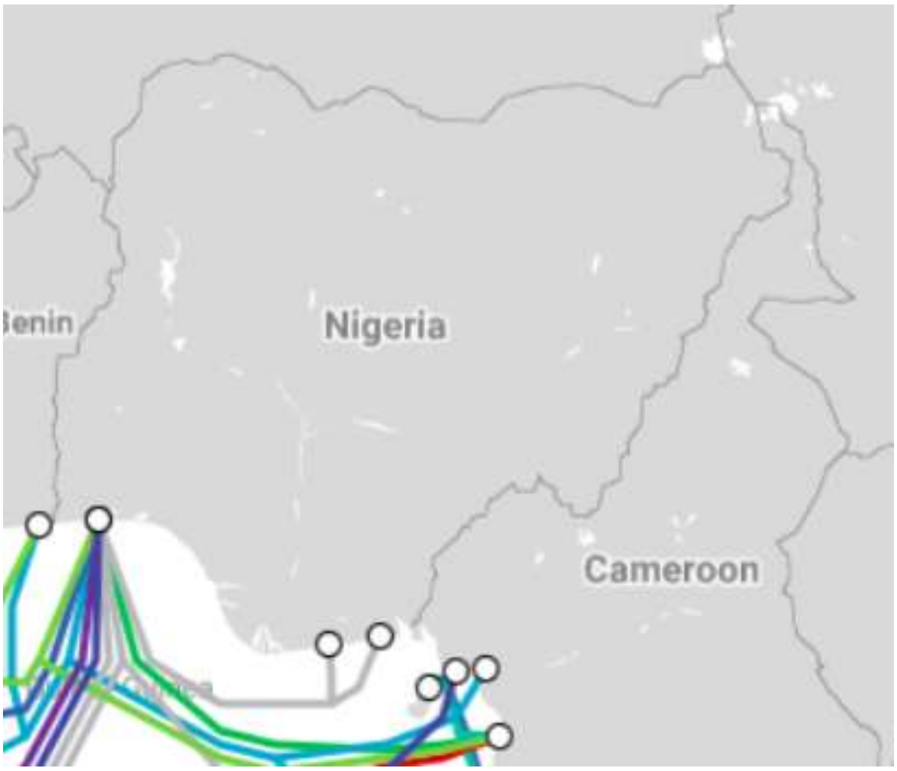
As illustrated in Exhibit 4.35, these submarine cable systems have their Nigerian landing points in Lagos. In addition to these existing submarine cable systems, there are three additional systems which are under construction.[168] These include:

- 2Africa (Owners include Facebook, Vodafone, MTN Group, China Mobile);
- Equiano (Google); and
- Glo2 (Globacom).

It is noted that Glo2 will link the Lagos landing point of Glo1 to other landing points in Nigeria.

167 Nigeria National Broadband Plan 2020-2025, page 18
168 www.submarinecablemap.com/#/

Exhibit 4.35: Submarine cable systems landing in Nigeria



Source: Telegeography, 2020

The collective utilization of these cable systems is reported to be just 10 *per cent* of their available capacity.[169] This low level of utilization is understood to be primarily due to domestic infrastructure limitations. *Prima facie*, with five currently underutilized submarine cable systems and further systems under construction, Nigeria would appear to be well equipped to cope with the international data traffic demands of 5G. Given the under-utilization of these systems, the priority area of policy concern is the apparent limitations in domestic infrastructure.

NigComSat is a Nigerian Government entity domiciled under the Ministry of Communications which owns and operates the Nigerian Communications Satellite systems. It began providing services in 2007, and operates "NigComSat-1R" which is a Chinese built satellite providing domestic and international data transmission capacity. NigComSat-1R was launched in 2011 after the original satellite "NigComSat-1" lost power and was ultimately de-orbited in 2009.

It is evident that NigComSat has been widely criticized for its under-performance.[170] It has not reported an operating profit and depends on Government subsidies to remain in operation. In addition to NigComSat, there is a wide range of international satellite service providers which operate satellites that have footprints covering Nigeria. These satellites provide *inter alia* two-way satellite Internet coverage. *Prima facie* with a wide range of satellites that cover Nigeria and which

169 Nigeria National Broadband Plan 2020-2025, page 18

170 See for example: https://technext.ng/2020/06/01/14-years-after-and-billions-in-allocation-nigerias-satellite-company-nigcomsat-has-nothing-to-show/

provide a range of communications services, it would appear that Nigeria has sufficient satellite capacity to cope with the international traffic demands of 5G services.

4.13.2. Cloud Infrastructure

The 5G environment is characterized by the data-hungry applications it enables the prolific number of devices that it can support. The result is a data-boom that creates huge challenges for data centers which provide the necessary network infrastructure to store and transport ever increasing volumes of data.

It is widely accepted that the emergence of 5G networks will force changes in how data centers are designed and structured and the role they play in the larger network. The old data center infrastructure is reaching a critical point. The demand for data has pushed data centers to expand their storage and transport capacities to meet the storage and processing needs of the billions of applications that are enabled in the 5G environment. At the same time, data centers are being required to operate more efficiently with regard to their consumption of energy and their impact on the physical environment.

Edge Computing

The emphasis is not on how much data is being generated, but where the data is coming from and the network requirements that are needed to support it. The challenges of coping with this growing flood of data is forcing data centers to be closer to their customers, resulting in more edge deployments, while also forcing data center operators to increase speed, security and efficiency at the same time as they minimize latency.

Increasingly, applications at the network edge such as IoT, artificial intelligence, machine-to-machine communications are generating tremendous amounts of data. Many such applications demand ultra-reliable low-latency: mid and single-digit millisecond performance. Mobile edge computing addresses this challenge by storing and conducting the analysis at the network edge which is outside the cloud. This dramatically reduces data transmission times.

Preparing for future data needs is as much about innovating data creation as it is about ensuring that the supporting infrastructure is flexible, scalable and responsive. The vast amount of data that will be processed at the edge in the 5G environment strongly suggests that there will be a shift from cloud-scale data centers towards localized, low-latency services in order operate efficiently and to meet user requirements. That is to say that data centers will “drag” some of their computing capability to the edge, resulting in smaller data centers which would be geographically dispersed rather than being concentrated in major cities.

Energy Efficiency

In addition to ever-increasing data speeds and volumes, data centers also face the challenge of reducing their energy consumption. The unstoppable appetite for data, both in terms of volume and speed, is putting unsustainable pressure on power consumption.

At the global level, data centers are estimated to consume about 3 *per cent* of electricity supply and account for about 2 *per cent* of total greenhouse gas emissions.[171] Data centers face the challenge of maximizing their operational performance while minimizing their power consumption. This is leading to innovative data center design. For instance, data centers are increasingly located in colder climates to ease the cooling requirements and renewable energy sources are being harnessed to reduce the burden on the energy grid.

Nigeria's Data Centers

Nigeria is understood to have at least 10 data centers of which most are located in Lagos. Among these are data centers operated by MainOne MDX-i, Rack Centre Limited and Medallion Communications. It is reported that a number of players are expected to develop regional data centers which include iColo, West Africa Datacenters / PAIX, etix Everywhere, IXAfrica and N+One.[172]

Prima facie, Nigeria would appear to have adequate current and future data center capacity to cope with the 5G environment. It was observed during the local aspect of the study that Nigeria already has some large data centers in Lagos and plans are underway to establish regional data centers in line with market trends. Moreover, the existence of multiple players would suggest that there will be on-going competitive pressure to ensure that data centers will be operationally efficient.

171 See Viavi Solutions, *The Data Center of Tomorrow, Insight Report*, April 2020
172 See https://data-economy.com/africa-data-centre-and-fibre-investment-sustained-in-forward-looking-markets/

Objective Four: to determine what Nigeria needs to do differently or uniquely with regards to global and regional deployment of 5G

Key Findings:

4.14. Using 5G for Fixed Wireless Access (FWA)

Globally, FWA has reached a landmark global take-up of over 100 million customers. In emerging markets, including but not limited to Thailand, Sri Lanka and South Africa, FWA deployment using 4G and 5G technologies offer a quick and affordable way of improving overall telecommunication service quality. In a fixed wireless update released on 30 November 2020, the GSA stated that of the more than 120 operators that had announced 5G deployments worldwide as of mid-November 2020, it had recorded 44 operators that have announced the launch of either residential or business 5G FWA broadband services. In six months, this figure jumped from 31% to 42%. [173]

FWA is both a viable substitute as well as complement to FTTX fixed services. Early FWA provisioning not only makes emerging country businesses more competitive, but also offers a way to quickly and cost-effectively bring high-speed broadband services to high-rise residential buildings in urban centers. Given the demand for video streaming and other content services, the delivery of faster broadband services with good-quality service at a lower cost is desired by many subscribers.

In addition, FWA deployment offers a stepping-stone towards future deployments of fixed infrastructure. Deploying higher speed 4G and 5G services will entail additional fiber to wireless base stations or nodes. This lays the groundwork for future FTTX deployments, while still delivering high-quality FWA services earlier than would otherwise be possible. In effect, FWA offers immediate benefits to telecommunications consumers as fiber reaches out from national telecommunications nodes to wireless distribution points and on to businesses and residences at later dates

From a spectrum management perspective, the NCC should be mindful the growing use of FWA, and include such services in the spectrum roadmaps and demand analysis. It must also be recognized that 4G, and especially 5G, are best implemented if harmonized IMT spectrum using the 2.3, 2.6 or 3.5 GHz spectrum bands are allocated to licensees in larger contiguous blocks.

Larger spectrum allocations – if they can be done at reasonable prices – allow mobile operators to deploy wireless networks which can be shared for both mobile and FWA applications. This provides a seemingly magical solution to the complicated problem of encouraging competitive pressures in the broadband markets. Certainly, artificial limitations on the use of spectrum for “fixed” and “mobile” services should be removed. Spectrum allocations should be technology-neutral as well, allowing providers to invest in and deploy optimal technology solutions.

Furthermore, to ensure that rural dwellers also have access to the digital economy, freeing up additional sub-1 GHz spectrum allows FWA services to also make use of these bands. 4G and 5G FWA services at sub-1 GHz offer the fastest and most cost-effective pathway to bridging the digital

173 GSA, *Fixed Wireless Access: Global Status update, November 2020, Industry Report to determine the extent of FWA services*. Available at www.gsacom.com

divide between urban and rural populations. The 2020 agreement between China Mobile and CBN in China which includes access to the 700 MHz spectrum to improve 5G access is a good example of a forward looking strategy in this regard.

Lastly, given the global coronavirus (COVID-19) pandemic, FWA services are becoming more critical. FWA services can be quickly deployed to regions where existing digital infrastructure is insufficient, obsolete or needs augmentation to meet increased customer demand.

4.15. Using 5G for Enterprise and Industry

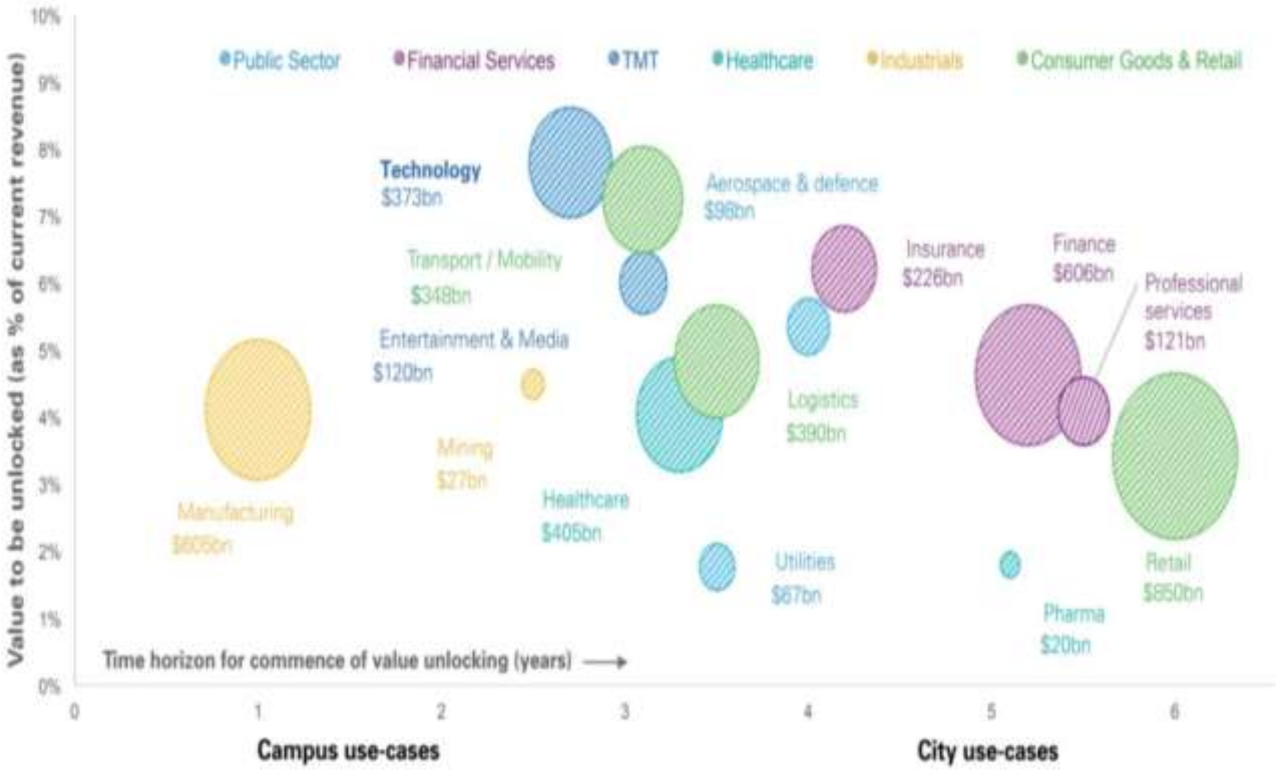
The 3GPP indicated this spotlight on industry expansion in July 2020 with 5G NR Release 16 and set the stage for enterprise and industry verticals (industries outside of mainstream ICT sector) to harness the benefits of providing high-performance wireless connectivity with 5G private networks. With a variety of options for spectrum, different network architectures, a rich feature designated to meet the huge demands of industrial IoT, as well as the privacy and security required for business assurance, 5G private networks are poised to transform enterprise and industry.

In 2019, HMS Labs, an industrial communications specialist, predicted that 5G would provide “safer, flexible and more efficient manufacturing systems,” filling an urgent hole.[174] ABI Research has forecasted that manufacturing will provide a significant percentage of revenue for the 5G URLLC use case market.[175]

5G will unlock value across major industry verticals. As shown below in Exhibit 4.36, certain industries are likely to benefit more from 5G systems.

174 https://5g.co.uk/news/5g-factories-super-smart/4834/
175 https://5g.co.uk/news/manufacturing-will-generate-25-of-5g-revenue-by-2028/5140/

Exhibit 4.36: KPMG (DNA of 5G industry value of various vertical industries)



Source: KPMG, Unlocking the benefits of 5G for Enterprise Customers, 2019

Manufacturing companies run highly precise, high-output, and largely automated operations using low-latency commercial and private 5G network. It is expected that by 2030, USD400 to USD 500bbillion of GDP will amount to business value resulting from manufacturing sector use cases running on improved connectivity.[176] See Exhibit 4.37.

176 McKinsey Global Institute (business and economics research arm of McKinsey & Company), *Connected world: An evolution in connectivity beyond the 5G revolution,* February 2020

Exhibit 4.37: Manufacturing Case Study: Centrica Storage

In August 2020, energy giant Centrica Storage announced that it will use Vodafone Business to build a 5G mobile private network (MPN) for gas plant in Yorkshire, United Kingdom. Safety is the critical measure of success at Centrica Storage and the solution aims to reduce risk for everyone on the site.

The MPN will be built by Vodafone Business using Ericsson equipment. This will be the first 5G mobile private network for the oil and gas industry.

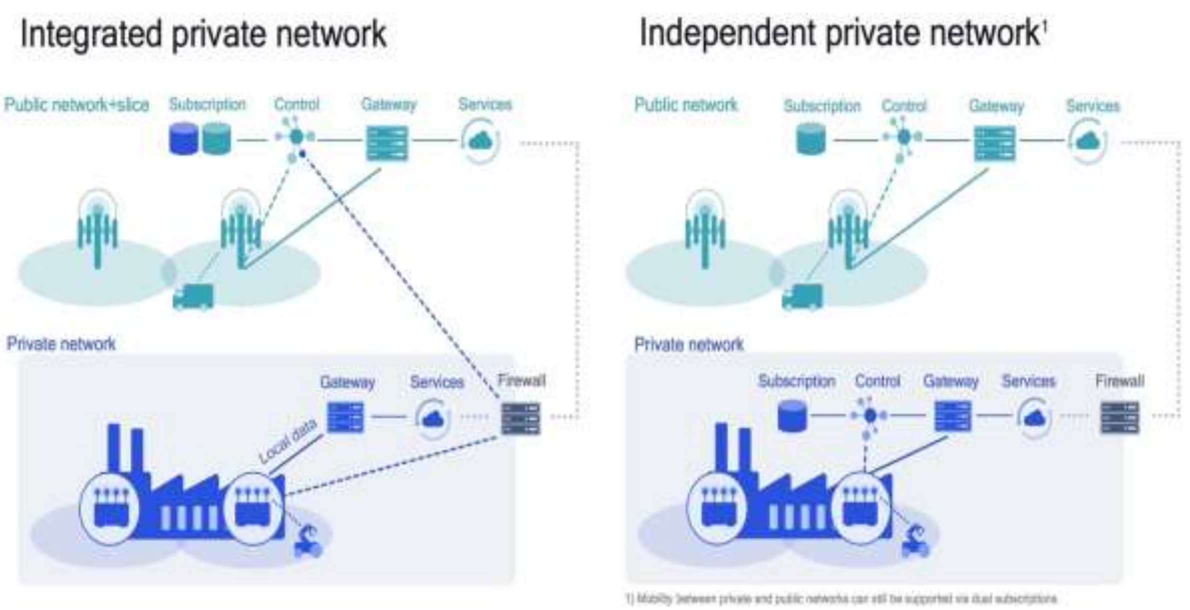
Centrica aims to create a "fully connected digital ecosystem" which allow for real-time indoor and outdoor monitoring of the plant and its equipment with the aim to improve maintenance and safety. For example, workers will be alerted to any gas emission or receive early warnings of any equipment on the point of failure.

There are a number of different models which could be adopted including enterprises running their own private networks or the MNOs assisting the enterprise customer by providing capacity, reliability, latency, bandwidth and efficiency (as shown in Exhibit 4.38).

There has been an increase in the number of MNO's working with businesses to create a variety of 5G powered businesses. Globally, licensing approaches have endorsed a licensing option for small-area and multi-device deployments for proposed 5G applications.

Such arrangements, while not exclusively restricted to industrial or commercial applications of spectrum, have often been utilized by a variety of industry verticals such as mining and infrastructure that use spectrum to facilitate their operations.

Exhibit 4.38: Multiple private network architectures for flexible deployments



Source: Qualcomm, *Transforming enterprise and industry with 5G private networks*, 15 October 2020, page 10

4.16. Implementing Coverage Commitments

In terms of 5G coverage or rollout commitments (and the incentives to facilitate such investments by the MNOs), it is instructive to examine the requirements imposed by a range of other country regulators and Governments globally and in the region. A range of selected country 5G coverage requirements can be found in Exhibit 4.39. With reasonable pricing and/or a direct allocation of spectrum, the NCC should consider including a network rollout obligation in the 3.5 GHz spectrum license of say, 30 percent coverage of Nigeria's population within 3 years. This coverage commitment figure could be increased to 50 percent or more by possibly making available sub-1 GHz spectrum and the re-farming of legacy IMT spectrum for 5G.[177]

Exhibit 4.39: Selected country 5G rollout/geographic commitments

Country	Rollout/Geographic Coverage Commitments
Austria	A successful bidder for a 5G license must provide up to 1,000 locations. Around a third of these locations must be provided by the end of 2020. By the end of 2025, an almost nationwide availability of 5G should have been realized.
China	The Chinese Government established a number of key policy initiatives to facilitate 5G rollout including *inter alia* that Beijing, Guangzhou, Shanghai and Shenzhen would have 100 percent coverage in 2 years. In addition, the Guangdong Province would have 100 percent coverage in 3 years. In March 2020, China's Ministry of Industry and Information Technology (MIIT) published a directive calling on localities to accelerate 5G network and applications to minimize the impact of the coronavirus.
France	ARCEP stipulated that each MNO that was a winning bidder for 3.5 GHz band spectrum must launch 5G services in at least 2 cities before the end of 2020. Operators must deploy 3,000 cell sites in 2022, 8,000 sites in 2024, and 10,500 sites in 2025. Eventually, all of the cell sites must provide 5G services using 3.5 GHz spectrum. 25% of 3.4-3.8 GHz band sites in the last 2 stages (2024 and 2025) must be located in sparsely populated areas, targeting economic activity, notably manufacturing, excluding major metropolitan areas. By 2022, at least 75% of cell sites must be capable of providing speeds of at least 240 Mbit/s at each site. This obligation will be gradually applied to all cell sites, up to 2030. Obligations also apply to coverage of the country's motorways (16,642 km) by 2025 then, by 2027, coverage of the main roadways (54,913 km). These obligations stipulate connection speeds of a minimum 100 Mbit/s at each cell site.
Germany	Operators winning 2.1GHz and 3.6GHz band licenses must supply minimum speeds of 100Mbps to at least 98% of households by the end of 2022. Operators must also install 1,000 5G base stations and extra 500 base stations in the 'white spot' area
Hong Kong	Spectrum assignees of the 26GHz, 28GHz 5G licenses are required to install 20% of the minimum number of radio units required to be installed within the first three years following spectrum assignment, an addition of 30% within four years, and an addition of the remaining 50% within five years.
Italy	Winners of both the 80 and 20 MHz and 3.5 GHz spectrum lots must cover 40 percent of the population in 2 and 4 years respectively at a minimum spectrum of 30 Mbps. Winners of the 700MHz band are required to roll out improved mobile coverage of national population, tourist locations and main

[177] Any such coverage requirements should be consistent with Nigeria's broader policy settings in relation to national broadband coverage, bridging the digital divide and universal services.

Country	Rollout/Geographic Coverage Commitments
	national road and rail transport routes. Winners of the 3600-3800 MHz band must roll out improved mobile coverage in a mandatory list of municipalities within 72 months from the date of the award.
Japan	While the 5G geographic coverage was set by the MIC at a minimum of at least 50 percent of national and regional blocks within 5 years, the MNOs who made a larger rollout commitment with higher spectrum utilization were allocated more mid- band spectrum. This was based on consolidated scoring and ranking of the MNO bids. 5G spectrum was also allocated for free. The final MNO coverage commitments were NTT Docomo 97.0%, KDDI 93.2%, Softbank 64% and Rakuten 56.1%.
Saudi Arabia	The population coverage target is 60 percent by 2021 with a user experience of at least 65 Mbps. As well as a reduction in spectrum fees, the royalty fee has also been reduced from 15 to 10 percent and other changes have been made in order to facilitate the MNO's expansion of their infrastructure over the next 3 years.
Singapore	The two winners of 3.5 GHz band spectrum in Singapore are required to deliver 50% island wide coverage by the end of 2022, and full coverage by the end of 2025.
South Korea	The KCC regulatory requirement was for 150,000 5G base stations in the 3.5 GHz band with 15 percent (ie 22,500) to be deployed in 3 years and 30 percent in 5 years (ie 45,000) however, competition in the market is driving much faster 5G deployment. About 90 percent of the South Korean population is covered for 5G. Some 70,000 base stations have been deployed by SK Telecom and 80,000 by LGU+.
Thailand	The NBTC is motivating 5G investment in Thailand by giving 3 years grace period for any repayment if 5G is deployed in 50 percent of Eastern Economic Corridor (ECC) Area within 1 year and 50 percent of smart city within 4 years.

Source: Windsor Place Consulting Analysis, November 2020 from a range of regulator and industry sources

Any rollout obligation applying specifically to the 3.5 GHz band must necessarily take into account the urbanization rate of Nigeria, the high cost of 5G network deployment and the likely adoption/availability of 5G enabled handsets and other devices in the country in the short term.

In addition, the NCC should mandate minimum 5G download speeds as this is the case in a number of global markets. To secure the benefits of 5G for Nigeria and to be significantly faster than current speeds, the minimum could be prescribed as at least 30 Mbps for users within 3.5 GHz 5G coverage areas and rising over time.

4.17. Assessing Suitable 5G Spectrum Licensing Options

Spectrum demands nationwide assignments of large contiguous bands at reasonable prices that will guarantee robust 5G investments and optimal socio-economic gains for Nigeria.

4.17.1. Overview of Spectrum Licensing

The ultimate goal of spectrum licensing is to ensure an efficient allocation of spectrum resources. In managing spectrum, governments and regulators should be concerned with achieving two forms of efficiency namely technical efficiency and economic efficiency. These are similar but distinct concepts. In summary:

- An ***economically efficient*** use of spectrum requires the maximization of the value of outputs produced from available spectrum, including the valuation of public outputs provided by the government or other public authorities; and
- A ***technically efficient*** use of spectrum requires the complete utilization of all available spectrum, with a particular focus on occupancy and efficiency. Exhibit 4.40 shows various degrees of regulatory control that are used in allocating spectrum. Even when considering an auction process, there are a range of restrictions that are employed by regulators or government on either the behavior of bidders during the allocation process itself, or the rights associated with spectrum licenses.

Exhibit 4.40: Degrees of regulation for initial and subsequent allocations

Allocation type	Initial allocation	Subsequent allocations
Market-based allocation	**Pure auction**: Auction involving few or no conditions on participants, with spectrum assigned to the highest bidders.	**Pure spectrum trading**: Holders may trade spectrum, with few or no limitations on who may buy or sell spectrum.
	Auction with caps or reserved spectrum: Limitations are placed on the total amount of spectrum bidders can acquire. Government may also set spectrum aside for new entrants.	**Spectrum transfers with caps**: Spectrum caps may also apply more broadly to operators so that they are prevented from holding spectrum over a certain amount. This may apply for trading and the acquisition of spectrum through consolidation.
	Auction with additional license obligations: Obligations may be imposed on successful bidders, e.g. roll out, coverage or QoS obligations that effectively limit participation and/ or affect the price paid.	**Transfer of license obligations**: Trade or transfer of spectrum may also result in transfer of obligations, effectively limiting the ability of some operators to hold spectrum.
Government-based allocation	**Comparative bidding**: Spectrum is allocated based on bids tendered by applicants. Spectrum is awarded to the highest bidder. Eligibility requirements may apply.	**Forced divestiture**: License holder is forced to sell spectrum, e.g. to address competition issues or if operator has exceeded spectrum cap.
	Beauty contest: Spectrum is allocated based on applications and proposals from operators. May involve obligations specific to licensee based on its network or business plan.	**Forced return of spectrum**: License holder is forced to return spectrum to the government, e.g. to address competition issues or if operator has exceeded spectrum cap.
	Direct assignment: Government makes assignments directly to operators without any auction or tender process, e.g. to private operators or to state-owned operators or public bodies.	**Suspension or revocation of spectrum rights**: Operator has license suspended or revoked, e.g. if it is in breach of law, regulations or license conditions.

Source: Windsor Place Consulting, 2020

A key consideration for the Government and NCC is to extract the maximum value of spectrum through the assignment process. Where spectrum is assigned through a market-based process, the regulator must ensure that participants have an incentive to bid according to their maximum willingness to pay, with no opportunity or incentive to collude with other bidders or coordinate their actions. However, it is critical that the key economic objective should always be maximizing the overall productive use of national assets, and consequently, maximizing returns for the nation.

4.17.2. Spectrum Auctions and Assessment of Formats

If a spectrum auction allocation process is adopted by the NCC, there are a number of spectrum auction types which include the following (see Exhibit 4.41).

Exhibit 4.41: Summary of the types of spectrum auctions

SMRA Simultaneous multiple round ascending auction	• Bid on specific blocks of interest (between minimum and maximum set by auctioneer for each block) • 'Standing high bids' for each lot in each round • Auction ends when there is no excess demand • 'First price': pay what you bid
CCA Combinatorial clock auction	• Bid on packages of generic lots rather than on individual lots • Pay 'second price': minimum needed to win and to avoid 'unhappy losers' • Separate assignment round for positioning in the band • Also pay 'second price' for assignment
Clock + 'First price' CCA	• Bid on packages of generic lots rather than on individual lots • Exit bids allowed (between last and current clock prices) • First price: pay what you bid • Auction ends when there is no excess demand • Separate assignment process (auction or administered)
Sealed bid auction	• Bidders simultaneously submit sealed bids - no bidder knows the value of other bids • Bidders submit one bid and cannot adjust based on competing bids • 'First price': pay what you bid (can use second price or shaded bid) • No subsequent rounds of bidding

Source: Copenhagen Economics, 2014

There are a number of different auction formats commonly used in bringing spectrum into the market. In line with the primary objective of efficiency in allocation, some auction formats will be more or less appropriate in the Nigerian context.

Some commonly known auction formats used for spectrum auctions are Sealed-bid auctions, Clock auctions, Simultaneous Multiple Round Ascending auction (SMRA) auctions, SMRA with switching auctions and Combinatorial Clock Auction (CCA) auctions. These formats can be characterized in terms of:

- *Price discovery*, i.e. whether or not bidders get to see bids from other bidders in the auction which can be used to update bidders' valuations during the auction.

- *Exposure risk*, i.e. whether or not bidders can win part of the spectrum they are interested in at a price that may exceed their willingness to pay for the given spectrum
- *Complexity*, i.e. how difficult it is to work with for bidders and the regulator in terms of understanding the rules.

It is generally desirable to choose an auction format that facilitates price discovery, has no exposure risk and has low complexity. A format that scores well in a given context against all of these criteria will likely yield a more efficient outcome. The inherent problem in auction design is that there is no simple solution to auction format given these preferences. Simple formats typically have either exposure risk or no price discovery.

Exhibit 4.42 characterizes auction formats according to the aforementioned three features.

Exhibit 4.42: Features of common spectrum auction formats

Auction format	Price discovery?	Exposure risk?	Complexity
Sealed-bid auction	No	Yes	Very simple
Clock auction	Yes	Yes	Very Simple
SMRA	Yes	Yes	Simple
SMRA with switching	Yes	Yes	Simple
CCA	Yes	No	Very complex

Sealed-bid auction

In a sealed-bid auction, each bidder delivers one set of bids in a sealed envelope, and the results are then calculated and announced. Each bidder is allowed to submit multiple bids for combinations of generic blocks called packages. The winning *allocation* are the combination of bids with the highest value, which is feasible to sell, while only selecting one package from each bidder.

The price paid depends on the price rule, which can either be a *first-price rule*, where all winning bidders pay their own winning bids. Or it can be a *second-price rule*, where a bidder pays the difference between the value of a counter-factual set of winning bids in which the bidder's set of bids is excluded and the value of the actual set of winning bids minus his own bid.[178] Bidders are free to bid any price above reservation prices for a given package. But bidders are restricted by spectrum caps in the amount of spectrum they can buy.

After the generic spectrum has been sold, the location of specific blocks won by each bidder is assigned in the *assignment round*. Bidders are guaranteed contiguous spectrum within each category but not continuous across time slices.[179] Each bidder bids on various placements given their

178 The bidder is said to pay 'the opportunity cost' of denying a package to the losing bidders.

179 Contiguity is only guaranteed within each category. Bidders are not guaranteed to win the same specific blocks across time periods.

respective winning packages. The assignment is selected by the combination of placement bids with the highest value, which is feasible to sell, while only selecting one placement from each bidder.

Clock auction

A clock auction is a first-price auction where bidders bid for generic spectrum blocks during multiple clock rounds. In each *clock round*, the auctioneer announces a price per block for each category, and each bidder responds with a binding bid for one package consisting of the number of blocks he demands. If total demand exceeds supply in any category the auctioneer increases the price and a new round commences. The clock rounds end when demand is less than or equal to supply. The winning allocation is the generic blocks demanded by the remaining bidders.

Bidders are restricted by spectrum caps in the amount of spectrum they can buy. Bidders are required to stay active in the auction. When a bidder demands a package of fewer blocks, the demand cannot be increased later. Further whenever a bidder reduces demand, it must place an *exit bid* (a last and final offer for an amount of spectrum that will be considered in the market clearing round at the end of the auction). Depending on the variation of the pricing rule, bidders pay between current round prices and the previous round prices per block demanded. Any unsold spectrum is sold to the demand reducing bidders through their exit bids.

After the generic spectrum has been sold, the location of specific blocks won by each bidder is assigned in the assignment round, as described above.

SMRA auction

The Simultaneous Multiple Round Ascending auction[180] is a relatively simple block bid auction that performs both allocation and assignment at the same time. In the standard SMRA, all blocks are open for sale simultaneously. Every specific block of spectrum has its own individual price in every round which is the *going price*. Each bidder places bids for the specific blocks of desired spectrum given their going prices. It has been used by regulators including the FCC and the NBTC.

After each round, a *standing high bidder* or *provisional winner* is identified for each block. If more than one bidder has placed a bid at the *going price* for the same block, the *standing high bidder* is drawn randomly and the round ends. The auctioneer then sets a minimum increment for new bids above the standing high bids. The bidders whose bids failed to become a standing high bid can either increase their bids on the same block or switch to another block. The bidders whose bids successfully became standing high bids cannot switch the standing high bids to any other block.

Bidders must actively participate in auction to stay in the auction. Each bidder's activity is measured in *eligibility points*. Every block of spectrum has an associated amount of eligibility points. A bidder is active, when it places bids for new blocks of spectrum equaling its eligibility points. A standing high bid also an active bid. If a bidder has active bids worth less eligibility points than its current eligibility, the bidder will lose the difference. When a bidder does not have any eligibility points left, it has withdrawn the auction.

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180 Paul Milgrom, "*Putting Auction Theory to Work: The Simultaneous Ascending Auction*", Journal of Political Economy, 2000, volume 108, no. 2.

The auction ends in the round where no new bids have been placed which is *the last round*. The *standing high bidders* will win their respective blocks paying the individual *going prices*.

SMRA auction with switching

The Simultaneous Multiple Round Ascending auction with flexible switching or SMRA+S is based on the standard SMRA, but allows the standing high bidder to switch his standing high bid to another block.

The procedures are exactly the same as standard SMRA except for two rules. First, a standing high bidder may switch to his standing high bid to another block. Second, inactive bids may become reactivated if superior bids are switched away from the block. If a bidder has an inactive bid reactivated, the bidder will recover the eligibility associated with the reactivated bid.

Combinatorial Clock Auction (CCA)

The Combinatorial Clock Auction, CCA auction is a complex package bid auction and has been used frequently in several European countries as well as by IMDA Singapore and ACMA in Australia.[181] CCA auctions involve three phases: a clock phase where bidders submit bid for one combination of generic blocks (one package) per round, a supplementary round where bidders can bid on many packages, and an assignment round where bidders bid for specific blocks. Bidders pay a *second price* based on the opportunity cost of denying a package to the losing bidders.

In the clock rounds, bidders bid for one package, i.e. one combination of blocks, in each round at prices that are given by the auctioneer. In the supplementary round, bidders can bid for many packages at prices that they can determine by themselves subject to bidding constraints revealed in the clock rounds. In both the clock rounds and the supplementary round, bidders bid for generic blocks. After the supplementary round bidders are notified of how many blocks they have won. In the assignment round, bidders can then bid for specific assignments for these blocks.

Assessment of optimal spectrum auction formats

In Exhibit 4.44, the benefits and problems of the auction formats are assessed.

Exhibit 4.44: Assessment of optimal spectrum auction formats

Type	Main Benefits	Main Problems
Sealed bid Auction	The main benefit of a sealed bid auction is that it performs fairly well in collecting revenue for the seller if auction lacks competition for the goods being sold as bidders will be wary of shading their bids too far due to the risk of not winning the required spectrum. However, this property critically hinges on the bidders being uncertain about both the number of	The main problem with sealed-bid auctions is lack of price discovery. Without price discovery bidders cannot update their valuations from competitors' behavior during the auction. Each bidder must predict the correct price level by himself or be forced to either pay too much or win too few or even no frequencies at all. This can lead to an inefficient allocation of the spectrum frequencies.

181 See www.acma.gov.au/theACMA/combinatorial-clock-auctions-reallocation-acma

Type	Main Benefits	Main Problems
	competing bidders and the size of their demands.	
SMRA	There are two main benefits of the SMRA. *First*, SMRA auctions are transparent throughout the auction, while facilitating price discovery. Bidders will know which package of blocks they will win and what prices they will pay, if the current round is the last round. *Second*, SMRA auction rules are simple to understand and formulate a bid strategy. This reduces the preparation time required for the bidders. Furthermore, the simplicity reduces the implementation costs for the NCC.	There are three main problems with the SMRA. *First,* bidders are not ensured of winning contiguous blocks of spectrum. Bidders can become stranded as standing high bidders on fragmented or undesirable blocks with no ability to switch to other blocks. This is referred to as *fragmentation risk*. *Second,* if spectrum blocks are complements, then a bidder can end up buying spectrum at a cost more than what it is willingness to pay. [182] This is referred to as *exposure risk. Third,* the SMRA suffers from the opportunity for strategic demand reduction.
SMRA+S	There are three main benefits of the SMRA+S auction. *First,* it is transparent throughout the auction, while facilitating price discovery. Bidders will know which package of blocks they will win and what prices they will pay, if the current round is the last round. *Second,* the auction rules are simple to understand. This reduces the preparation and simplifies the execution of a bidding strategy. Furthermore, the simplicity reduces the implementation costs of the NCC. *Third,* the fragmentation risk and some of the exposure risk are addressed by allowing the bidders to switch undesirable standing high bids.	There are three main problems of SMRA+S auction. *First,* it does not remove the exposure risk altogether. Bidders still run the risk of making a loss by winning an undesirable smaller part of the spectrum as they can switch but **not** drop their standing high bids. *Second,* a problem arises with SMRA+S auction due to the switching rule. If a bidder wishes to switch back to a block he has previously bid for, what price should the bidder then be required to accept? It can either be the current going price plus one increment (uniform pricing) or it can be the largest of his own previous bid and the current going price plus one increment (discriminatory pricing). Either solution has inherent problems. The going price plus one increment can potentially lead to the auction never ending while repeating the same pattern over and over again. Own bid plus one increment leads to bidders facing different prices, which can be perceived as unfair and result in an inefficient allocation. *Third,* the SMRA suffers from strategic demand reduction as the clock auction.
Clock Auction	There are three main benefits of the clock auction. *First,* clock auctions are transparent throughout the auction, while facilitating price discovery. Bidders will know which package of blocks they will win at a predictable price, should the current round be the last. *Second*, the clock auction is very simple to understand and formulate a bid strategy. This reduces the preparation time required for the bidders. At the same time the simplicity reduces the implementation costs for the NCC. *Third*, the clock auction with its generic block structure ensures bidders are awarded contiguous spectrum within each category.	There are two main problems with the clock auction in general if used in auctions where bidders can buy more than one lot (i.e. the problems will not exist in the 1800 MHz if bidders are only able to bid on one lot). *First,* it cannot eliminate *exposure risk* without introducing spiteful bidding (where a bidder with no intention of winning can artificially push prices up for others) if spectrum caps allow bidders to bid on several lots of spectrum. The clock auction format offers blocks of spectrum at a uniform per block price. However, the valuations of the demand reducing bidder in the last round need not be linear in respect of the number of blocks. If the blocks are complements[183] and the bidder wins one or more blocks in his exit bid, the price paid may exceed his valuation. The exposure risk can be removed by tweaking the exit bids, but it comes at the cost of allowing spiteful bidding. *Second,* the 'first price

182 The allocation exposure risk materializes if a bidder is outbid on one block based on his combination valuation and left stranded on the other at a going price exceeding his valuation for a single block.

183 Two blocks are said to be complements, if the half value of two blocks is larger than the value of one block

Type	Main Benefits	Main Problems
		rule' (you pay what you bid) may incentivize bidders to strategically lower their demand. This is done in order to obtain lower prices, but possibly at the cost of winning fewer blocks. However, this problem can be alleviated to an extent by reducing the information available to bidders during the auction. However, lowering demand in order to pay a lower price is not a relevant strategy when each bidder can only buy one lot in the auction.
CCA	There are two main benefits of the CCA auction that proponents have pointed out. *First,* the CCA auctions eliminate the exposure risk, because bidders submit bids for packages. Hence, there is no risk that bidders will end up with only a part of a package. *Second,* the auction format incentivizes truthful bidding, such that the bidders submit a bid for each package which corresponds to the valuation of this package (basically they bid based on maximizing the different between their valuation for a given package and the prevailing round price).	The CCA auction has three main problems apart from the unfulfilled assumptions for truthful bidding. First, the CCA format is highly complex and that the pricing rule is not transparent. This increases the costs of designing and implementing the auction significantly. Second, the outcome may not be perceived as fair. The packages won and prices paid can differ significantly between seemingly equal bidders. Third, is that the clock round may not identify the winning bids. This means that the primary rounds – which are intended for price discovery – have not properly revealed the prices for the bidders. Instead, they still face considerable uncertainty over prices and outcomes when going into the important sealed-bid supplementary round.

Source: Author, Copenhagen Economics, ACMA and other publications, 2019

A general criticism of the SMRA auction and variations of it as the SMRA+S, is the fact that it tries to solve both the allocation problem (how many blocks should each bidder win?) and the assignment problem (what specific blocks should each bidder win?) at the same time. This can prevent the format from solving either of the problems well.

Suppose the allocation of blocks has been settled, i.e. how many generic blocks each bidder is winning, bidders still need to coordinate within the two bands to obtain contiguous spectrum. Due to the standing high bidder rule, prices can inefficiently increase in one band and force a new allocation battle in the other band. Similarly, if the assignment has been settled and the allocation is ongoing, the competition for blocks can break up the assignment.

In summation, we find the combinatorial sealed bid auctions simple but lack the critical price discovery, while only offering a potential higher revenue in case of the auction lacking competition.

The SMRA format is a simple format, but there is an improved version with similar properties that take care of the fragmentation risk. However, the improved version still suffers from solving both allocation and assignment problems at the same time. Finally we find a number of challenges with the CCA format which adds significantly to the complexity.

Some of the problems of fragmentation risk can be alleviated with the inclusion of generic lots in the SMRA. In the simple case, the SMRA shares many characteristics of the Clock Auction which is a suitable candidate auction design for Nigeria.

In conclusion, we consider that while the Clock Auction and the SMRA share a number of characteristics in the Nigerian context, the Clock Auction is likely to be a better choice due to its reduced complexity and the additional flexibility applicable to the auctioneer in restricting certain information given to bidders during the auction that could be used by the bidders to tacitly collude.

The Clock Auction has merit on the basis of simplicity, price discovery and robustness to fragmentation risk.

Other benefits are:

I. very simple to understand, implement and prepare for;
II. transparent with a clear pricing rule;
III. can be designed to ensure contiguous allocations of spectrum;
IV. easy to manage the information given to bidders; and
V. maximizes the chances of yielding an efficient allocation of spectrum.

4.17.3. Administrative Approach to Spectrum Release

The administrative approach, often called 'beauty contests', is the other main approach for assigning the rights to use a particular spectrum band. It generally involves a licensing authority using its policies and processes to establish where sharing should take place and what rules should apply. It then assigns the spectrum to the candidate that is considered to have best met the criteria such as financial resources, industry experience, and rollout plans.[184]

Spectrum auctions are widely considered to be the most appropriate approach to assigning spectrum where demand exceeds supply, which is usually the case with IMT spectrum bands. However, there can be undesirable outcomes from auctions with artificially high reserve prices. For instance, high spectrum fees can discourage network deployment and negatively impact on consumer affordability. This is a particular concern with 5G given the costs of network provisioning and at least the initial pricing of 5G smartphones and other devices. 5G capital expenditure will also put more pressure on MNOs whose real rates of return have been under pressure given intense sector competition and may even be under more pressure due to the pandemic.

As such, the administrative approach is more appropriate in some cases as authorities set the license fee, which can encourage 5G network rollout including investment in backhaul transmission to support higher end-to- end broadband speeds. The administrative approach also has other notable advantages such as enabling authorities to consider a range of criteria and balance the trade-off between objectives, as well as facilitating a focus on delivering high quality services rather than raising revenues.[185]

The importance of pricing spectrum at reasonable levels was recognized in Singapore in its recent decision on 5G spectrum licenses and the applicable spectrum fees. In 17 October 2019, Singapore's

184 SATRC Working Group on Spectrum, 'SATRC Report on Spectrum Trading and Sharing', 2012; GSMA, 'Best practice in mobile spectrum licensing', September 2016.

185 GSMA, 'Best practice in mobile spectrum licensing', September 2016.

telecoms regulator, Infocomm Media Development Authority (IMDA) announced its plan for a base price of SGD55 million (USD40 million) for one 100 MHz lot of 3.5 GHz band spectrum (for a standalone 5G network), with a view to awarding the spectrum by the middle of 2020.[186]
The IMDA envisions that half the city-state will be covered by a standalone network by 2022 to 'maintain competitiveness in developing technology'.[187] The allocation of spectrum for nationwide deployment will be done via a call for proposal (CFP) approach, instead of an auction. This is in recognition that the auction mechanism will not be able to bring about the desired policy outcomes in this first wave of spectrum assignment.[188]

4.17.4. Spectrum Trading and the Nigerian Guidelines

Overview

Spectrum trading allows the market, as opposed to regulators and bureaucrats, to assign spectrum. This means that operators can decide the use they intend to make of their spectrum band, and the number of licensees that arise from the working of a marketplace.[189]

Spectrum trading is viewed as more economically efficient than administered methods of spectrum allocation. This is because trade only occurs only when there is a 'double coincidence of wants'. That is, a trade will only occur when the spectrum is worth more to the new user than it was to the old user, thereby reflecting the greater economic benefit which the new user expects to obtain from its use. [190] In addition to contributing to greater economic efficiency, spectrum trading also provides other benefits which include:

I. making it easier for new services to access spectrum and for existing users to balance their needs against costs;
II. helping optimize the use made of the spectrum on a dynamic basis;
III. providing additional flexibility;
IV. preventing spectrum hoarding;
V. making market entry easier for new players; and
VI. allowing operators to respond faster to changes in the technology and the market.

The Nigerian Spectrum Trading Guidelines

Sequel to the powers invested by the Nigerian Communications Act 2003, the NCC published the Spectrum Trading Guidelines on 12 April 2018. The objective is to promote efficiency and transparency by outlining the procedures and conditions for spectrum trading in Nigeria. The guidelines also seek to further liberalize the NCC's spectrum management policy towards the following:

- efficient and flexible transfer of spectrum to users who value it most;

186 www.zdnet.com/article/singapore-readies-5g-rollout-with-potential-for-two-additional-licenses/
187 www.commsupdate.com/articles/2019/10/17/imda-singapore-to-ensure-competitive-edge-by-allowing-four-5g-networks/
188 www.imda.gov.sg/-/media/Imda/Files/About/Media-Releases/2019/Annex-A---5G-Policy-and-Use-Cases.pdf
189 Tommaso M. Valletti, 'Spectrum trading', *Telecommunications Policy* 25 (2001) 655–670.
190 Ibid, SATRC Working Group on Spectrum, 'SATRC Report on Spectrum Trading and Sharing', 2012.

- reducing the barriers to market entry by allowing flexible access to spectrum;
- deepening competition; and
- promoting innovation by enabling entrepreneurs to acquire spectrum and offer new services.

Under the Guidelines, spectrum trading includes the following transactions: spectrum transfer, spectrum leasing and spectrum sharing. For licensees to be eligible to engage in spectrum trading, they must satisfy the following requirements specified in Section 4 of the Guidelines:

- The seller has held the spectrum for a minimum of two years;
- Where applicable, the seller must have achieved at least 25% of the roll-out obligation specified in the spectrum license; and
- Any spectrum license that is to be traded must still have a validity period of at least one year before the expiration of its tenure.[191]

Significantly, the Guidelines promote flexibility by allowing licensees to lease a part of its spectrum holding or the whole of the spectrum holding with respect to a particular part of the licensed area.[192] With respect to competition, if the NCC suspects that a transaction will negatively impact competition and other regulatory considerations, it may conduct an inquiry in respect of an application for spectrum trading.[193] Other key provisions include Section 6 and 7 which outline the fees and procedures for spectrum trading, as well as Section 10 which explains the effect of spectrum trading on roll-out obligations.

The Guidelines presents a welcome departure from the old spectrum licensing regime in Nigeria. Previously, the approach to spectrum trading was strict and inflexible such that a licensee was only able to acquire a spectrum license by acquiring the company holding the spectrum and seeking NCC's authorization to use the license.[194] In contrast, the current approach promotes flexibility, transparency and clarity in spectrum trading. It is also expected that the Guidelines would be beneficial to the 5G regime in the aspect of satisfying spectrum requirements.

Due to this revised regime, in March 2020, Airtel was able to acquire 10 MHz spectrum in the 900 MHz band from Intercellular for 94 million USD. According to Airtel, the additional spectrum will help reinforce its 4G position, increase the available capacity of the existing network, as well as provide more opportunities for data and home broadband services.[195]

Additionally, the Guidelines were welcomed by MNOs and other stakeholders, notably the GSMA. In June 2018, the GSMA released a statement commending the new Guidelines and commenting,

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191 Section 4.4 of the Spectrum Trading Guidelines. See https://www.ncc.gov.ng/docman-main/legal-regulatory/guidelines/802-legal-guidelines-spectrum-trading/file.

192 Ibid, Section 5.7.

193 Ibid, Section 5.5.

194 www.mondaq.com/Nigeria/Media-Telecoms-IT-Entertainment/797936/Opening-Up-Access-To-Spectrum-Transfer-In-Nigeria-Examining-The-NCC-Spectrum-Trading-Guidelines

195 https://guardian.ng/technology/bridging-access-gaps-through-spectrum-trading/

"This is a great revolution in the Nigerian regulatory environment and is a great achievement for the spectrum, policy and regulatory team in the Sub-Saharan Africa region."[196]

However, one aspect of Guidelines that may need review is the transaction costs. Although the administrative fee payable to the NCC is only 1% of the gross proceeds of the transaction,[197] the Guidelines also provide that the NCC will earn 60% commission on the net proceeds of the transaction when a licensee trades in frequency spectrum acquired through administrative process.[198] The NCC will also receive a commission of 40% of net proceeds for spectrum acquired before 31 December 2017.[199] It is still unclear how these significant charges will affect the motivation of licensees, who may be seeking to put together a large contiguous spectrum block for 5G use.[200]

Spectrum trading from a global perspective

As at 31 December 2020, no other country in Africa has allowed spectrum trading. In South Africa, a draft of the Electronic Communications Amendment Bill in September 2018 proposed that spectrum licenses can be traded, subject to approval from the regulator.[201] However, the subsequent withdrawal of this bill also resulted in the withdrawal of provisions relating to spectrum trading.[202] Furthermore, although the ECOWAS Spectrum Management Guidelines encourages the community to permit spectrum trading, no other member state has done so except Nigeria.[203]

As such, the introduction of the Guidelines puts Nigeria's spectrum regulatory regime ahead of its neighbors, bringing it in line with international best practice with countries such as Guatemala, UK and Australia (Exhibit 4.45).

Exhibit 4.45: Spectrum trading regimes in selected countries globally

Country	Comments
Australia	In Australia, the rules to trade a spectrum license are set out in the Radiocommunications Act 1992 and the Trading Rules for Spectrum Licenses Determination 2012.
Brazil	It was announced in November 2019 that Law 13,879/19 amended Brazil's General Telecommunications Law to allow the regulator to issue indefinite licenses and to allow spectrum trading.
Guatemala	Spectrum trading has been adopted in Guatemala since 1996.

196 www.gsma.com/subsaharanafrica/gsma-advocacy-produces-spectrum-trading-guidelines-in-nigeria
197 Section 7.1(i) of the Spectrum Trading Guidelines. See https://www.ncc.gov.ng/docman-main/legal-regulatory/guidelines/802-legal-guidelines-spectrum-trading/file.
198 Section 7.1(ii) of the Spectrum Trading Guidelines. See https://www.ncc.gov.ng/docman-main/legal-regulatory/guidelines/802-legal-guidelines-spectrum-trading/file.
199 Ibid.
200 www.mondaq.com/Nigeria/Media-Telecoms-IT-Entertainment/797936/Opening-Up-Access-To-Spectrum-Transfer-In-Nigeria-Examining-The-NCC-Spectrum-Trading-Guidelines
201 www.commsupdate.com/articles/2018/09/03/spectrum-trading-to-be-allowed-under-new-telecoms-bill/
202 www.mondaq.com/southafrica/Media-Telecoms-IT-Entertainment/798404/Assigning-High-Demand-Spectrum-In-The-ICT-Sector-A-Possible-Hybrid-Method
203 Rachel Alemu 2018, The Liberalization of the Telecommunications Sector in Sub-Saharan Africa and Fostering Competition in Telecommunications Service Markets; https://www.itu.int/ITU-D/treg/projects/itu-ec/Ghana/modules/Compil-Guidelines_final.pdf.

India	In October 2015, India Department of Telecommunications published Guidelines for Trading of Access Spectrum by Access Service Providers allowing mobile operators to trade any frequencies that they have held for over 2 years.
Singapore	In Singapore, spectrum trading is allowed, albeit not through a full-fledged trading regime.
New Zealand	Under the Radiocommunications Act 1989, spectrum rights can be freely traded by licensees.
UK	Holders of certain wireless telegraphy licenses granted by Ofcom under section 8 of the Wireless Telegraphy Act 2006 can transfer or lease the rights to use spectrum to another party.

Source: Windsor Place Consulting Research, May 2020 from a range of regulator and industry sources

4.17.5. Spectrum Valuation

Overview

The value or price of spectrum is determined by a range of factors, including the spectrum's highest value use, changes in technology and its availability across spectrum users, government's spectrum allocation plans, etc. Value of spectrum may be summed up as:

> *V = f {physical characteristics, geographic coverage, license regulations and conditions, technological change, underlying demand, policy certainty, etc.}*

There are two general methods used for calculating spectrum price. These are the direct calculation method using some form of net present value (NPV) or cost reduction approach, and market-based relative benchmarking method which incorporates current/recent market information. Looking at the first method, a rational firm will value spectrum based on its expected NPV of future returns (ie present value of net project cash flows minus the initial investment outlay of the spectrum).

This can be represented by the generic NPV equation:

$$NPV = \sum_{t=1}^{n} \frac{C_1}{(1+r)^t} - I_0$$

Where C_1 = net cash inflow-outflows during a single period t; I_0 = Initial Investment; r = required rate of return per period (the hurdle rate) or what could be earned in alternative investments; n = Life of the project and t = the time period

The NPV should in theory incorporate both the project-value and defensive value of the spectrum. This is sometimes known as full enterprise value. Internally, the mobile operators will develop a NPV value for any spectrum as part of their internal management approvals and/or prior to bidding in a spectrum auction. It should be noted that spectrum licenses may have different characteristics or conditions that affect their value. These include license term and duration, license coverage, technology, license fees, and other conditions such as rollout requirements, coverage requirements, quality of service, capacity of MNOs, etc.

For the second method, a valuation is done which assesses the value arising from use of an incremental block of spectrum to reduce infrastructure costs. Cost reduction value is calculated by modelling infrastructure costs with and without additional spectrum. Without the requisite corporate data, this type of analysis is not possible.

In congested areas, additional spectrum allows more capacity to be deployed per site (and therefore fewer sites are required). The valuation must account for coverage and capacity, including in-building penetration advantages of lower frequency bands, etc. The cost-reduction value is calculated as the difference between costs from a spectrum scenario with a marginal block of spectrum deprived in the relevant band and a base-line spectrum scenario. The cost reduction value sets a lower bound for spectrum value and hence the reserve price, because competition between operators will prevent price from falling below this value.

It ought to be noted that spectrum has no intrinsic value except that it enables an operator to create the value, which has much greater value than the cost of the spectrum. This includes investing and operating the network, and securing income or revenue from customers. The network operator must do so in a way that ensures income exceeds costs so as to create cash flow to give an adequate Return on Investment (ROI).

International spectrum pricing benchmarks

Benchmarking involves using data from spectrum awards in other jurisdictions to determine the likely price range of spectrum. Benchmarking derives estimates of spectrum value from revealed willingness to pay for spectrum in other awards. The benchmarks are therefore based on prices that have been paid by specific buyers in a particular country.

It is important to ensure comparison countries are properly selected. Awards must be as comparable as possible in the following respects:

I. Country should have similar income, level of economic development, political development;
II. Spectrum should have similar physical characteristics;
III. Licenses should have similar duration;
IV. Market should have similar structure, level of competition, existing spectrum holdings, access to technology; and
V. Recently, that is within a few years, to ensure that changes in forex to a common currency, GDP/capita as well as changes in population have not varied significantly, and because the nature and use of a particular band has changed significantly (eg 1800 MHz for LTE/4G services, 700 MHz for both 4G/5G services, 2600/3500 MHz for 5G services etc).

Therefore, several factors must be taken into account in making international benchmark comparisons in order to rebase the source numbers to a benchmark number. This is a simple yet complex process, which includes but not limited to the identification of comparable benchmarks (preferably in Asia), and adjusting for GDP/capita etc.

Calculating reserve prices

To convert a benchmark price to a reserve price is a simply applying X percent discount to that benchmark price. As indicated, these are typically in the range of 20 to 30 percent. However, it is important that the reserve price should be realistic and should not be bound by that band. Specifically, if the reserve price is set:

I. ***Too high*** – bidders may be deterred from entering thereby reducing competition. This could leave unsold spectrum although this is unlikely in Nigeria which could be releasing a small amount of spectrum. There is possibility of artificial scarcity in Nigeria as setting a high price usually results in a faux or fake auction (see a recent GSMA paper about what has happened to reserve prices in emerging markets);[204] and

II. ***Too low*** – too many bidders may be encouraged to enter into the auction. This is inefficient and obviously puts a question mark in the Nigerian context about under-pricing the asset.

Either could lead to a sub-optimal outcome. It is important to note that a low reserve price does not necessarily mean that final auction price will be low. However, if the competition in the spectrum auction is expected to be low, then the reserve price can be set higher to permit only a 10 percent discount. Ultimately, there is a judgement call to be made by the NCC on the reserve price in any price based allocation process. This is why most regulators seek an independent view as to fair and reasonable value from experts who have been involved in multiple spectrum auctions. See NERA paper on pricing.[205]

Annual frequency charges

Typically, foreign experiences indicate that even in the event of a spectrum auction, the successful bidders have to pay the administrative usage charges related to spectrum fees. This does not cause any difficulty as depending on the quantum of those fees[206], they will be included in the net present value (NPV) calculations of bidders (see Exhibit 4.46). As long as those fees are administrative (ie related to cost recovery etc), it is preferable they remain. If there are any increases because they were originally set too low, then optimally, they should be increased by way of glide path of possibly, 3 years.

Exhibit 4.46: Computation of Spectrum Prices in a Spectrum Auction (from the GSMA)

204 GSMA, Spectrum pricing in developing countries: Evidence to support better and more affordable mobile services, July 2018

205 NERA, Dr Hans Ihle, *Impact of excessive spectrum prices*, 3rd Annual Asia Pacific Spectrum Management Conference Bangkok, 2 May 2017

206 For example given the large annual fees in markets like Mexico and Denmark then they need to be included.

Bidding documents/ information memorandum contents and related issues

In the ITU publication, *Exploring the Economic Valuation of Spectrum*, April 2012, the paper details the recommended approach of pricing of in-demand spectrum from page 31. It also points out that: *"… there likely will be several potential applicants for each available spectrum block, requiring an assignment process that will apportion spectrum rights to the most qualified and/or financially capitalized operators. Potential assignment methods can include administrative evaluations or beauty contests, closed-bid tenders, or open, multi-round auctions."*

In the pages which follow the above quote, the ITU paper details the processes needed to undertake a transparent, competitive and open bidding process for those frequency bands where demand exceeds supply and where such processes ought to be followed. The topics explored in the ITU paper include the following:

- Determine the assignment method for competitive spectrum bands;
- Calculate a monetary value, defined in terms of per megahertz pop, for the spectrum offer;
- Design a competitive tender or auction;
- Undertaken pre-qualification; and
- Auction infrastructure and procedures.

In the paper, the ITU states that the best practice is to "*Seek public input and promote transparency of rule-setting*" and to "*Continue emphasis on transparency, openness and responsiveness."*[207]

Some countries like Australia have legislatively encoded such principles. The objects of the Australian *Radiocommunications Act 1992 (as amended)* in Section 3 include *inter alia* that the management of the radio frequency spectrum should:

"(a) maximize, by ensuring the efficient allocation and use of the spectrum, the overall public benefit derived from using the radiofrequency spectrum;

….

(e) provide an efficient, equitable and transparent system of charging for the use of spectrum, taking account of the value of both commercial and non-commercial use of spectrum;"

Potential assignment methods can include administrative evaluations or beauty contests, closed-bid tenders (ie using envelopes with say 2 rounds of bidding), or open, multi-round auctions (utilizing computer software etc). Lotteries were used in the early days of spectrum allocation in the United States but this method is discredited and no longer used. Based on exemplars from Australia, Asia and selected Middle Eastern markets, the items detailed in Exhibit 4.47 are typically included in an Information Memorandum prior to the allocation of spectrum.

[207] ITU, *Exploring the Economic Valuation of Spectrum*, April 2012, pages 33 and 34. Available at www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_SpectrumValue.pdf

Exhibit 4.47: Information memorandum typically prepared by the regulator prior to the release of spectrum

Issue	Typical Information	Country specific Inclusions
Market/ Sector	1. National economy 2. Overview of telecommunications sector 3. Fixed telephone market 4. Fixed broadband market 5. Mobile broadband market 6. International benchmarks (penetration rates, etc.)	Future forecasts
Legislation and Regulatory Framework	1. Relevant telecommunications act(s) outlining: a. Authorized regulator and its duties, objectives, and powers b. Licensing and regulations c. Tariffs d. Control of interference e. Penalties 2. Competition codes	Role of the government
Allocation method	E.g. Second-Price Simultaneous, Multiple-round, and Ascending (recommended); beauty contest; clock auction.	Bidder information sessions and mock auctions (offered prior to auction)[208]
Spectrum offered	1. Spectrum band(s) 2. Blocks or lots of spectrum (in MHz) 3. Reserve price 4. Spectrum caps (typically capped at one block/lot per bidder)	Can adjust cap based on spectrum band or whether winner is a new bidder or not[209]
Technical parameters and terms of license	1. Type of license offered (public vs. non-public, fixed vs. flexible, FDD vs. TDD) 2. Length of authorization (typically 15 years) 3. Geographic area and frequency range of license 4. Permissible outside-the-area emission limits 5. Coverage, speed of rollout or infrastructure sharing requirements 6. Levels of unacceptable interference	Corporate social responsibility plan and consumer protection plan[210]
Factors considered for pre-qualification (If Auction)	1. Non-affiliation (demonstrated compliance with anti-competition laws) 2. Financial capacity 3. Technical capacity 4. Commercial expertise	Require legally binding offer at reserve price for pre-qualification and/or bank guarantee[211]
Bidder Criteria (if Beauty Contest[212])	1. Preliminary business plan a. Technical plan b. Commercial proposal c. Financial projections and plan d. Coverage 2. Financial offer	
Cross-border co-ordination	1. Multilateral agreements the use of spectrum to which the spectrum may currently be subject	

208 NBTC, *Licensing of Spectrum for Telecommunications Service in the Frequency Band of 900 MHz*, p 39 (translation); ACMA, 3.6 GHz band auction, November 2018 Auction guide, p 62, August 2018.

209 IDA, *2016 Spectrum Auction*, p 11, updated 14 July 2016.

210 NBTC, Licensing of Spectrum for Telecommunications Service in the Frequency Band of 900 MHz, page 37 (translation).

211 IDA, *2016 Spectrum Auction*, page 26, updated 14 July 2016.

212 TRA, *Award of the Second Public Mobile License*, section B, 12 February 2004; MCMC, *Marketing Plan No. 1 of 2017*, section 3, 11 October 2017.

Issue	Typical Information	Country specific Inclusions
	2. Future cross-border agreements use of spectrum is conditional upon	
Auction forms	1. Bidder registration and authentication 2. Round-by-Round bid(s) 3. Participation waiver(s) 4. Drop out/Termination	
Price and payment terms	1. Spectrum auction fee is typically paid in instalments over 2 to 3 years, but can be paid in lump sum[213] Others like Indonesia have a 10 year payment term 2. Annual spectrum management fees and one-time application fees may also apply[214]	

Source: Windsor Place Consulting, 2019

<u>Spectrum license term</u>

In relation to the term of the spectrum license, a number of options are open to the NCC. These include a standard 15-year license, a lesser term of 10 years like Indonesia or a longer term of 18 years like Thailand. Alternatively, the license term could be made co-terminus with any of spectrum license which has been issued. A 15-year license is consistent with global exemplars. If the spectrum auction for any IMT spectrum bands is open to all bidders and not just the major operators, then it is appropriate that operators have the longer investment horizon and can secure longer and/or new operational licenses accordingly.

It is important to emphasize that from an optimal spectrum management perspective, spectrum allocations in the same IMT band ought to expire at the same or approximately the same date. Recently, various countries such as Australia, Austria, Ireland, Malaysia and other countries have had to extend spectrum allocations for short period of time in order to allow re-farming and re-allocation of the respective IMT bands. These is especially important if the spectrum band is to be auctioned.

Using synchronized expiry dates allow for contiguous spectrum allocations, even 2x5MHz (or larger) block sizes and one common expiry date per band. Different expiry dates also creates a risk of harass bidding. This issue arises because some current spectrum holders compete with challengers that do not have spectrum for sale during the period.
The challengers can then bid strategically to weaken the market position of the current spectrum holder in the transition period until more spectrum is available.

4.17.6. Pricing of Spectrum Licenses

Spectrum auctions are widely considered to be the appropriate and most transparent approach to assign spectrum where demand exceeds supply. This typically happens in the case of the IMT

213 MCMC, *Marketing Plan No. 1 of 2017*, p 14, 11 October 2017.
214 IDA, *2016 Spectrum Auction*, p 20, updated 14 July 2016.

spectrum bands. However, there are sub-optimal outcomes from poorly designed auctions - especially those with artificially high reserve prices - which should be avoided.

There is a growing global recognition that high spectrum fees can discourage network deployment, and negatively impact on consumer affordability. This is a particular concern with 5G given the costs of network provisioning and at least the initial pricing of 5G enabled smartphones and other devices. It is important to highlight that 5G capital expenditure will put more pressure on MNOs whose real rates of return have been under pressure due to intense sector competition.

Given the above, to encourage 5G network rollout in Nigeria including investment in backhaul transmission to support higher end –to- end broadband speeds, it is critical that spectrum be priced at reasonable and sustainable levels. This has also been recognized in Singapore, in its recent decision on 5G spectrum licenses and the applicable spectrum fees (see Exhibit 4.48). The French regulator, ARCEP has also taken a similar approach.[215] China has also facilitated the allocation of 5G spectrum including the 2.6, 3.5 and 4.8 GHz bands to the major Chinese MNOs while Japan allocated 3.5 GHz and other 5G bands for free to its major MNOs based on their level of 5G rollout commitments.[216]

It is for this reason that the pricing of 3.5 GHz spectrum allocations to the MNOs should be determined by the NCC to incentivize early deployment, and hence the fees should only recover any costs of spectrum re-farming of the 3.5 GHz band in Nigeria. The benefits of making 5G services available early in Nigeria significantly outweigh any revenue foregone from maximizing 5G spectrum prices.

Exhibit 4.48: Singapore IMDA's 5G licensing framework

On 17 October 2019, Singapore's telecoms regulator, Infocomm Media Development Authority (IMDA) announced its chosen method to allocate 5G-suitable spectrum in Singapore.[217] It envisioned that half the city-state would be covered by a standalone network by 2022 to 'maintain competitiveness in developing technology'. The allocation of spectrum for nationwide deployment was done via a Call for Proposal (CFP) approach, instead of an auction. This was in recognition that the auction mechanism would not be able to bring about the desired policy outcomes in this first wave of spectrum assignment.

Each operator was required to submit detailed proposals for their 5G deployment. IMDA scored and ranked the proposals according to the following: (a) network design and resilience (40%); (b) network rollout and performance (35%); (c) price offered for one lot of 3.5 GHz band (15%); and (d) financial capability (10%). The weights reflect their relative importance vis-à-vis IMDA's 5G policy outcomes. At the close of the CFP on 17 February 2020, IMDA had received three submissions: one from Singtel Mobile Singapore, one from TPG Telecom Pte Ltd, and one from the Joint-Venture Consortium (JVCo) formed by M1 Limited and StarHub Mobile Pte Ltd.

215 ARCEP proposed a mixed allocation mechanism, which does not rely on pure financial bidding. The procedure will include a first stage, in which up to four operators can obtain frequency blocks for optional commitments (aiming to ensure 5G fosters competitiveness in other sectors of the French economy, increase operators' transparency and stimulate innovation), before a second stage (auction), which will allow candidates to obtain additional frequencies. Each bidder will be allowed to purchase a maximum of 100MHz. See https://en.arcep.fr/news/press-releases/p/n/5g-4.html

216 See www.soumu.go.jp/main_content/000593247.pdf

217 IMDA, *Op cit*

On 24 June 2020, following an assessment of the submissions, two operators were awarded the 3.5 GHz Spectrum Rights: Singtel Mobile Singapore and the JVCo. Their spectrum rights come into force on 1 January 2021, and are valid until 31 December 2035.[218] TPG was applied for, and was ultimately assigned two 400MHz lots in the mmWave band.

The IMDA required each operator to pay a **base price of SGD55 million (USD40 million) for one 100 MHz lot of 3.5 GHz band spectrum** (for a standalone 5G network). Singtel submitted the winning assignment bid of SGD2, 100,128 to be assigned its preferred 100 MHz lot.[219]

Fitch Ratings, a credit rating company, noted that Singapore's base price translates to USD0.07 per MHz per capita. This is below Hong Kong's latest 5G spectrum auction which stood at USD0.09 per MHz per capita.

4.18. Non-Supporting Multiple Taxation and Regulatory Regimes

Taxation levels can influence the actions of telecommunication operators and investments in 5G. If taxation is so high such that it significantly impacts the profitability of a 5G rollout, there is less incentive for operators to make investments in 5G infrastructure. Telecommunications has historically been an important source of revenue for the Nigerian Government. For example, in the 2017 financial year, the mobile market was responsible for 16% of government tax revenue.[220]

With oil prices declining, the taxation of telecommunications operators remains a crucial source of revenue. However, operators and ancillary service providers in Nigeria have complained that there are over 38 different taxes and levies on their operations by various tiers of governments, and indicated that this scenario threatens the development of the industry.[221]

Telecommunication operators in Nigeria are subject to overlapping taxes in different jurisdictions. Because the nature of telecommunication services requires infrastructure to be located across the country, different government agencies, communities and tax authorities have to impose tax, leading to duplication. This also can create uncertainty about the amount of tax a telco may be required to pay, which is problematic because anticipated taxes are likely to be passed onto the consumer, thereby increasing the cost of services. One of such example of overlapping taxes are ROW charges.

In Nigeria, the National Inland Waterways Authority (NIWA) competes with the Federal Ministry for Works in charging ROW fees. NIWA charges fees for passing over waterways, whilst the Federal Ministry for Works charges ROW fees on bridges and other civil infrastructures.[222] This is also in addition to the ROW fees that are often charged by state governments. It should be noted, however, that certain states such as Ogun and Ekiti have slashed their ROW charges in an attempt to

218 www.imda.gov.sg/-/media/Imda/Files/Regulation-Licensing-and-Consultations/Frameworks-and-Policies/Spectrum-Management-and-Coordination/M1-and-StarHub-35-GHz-spectrum-right-2-Nov-2020.pdf?la=en

219 www.imda.gov.sg/regulations-and-licensing-listing/spectrum-management-and-coordination/spectrum-rights-auctions-and-assignment/5G-CFP-2020

220 www.gsma.com/publicpolicy/wp-content/uploads/2019/02/GSMA-Spotlight-on-Nigeria-Report.pdf

221 www.mondaq.com/nigeria/withholding-tax/751100/multiple-taxes-levies-and-regulations-in-the-nigerian-telecommunications-industry

222 ibid

encourage greater investment by operators in these areas after complaints about exorbitant pricing. Since May 2020, the federal government has waived ROW charges on federal highways in Nigeria.[223]

VAT

Telecommunication operators are subject to a VAT. In February 2020, the amount of VAT payable increased from 5 percent to 7.5 percent, and applies to voice, SMS and data tariffs on all mobile networks.[224] These increased charges were passed onto consumers.

In June 2020, the NCC announced it had signed a Memorandum of Understanding with the Federal Inland Revenue Service (FIRS). Under the MOU, FIRS will be able to independently verify the amount of VAT payable on qualifying transactions, rather than relying on account books of operators. This due diligence is not intended to create another layer of tax, but rather increase certainty in taxation and reduce incidents of multiple taxation.[225]

Sector-Specific Taxes

Additionally, telecommunication operators are subject a myriad of sector-specific and other 'bespoke' taxes in addition to general company taxes. The sector-specific taxes are:

- Annual Operating Levy (AOL): payable to the NCC, the tax is 2.5% of the operator's net revenue if they are a network operator, and 1% if they are a non-network operator. Since 2007, with the establishment of the Nigerian Universal Service Provision Fund (USPF), the NCC gives 40% of the AOL to the USPF.[226] The NCC has the discretion to increase or decrease the contribution to the USPF upon consideration of USPF operating expenses and recommendations made by USPF;
- National Cyber Security Fund: a levy of 0.005% is imposed on mobile service providers, all telecommunication companies and internet service providers. The levy applies to all electronic transactions;
- National Information Technology Development Fund Levy (NITDF): this tax is payable by telecommunication companies with a turnover of N100 million and above. The amount payable is 1% of the profit before tax. Contributions to the NITDF are tax deductible for income tax purposes; and
- Right of Way Charges: The size of the Right of Way charge varies dramatically in the different states in Nigeria. For example, the Lagos State government has fixed Right of way charges at 500 naira per linear meter of deployed optic fiber, but some other states charge up to N4000 per linear meter.[227]

223 https://techpoint.africa/2020/08/25/nigerian-states-rewards-row-charges/
224 https://techpoint.africa/2020/06/12/nigerias-digitally-verify-telcos-taxes/
225 https://assets.kpmg/content/dam/kpmg/us/pdf/2020/06/tnf-nigeria-jun16-2020.pdf
226 www.gsma.com/publicpolicy/wp-content/uploads/2016/09/GSMA2014_Report_SubSaharanAfricaUniversalServiceFundStudy.pdf
227 www.mondaq.com/nigeria/withholding-tax/751100/multiple-taxes-levies-and-regulations-in-the-nigerian-telecommunications-industry

Going forward, there is a strong argument that telecommunication investment in 5G and future innovative services should be encouraged by rationalizing and reducing the current taxation burden in Nigeria. Very importantly, the harmonized ROW charges of N145 naira per linear meter should be adopted and implemented nationwide.

4.19. Small Cell Deployment and Managing Traffic in Business Districts/Crowded Areas

5G will continue to utilize towers with transceivers operating in lower bands and providing wide area coverage. In areas with greater concentrations of users, 5G will use high band frequencies to carry larger amounts of data with less latency but over shorter distances, and will use more small cells to do so. Typically small cells are used in high traffic areas such as transport hubs or office buildings, as is common with 4G today.

Small cells need to be placed close to end users, and therefore, existing physical infrastructure such as street furniture, for instance, lamp posts can be efficiently re-purposed to deploy small cells. The use of street furniture for small-cell deployment has been used in leading markets including the USA, but deployment can be costly, and therefore deployment locations must be selected carefully.

Small cells, which generate less power, collect and transmit the signals in a short range from one another and require collocating the cells on other infrastructures. This means that they will be many more installations per unit area than were necessary for 4G rollout. To make it economically feasible for wireless companies to deploy 5G small cell wireless facility deployment will require streamlined approval and permit processes for rights of way and relatively low application fees.

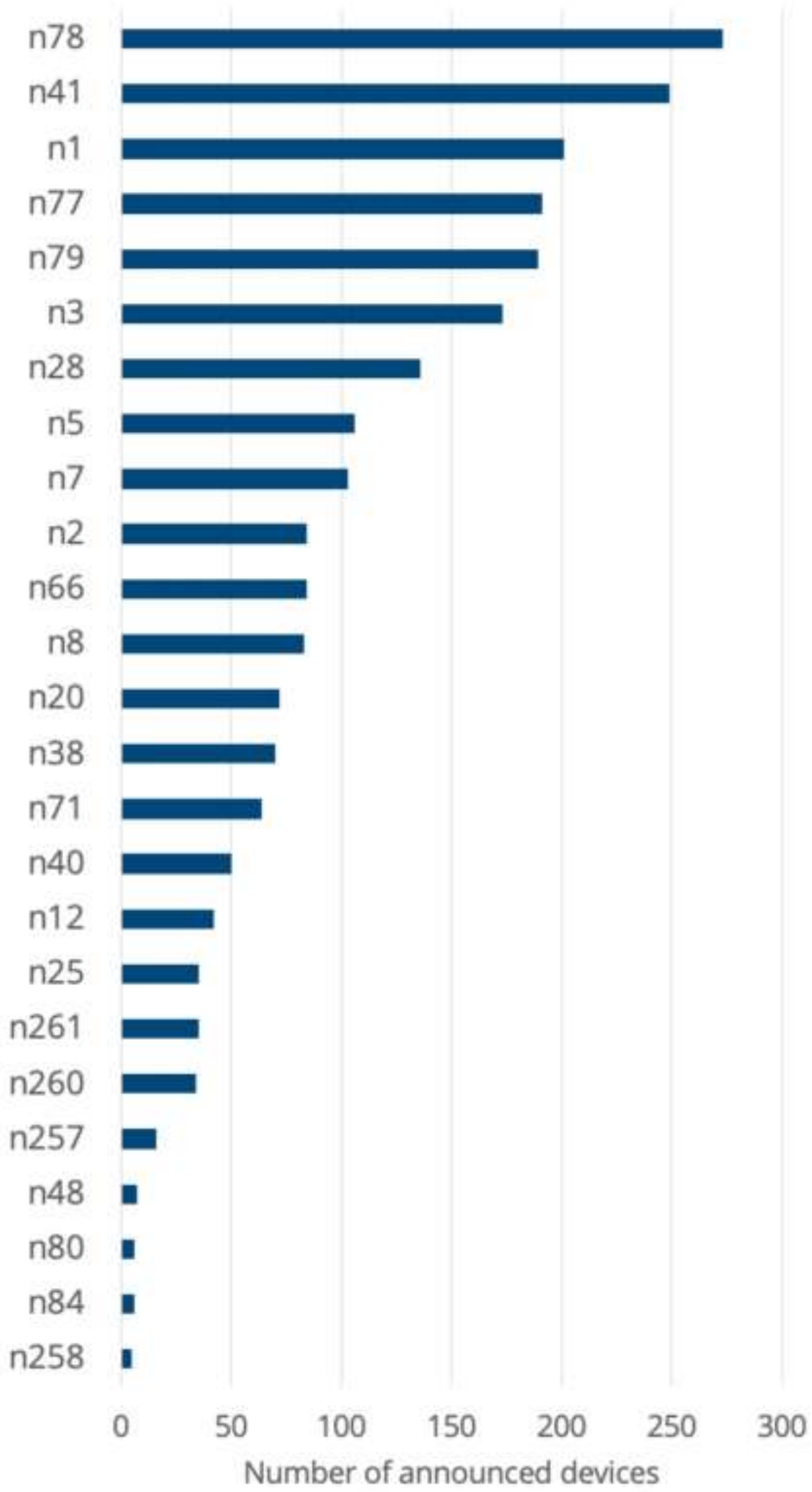
4.20. 5G Device Affordability and Availability

The 5G device ecosystem has grown rapidly and it can be expected to continue to do so. As at the end of October 2020, the GSA announced that there are over 492 5G enabled devices which constitute the ecosystem. These devices include 20 form factors including phones, head-mounted display, hotspots, indoor and outdoor customer-premises equipment (CPE), laptops, modules, snap-on dongles/adapters, enterprise routers, IoT routers, drones, robots, TVs, USBs terminals, switches, heads-up displays, and a vending machine from 99 vendors.[228] This includes 241 phones including at least 169 phones which are commercially available. See Exhibit 4.49.

Majority of devices (118) support the n77/79 band (including the 3.5 GHz band) with the n41 (2.6 GHz TDD), n78 (4.9 GHz) and n28 (700 MHz) being well supported. Of the legacy bands in use, 2100 MHz (n1) and 1800 MHz (n3) are the best supported. About 20 percent of devices support mmWave 5G services. A range of cheaper priced 5G handsets are expected later in 2021 given the growth in demand in China and many other global markets.

228 GSA, *5G Devices November 2020: Global Update*, 12 November 2020

Exhibit 4.49: 5G device ecosystem – supported bands



Source: GSA, 5G Devices November 2020: Global Update, 12 November 2020

In our view, while Band n78 (3.5 GHz) and Band n41 (2.6 GHz TDD) are the most supported bands from an ecosystem perspective, we consider that Band n28 (700 MHz) and Band n40 (2.3 GHz) will grow proportionally faster. This is because of the deployment of 5G in the 700 MHz in Asia

(China, India, Thailand, Philippines) and in Europe (mandatory for all EU members). The 2.3 GHz band which is already a TDD band is well placed to grow fast as a 5G band given the interest in the band following its first launch by Singtel Optus in Australia.[229]

4.21. Integration with 4G and VoLTE

VoLTE is a feature that allows voice calling over 4G networks, while Vo5G allows voice calling over 5G networks.[230] It allows consumers to remain connected to the 4G/5G network during calls, which means they can continue using mobile data while making and receiving calls.

Optionally, MNOs have low sub-1 GHz spectrum such as 700 or 900 MHz in order to optimally deploy robust VoLTE services especially in relation to in-building coverage. In the interim, voice calls will use circuit switch fall back (CSFB) to the 2G/3G networks where necessary (ie where there is no 4G or 5G coverage or VoLTE has not been deployed). Ongoing calls originating on VoLTE will also need to be handed over to 2G/3G when mobile users move out of VoLTE coverage, which is enabled by the Single Radio Voice Call Continuity protocol (SRVCC).

The implementation of VoLTE can be associated with many technical challenges. Essentially, VoLTE is a data service. However, in contrast to typical best-effort IP data traffic that can be reduced if the link is of low quality, VoLTE requires a guaranteed data rate. The network responds to these situations by allocating more capacity resources to the VoLTE call, which may cause the overall quality of the network to degrade. As such, LTE radio access networks (RAN) may need to be re-optimized to provide the required VoLTE service guarantees. Further complications arise if the LTE coverage is not continuous.

As of October 2020, the GSA reports there are 273 operators that are investing in VoLTE in 120 countries and territories. 224 operators have commercially launched VoLTE-HD voice service in 104 countries and territories. By the end of September 2020, GSA had identified 81 commercially launched 5G devices supporting VoLTE.[231] The global number of VoLTE users will approach 5 billion by 2024.[232] See Exhibit 4.50.

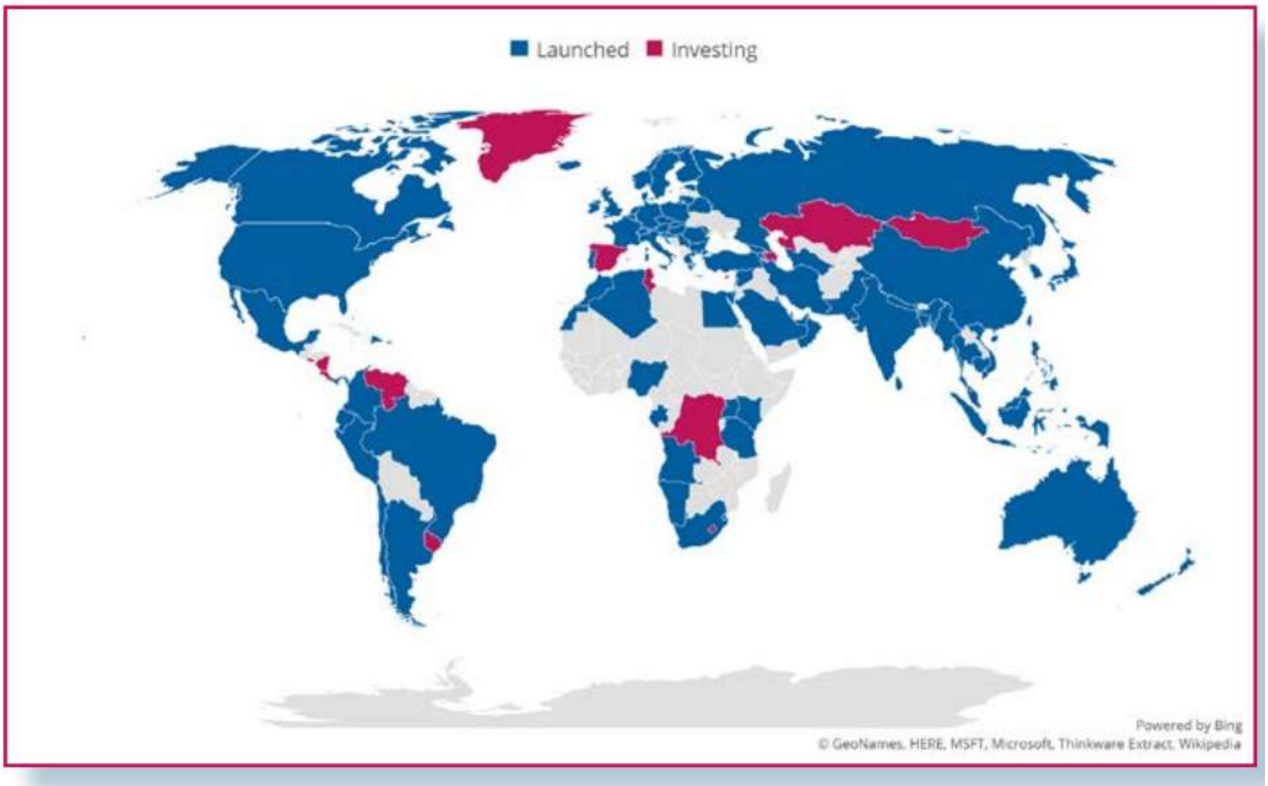
229 For more information see www.gtigroup.org/news/ind/2020-07-30/15373.html and www.optus.com.au/about/media-centre/media-releases/2020/02/optus-launches-worlds-first-2300mhz-and-3500mhz-dual-band-5g-production-network

230 Refer to www-file.huawei.com/-/media/corporate/pdf/white%20paper/2018/vo5g-technical-white-paper-en-v2.pdf

231 https://gsacom.com/paper/volte-member-report-october-2020-global-update/

232 www.juniperresearch.com/press/press-releases/volte-connections-to-near-5-billion-by-2024

Exhibit 4.50: Countries with VoLTE service[233]



Source: GSA, 2020

It should be noted that in Nigeria, Smile launched the first VoLTE in March 2016, followed closely by ntel in April 2016.[234] The service currently runs on their 4G LTE broadband networks.[235]

4.22. Regulatory Sandbox for 5G

The 5G environment raises key questions about how policy makers and regulators in Nigeria should handle fast-changing technologies and industries. How can regulators balance the risks that come with new ideas without impeding innovation? How can they help to ensure that the benefits of new technologies are widely spread without breaking commercial agreements?

It is necessary to create an appropriate legal framework for 5G technologies, as well as for regulators to adopt new ways of working in order to rise to the modern challenges of a 5G environment. As such, globally regulators are now considering innovative, out of the box regulatory solutions such as regulatory sandboxes for enterprises wishing to test an emerging technology or innovative service without being bound by all the regulations that would normally apply.[236]

A regulatory sandbox is a tool providing a safe and secure environment for businesses to try out their ideas and test their innovations. Ultimately, a sandbox environment enables digital

233 https://gsacom.com/paper/volte-status-march-2020/
234 https://en.wikipedia.org/wiki/List_of_LTE_networks_in_Africa
235 https://telecoms.com/452742/smile-rolls-outs-nigerias-first-volte-network/
236 www.itu.int/en/ITU-D/Regulatory-Market/Documents/Publications/Document-Summary_English.pdf

experimentation by creating a dynamic regulatory environment in which digital market failures and opportunities have space and flexibility to address present and future challenges.[237]

This may in turn foster change within the regulatory environment by guiding the NCC towards emerging structures and practices. It also provides well-defined testing fields which are transparent for authorities, allowing them to experiment within a protected regulatory framework.

Examples of regulatory sandboxes which have been launched by national regulators in other countries include:

- On 27 November 2018, the French Telecom Regulatory Authority (ARCEP) launched a regulatory sandbox to allow start-ups to test new technologies with lighter obligations. The regulator states that the sandbox is "an unprecedented device in France, allowing entrepreneurs to test the technical robustness and profitability of a service in real conditions".[238]

- On 14 August 2019, through the issuance of an official Notification, the National Broadcasting and Telecommunications Commission of Thailand (NBTC) established a sandbox regime to facilitate technology testing for businesses and in preparation for the adoption of 5G technologies in Thailand. This regime is discussed below in Exhibit 4.51.

Exhibit 4.51: The Regulatory Sandbox in Thailand

Notification: The Criteria for Permitting Frequency Use for Innovation Development and Testing in a Sandbox Area (the “Sandbox Notification”) allows sandbox participants to use certain frequencies and conduct frequency testing, within a limited sandbox area, for the development and testing of equipment, network, or system, which is done to obtain a finished product. The sandbox license will be granted for R&D and pre-commercialization purposes, but not for business operation nor any profit-making activities.

The Sandbox Notification permits the NBTC to consider certain areas to be sandbox areas, including areas within the Eastern Economic Corridor (EEC) promotional zones, areas in public and private universities, industrial estate areas, etc.

The sandbox license holder shall have certain obligations, as follows:

i. carrying on activities within the specified objectives as provided in its sandbox license application;
ii. set in place cybersecurity and data protection measures;
iii. report its progress to the sandbox operator every three months; and
iv. must not charge any fees from the operation within the sandbox, conduct commercial business, nor provide service in connection with any existing telecommunications services.

The sandbox license has a term of 360 days and is extendable. However, the maximum term of the sandbox license is 720 days (approx. two years).[239]

[237] ITU, *Global Symposium for Regulators (GSR) Best Practice Guidelines, Fast Forward Digital Connectivity for All,* 2019

[238] www.linfodurable.fr/telecoms-larcep-veut-faciliter-le-lancement-de-nouveaux-services-572

[239] www.bakermckenzie.com/en/insight/publications/2019/09/thailands-nbtc-introduces-regulatory-sandbox

Objective Five: to provide an approach to addressing 5G and public health issues concerns

Key Findings:

4.23. 5G EMF and Public Health Issues

Although there are no established health effects from the radio waves used by 5G network, the wrong information circulating across Nigeria and the globe in general should be taken seriously. The electromagnetic frequencies used for 5G constitute part of the radio frequency spectrum which has been extensively researched upon in terms of health impacts for decades.

Low and mid-band frequencies used for 5G have been in use for 2G, 3G and 4G services while 5G mmWave frequencies are already in use by the satellite industries for other purposes and are covered by international safety guidelines.[240] The consistent conclusion of public health agencies and expert groups is that compliance with the international guidelines is protective for all persons including children against all established health risks.[241]

4.23.1. Transmitting Power

It is important to highlight that 5G devices will automatically minimize the transmit power to the lowest level in order to complete a satisfactory communication with the network. Base stations used for 5G consist of various types of facilities including small cells, towers, masts and dedicated in-building and home systems. 5G networks are specifically designed to minimize transmitter power, even more than existing 4G networks. 5G networks use a new advanced radio and core architecture which is very efficient and minimizes transmissions consistent with service requirements which results in optimized Electromagnetic Field (EMF) levels.[242]

The use of higher frequencies does not imply or translate to higher or more intense exposure. Higher frequency radio waves are already used in security screening units at airports, police radar guns and in medicine. These uses have been thoroughly tested and found to have no negative impacts on human health.[243]

Changes to Exposure

The WHO conducted the EMF project which researched potential changes to exposure levels. The WHO and ICNIRP have assessed that there is no established scientific evidence to support any claims of adverse health effects from very low RF EMF exposures. The WHO findings are as follows:

- no significant change in overall RF-EMF levels;
- no significant change in network exposure levels;
- no significant change in personal exposure; and

240 www.gsma.com/spectrum/resources/wrc-19-addressing-5g-and-emf/
241 www.gsma.com/publicpolicy/wp-content/uploads/2019/06/GSMA_Safety-of-5G-Mobile-Networks_July-2019.pdf
242 www.emfexplained.info
243 www.arpansa.gov.au/news/misinformation-about-australias-5g-network

- no risk increases near broadcast transmitters.[244]

4.23.2. Comprehensive International Guidelines

WHO and ICNIRP

Safe exposure limits are set by independent, publicly funded organizations; the WHO and the ICNIRP.

Comprehensive international guidelines exist which govern exposure to radio waves including the frequencies proposed for 5G. Independent scientific organizations such as the ICNIRP have established the limits,[245] and include substantial margins of safety to protect everybody from all established hazards.

These guidelines have been widely adopted as standards around the world, and are endorsed by the WHO.[246] Over 50 years of scientific research has already been conducted into the possible health effects of the radio signals used for mobile phones, base stations and other wireless services including frequencies planned for 5G including mmWave exposures.

ITU

The ITU has also released numerous Resolutions concerning human exposure to electromagnetic fields. The ITU has found that no adverse health effects have been established from RF fields' exposures. The results of the simulation indicate that where RF-EMF limits are stricter than ICNIRP or IEEE guidelines, the network capacity buildout (both 4G and 5G) might be severely constrained and may prevent accommodating the growing data traffic demand and the launching of new services on existing mobile networks.

Mitigation measures include:

- avoiding wireless communications if the transmitter & receiver stations are fixed;
- avoiding WiFi routers based on cellular infrastructure;
- using satellite and cable TV;
- maximizing sharing, including active frequencies sharing among cellular operators; and
- maximizing the RF to operators in order to decrease sites[247]

GSMA

GSMA indicates that with regards to radio signals, 5G is similar to current wireless technologies and covered by national and international safety guidelines which protect the public and the environment. The European Commission points out that these 'strict and safe' guidelines include all the frequencies both currently used and under consideration for 5G. Further research indicates that there are no established health effects and 5G trials demonstrate that the overall levels of radio signals in the community remain low and well below international safety guidelines. GSMA suggests

244 www.gsma.com/spectrum/wp-content/uploads/2019/11/Jrowley_201911_WRC_EMF.pdf
245 www.icnirp.org
246 www.emfexplained.info/?ID=25914
247 www.itu.int/ITU-T/recommendations/rec.aspx?rec=13643&lang=en

that as the world move into the 5G era, there is an important role for national authorities to communicate accurate and reliable information.[248]

4.23.3. Global Views

The prevailing view among researchers in many countries today is that the radiation from wireless technology is not hazardous to health, as long as the levels are below the recommended limit values.[249] Despite the public concern, health authorities have consistently declared 5G safe for use. There is a large body of research on the radio signals used by mobile technologies. The scientific evidence is continuously monitored by independent expert groups to ensure that safety guidelines remain valid.

WHO

While an increased risk of brain tumours from the use of mobile phones is not established, the ever increasing use of mobile phones and the lack of information on mobile phone use for more than 15 years warrants further research of mobile phone use and brain cancer risk.[250]

Australia

Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) is not aware of any well-conducted scientific investigations where health symptoms were confirmed as a result of radio wave exposure in the everyday environment.[251]Additionally, Australia's largest MNO, Telstra, completed extensive testing of its 5G network infrastructure in real-world settings using commercially available 5G devices. Telstra reported that testing of their 5G network with commercial devices in real-world setting shows levels similar to 3G, 4G and Wi-Fi and in many cases around 1,000 times below the safety limits.[252]

France

During measurements on 4G small cells by the French spectrum regulator, ARCEP found out that levels in nearby areas did not change significantly and remained well below the safety guidelines. Small cells also increased the data rates available to users.

Canada

According to the Government of Canada, international studies have concluded that effects associated with exposure to RF energy (one form of electromagnetic energy) depend on the frequency range. For example, higher frequency ranges may result in tissue heating, while short-

248 www.gsma.com/publicpolicy/emf-and-health
249 https://amta.org.au/international-health-authorities-on-5g-and-eme-health-risk/
250 www.gsma.com/spectrum/wp-content/uploads/2019/11/Jrowley_201911_WRC_EMF.pdf
251 www.arpansa.gov.au/news/misinformation-about-australias-5g-network
252 https://exchange.telstra.com.au/5-surveys-of-5g-show-eme-levels-well-below-safety-limits/. For the approach of other MNOs see – Vodafone - www.vodafone.com/what-we-do/public-policy/mobiles-masts-and-health/health-the-science-and-evidence/is-5g-safe-to-use.

term exposure to lower frequency ranges may produce nerve stimulation like a tingling sensation. RF exposure limits have been established to prevent these effects from occurring.[253]

European Union

The European Commission has emphasized that since existing scientific evidence on electromagnetic field exposure confirms that 5G networks will not cause more electromagnetic emissions than permitted, 5G will not have a negative effect on people's health.[254]

Germany

Germany has publicly stated that where the limit values are adhered to, no health-relevant effects are to be expected according to the current scientific knowledge. They note however, that the use of additional frequency bands in the centimeter and millimeter wavelength range require further research.

Finland

Finland have stated that from the point of view of exposure to radio frequency radiation, the new base stations do not differ significantly from the base stations of existing mobile communication technologies (2G, 3G, 4G).

Norway

Norway have publicly announced that they have used cell phones and radio transmitters for decades and lots of research has been carried out on how these devices affect our health. Risk factors of concern to public health have not been found. With the knowledge we have today, there is no need to worry that 5G is hazardous to health.

South Africa

The Council of Scientific & Industrial Research (CSIR) issued a document to dispel some of the myths around 5G mobile telephony. Specifically, they stated that 'there is no evidence to suggest a link between 5G technology and SARS-CoV-2', the virus which is said to cause COVID-19. The claims that we have come across do not provide any credible scientific evidence to substantiate them. Our view is that the radio frequencies of 5G networks are not high enough to break chemical bonds or remove electrons in human tissue. Therefore, it is highly unlikely that 5G may cause mutations in the SARS-CoV-2 virus in-vitro or in-vivo'.

United Kingdom

ICNIRP guidelines apply up to 300 GHz, well beyond the maximum (few tens of GHz) frequencies under discussion for 5G. In the UK, it has been noted that it is possible that there may be a small increase in overall exposure to radio waves when 5G is added to an existing network or in a new area; however, the overall exposure is expected to remain low relative to guidelines, and as such there should be no consequences for public health.

253 www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11467.html
254 https://ec.europa.eu/digital-single-market/en/electromagnetic-fields-and-5g

USA

The Federal Communications Commission (FCC) has taken a position that there are no adverse health effects.

Firstly, hundreds of independent studies from international agencies have indicated there have been no established negative health caused by radio waves emitted from mobile phones and base stations complying with international limits.

Secondly, according to the FDA and the WHO among other organizations, to date, the weight of scientific evidence has not effectively linked exposure to radio frequency energy from mobile devices with any known health problems. Finally, in the US, several federal agencies constantly monitor research and update regulations relating to health and wireless, including the FCC, Centers for Disease Control & Prevention, National Institutes of Health, and Food & Drug Administration.[255]

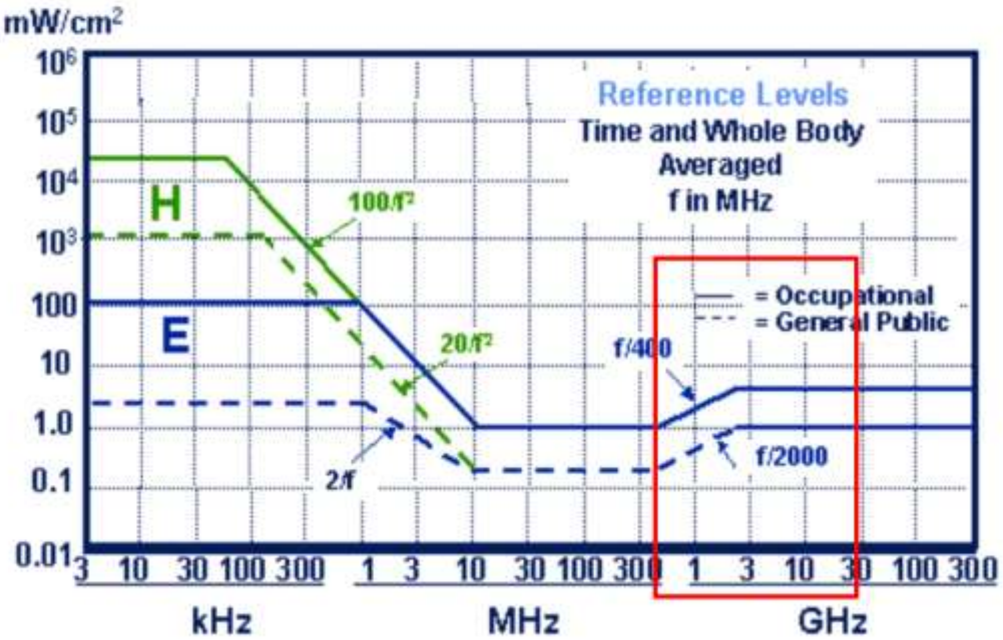
4.23.4. The Nigerian Scenario

In accordance with ITU and WHO recommendations, the EMF national guidelines are based on the ICNIRP standards. The NCC is able to regulate EMF emissions through a functional and comprehensive type approval procedure and compliance monitoring of installed wireless equipment. Among other reasons, the type approval process implemented by the NCC is to ensure that radio frequency radiation levels are well below ICNIRP limits. It should be noted that ICNIRP limits for various frequencies are as much as 50 times lower than actual values which could pose a risk to the human body.

In Nigeria, the *Appendix of Legal Guidelines -Technical Specifications for the Installation of Telecommunications Masts and Towers* provides for approved Radiation levels in mW/cm2 of body weight based on the ICNIRP guidelines (see Exhibit 4.52). Such levels vary between those provided for occupational staff on site compared with the general public.

255 www.5gamericas.org/5g-and-health/

Exhibit 4.52: NCC's radiation guidelines based on ICNIRP guidelines (red highlight is 5G spectrum)



Source: NCC

Exhibit 4.53: Radiation level in E, H and S for Occupational Staff on site

Frequency Range	Electric Field (E) (V/m)	Magnetic Field (H) (A/m)	Power Density (S) (E: H Fields) mW/cm²
400 - 2000 MHz	$3f^{1/2}$	$0.008f^{1/2}$	f/400
2 -300 GHz	137	0.37	5.0

Source: NCC

Exhibit 4.54: Radiation level in E, H and S for General Public

Frequency Range	Electric Field (E) (V/m)	Magnetic Field (H) (A/m)	Power Density (S) (E: H Fields) mW/cm²
400 - 2000 MHz	$1.375f^{1/2}$	$0.0037f^{1/2}$	f/2000
2 -300 GHz	61	0.16	1.0

Source: NCC

While the theories that there is a link between 5G and coronavirus are utterly baseless, it has not stopped such theories from gaining popularity among Nigerians. A collaborative initiative between the NCC and the Ministry of Health is required in dealing with the misinformation.

During the local aspect of the study, it was gathered that Nigeria is yet to record an incident of vandalism related to the misinformation even though several Nigerians erroneously believe that 5G has already been introduced in Nigeria. In addition, the Ministry of Health is committed to working with NCC in addressing all public health concerns on 5G. It is also noteworthy that the Ministry of Health is committed to improving healthcare delivery services by leveraging on 5G and associated technologies such as Artificial Intelligence (AI).

5.0. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The study was carried out under the supervision of the Research and Development Department of the NCC. It involved investigations on global best 5G practices and what needs to be done in Nigeria to ensure that requirements in terms of 5G drivers are adequately satisfied. It utilized both global and local consultations bothering on economic, policy, regulatory and industrial practices.

While global aspect of the study included investigations on global trends and developments, telecommunication economics, spectrum and network requirements, and EMF issues, the local aspect of the study involved consultations with key stakeholders in Nigeria, identifying deficiencies in 5G drivers, and modelling optimal approaches to 5G deployment. Specifically, the local aspect of the study dealt with issues which are considered peculiar to Nigeria.

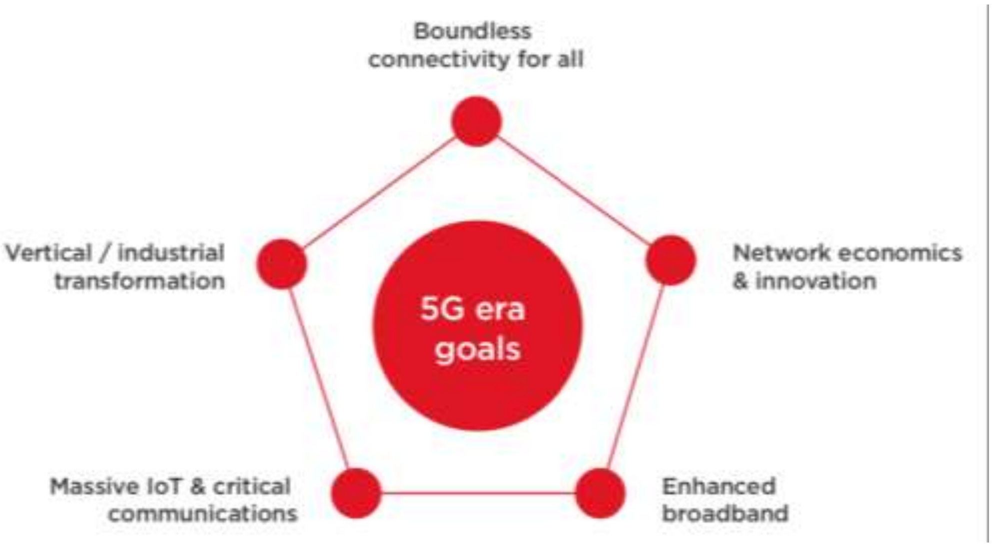
This Report has provided approaches and strategies for an optimal utilization of the 5G technology in Nigeria in accordance with the objectives of the study. It validated that 5G is a transformative technology that could have significant socio-economic impacts by supporting greater innovation such as IoT, Cloud Computing and AI thereby enhancing productivity and international competitiveness.

5G will provide a platform for Nigerian communities and businesses to harness the socio-economic benefits delivered by an advanced, data-intensive digital economy. It will facilitate Nigeria's recovery from the effects of the global COVID-19 pandemic. Indeed, 5G introduction should be seen as a path to economic recovery.

5G is an opportunity for policy-makers in Nigeria to empower citizens and businesses, and it will play a key role in supporting all the levels of Government in achieving smart cities. It is an opportunity for the NCC to facilitate sector investments in high speed services thereby promoting mobile and fixed competition with the acceleration of 5G FWA services.

It will help to achieve the 5 mobile industry goals detailed in Exhibit 5.1.

Exhibit 5.1: Five mobile industry goals



Source: GSMA Intelligence, The 5G era: Age of boundless connectivity and intelligence automation, 2017

Globally, 5G adoption is occurring very rapidly with 407 operators in 129 countries investing in 5G as at mid-November 2020. Following multiple announcements of 5G deployments in 2020, 146 operators have now launched 3GPP compliant commercial 5G services.

The Nigerian economy exhibits multiple characteristics which strongly suggest that 5G deployment will generate significant economic benefits. It faces ongoing service quality challenges in wireless telephony and broadband services. It has relatively undeveloped fixed line infrastructure, and presently faces significant opportunities for economic growth. All these indices suggest that the benefits from early 5G deployments would be significant.

In addition, it is important to note that 5G deployment offers a stepping-stone in an incremental development path that includes future deployments of fixed line infrastructure. Deployment of 5G will entail additional fiber connectivity to 5G base stations and this can provide a solid platform for future fiber-to-the-premises deployments while delivering high quality broadband over 5G using FWA services earlier than would otherwise be possible.

These considerations suggest that Nigeria can harness significant economic benefits from the early 5G deployment.

5.2. Recommendations

Sequel to global investigations on 5G best practices as well as the specific challenges observed and analyzed in relation to the Nigerian scenario, this Report recommends the following with respect to the objectives of the study.

Objective One: to investigate and provide possible solutions for some of the key challenges that will be the deployment of 5G cellular networks

Recommendation 1

Based on technology and service neutrality, all existing IMT spectrum licensees should be able to deploy 5G NR through the use of DSS or an exclusion use of their existing spectrum for 5G NR. If certain spectrum licenses do not grant this permission, they should be amended by the NCC.

Recommendation 2

In the short term, the optional spectrum bands to facilitate 5G deployment in Nigeria fall into two categories namely the vacant spectrum in the current IMT spectrum bands and the mmWave spectrum specifically the 26 GHz band (n258). Such additional spectrum will improve 4G services and provide a better opportunity for MNOs to deploy 5G services. In relation to existing vacant spectrum, it is recommended that NCC in early 2021, auction:

I. 2 Lots of 2 x 10 MHz of 2.1 GHz (n1) spectrum. To the extent permitted by law, Cobranet may wish to include its current spectrum allocation in Lagos in one of the Lots concurrently for auction;
II. 2 Lots of 2 x 10 MHz of 2.6 GHz (n7) spectrum subject to any reservation of spectrum to OpenSkys;
III. 1 Lot of 2 x 10 MHz of 700 MHz (n28) spectrum depending on the Government's view on whether such spectrum should be reserved or it should be auctioned on the basis that certain capacity in that band should be reserved for the rural telephony initiative of the Ministry of Communication and Digital Economy.

In relation to the mmWave spectrum, the NCC should consider whether it initially reserved part of the 26 GHz (say 750 MHz of the 3250 MHz available) or indeed the 28 GHz band for enterprise/private network use. The remaining 2500 MHz could be auctioned in Lots of 100 MHz with a cap of 800 MHz;

Recommendation 3

In the first half of 2021, the NCC should commence the following:

I. the re-farming of the key 5G pioneer band of 3.5 GHz (n78) spectrum in order to make available at least 110 MHz for IMT purposes on nationwide basis from 3400 to 3510 MHz, and also explore whether additional spectrum in the 3.3-3.4 GHz and spectrum higher than 3510 MHz is available for IMT use by re-farming the spectrum;
II. with respect to the 3.5 GHz, it is preferable if Nigeria can implement exclusive national licensing of 3.3-3.8 GHz for 5G services;

III. consider re-farming the 2.3 GHz band in order to create larger contiguous blocks (50 MHz/40 MHz) as detailed in Section 4.2.5 which could be better used for 4G/5G services;

IV. consider converting the 2.6 GHz to n41 status as detailed in Section 4.2.6.

Recommendation 4

Within Nigeria and its neighbouring countries, post re-farming of the 3.5 GHz band with TDD synchronisation between MNOs should be mandated with a 4:1 frame structure.

Recommendation 5

The NCC should facilitate 5G deployment in the Nigeria by instituting a range of policy and regulatory reform detailed in Sections 4.6 and 4.7 bothering on improved ROW and access to cell sites and towers, taking into cognizance international exemplars detailed in Section 4.5. This should take place over the next 12 months or so especially for public land, sites and road infrastructure.

Very importantly, the recommendations of the present national broadband plan itemized in Section 4.6.1 should be implemented.

Recommendation 6

The presidential declaration of telecommunication infrastructures as critical national assets on 2 June 2020 is a progressive step towards safe guiding investments and promoting QoS. Signing an Executive Order to this effect is expected to strengthen the protection of network resources including 5G deployments. It is important that the NCC initiates and sustains a collaborative partnership with the institutions listed in the declaration towards safeguarding telecom networks across the country.

Objective Two: to determine the reliability and energy efficiency of 5G cellular networks

Recommendation 7

It has been established that 5G networks using beamforming MIMO antennas utilize about four times less power than 4G networks. The reliability and energy efficiency of 5G networks are detailed in Section 4.9. MNOs and site providers should be encouraged to increase the use of alternative energy sources in order to reduce dependence on the main power grid. Likewise, network load optimization as detailed in Section 4.9.2 aimed at reducing energy consumption should be encouraged among MNOs.

The NCC should begin to consider regulatory and industrial requirements aimed at shutting down lower technologies such as 2G and possibly 3G, and focus on 4G and 5G which have better energy efficiency.

Objective Three: to devise a means by which the 5G cellular network can support more users, more devices, and more services without a corresponding impact on cost

Recommendation 8

Spectrum sharing should certainly be part of the NCC's regulatory strategy for infrastructure sharing as it may help alleviate cost and resource issues with 5G rollout in Nigeria, and facilitate connectivity of users and devices. In addition, ROW challenges are obvious impediments to massive deployment of fiber to connect base stations in major cities. Incentivizing fiber deployment and nationwide adoption of 145 naira per linear meter for ROW as contained in the present national broadband plan are key to supporting more users at lower costs.

Recommendation 9

Implementation of 5G IoT is key to massive connectivity of users and devices. It is recommended that the NCC aligns its regulatory framework with global and regional development, and should also utilize sub 1 GHz bands for IoT as detailed in Section 4.12.4.

Although the study established sufficiency of international transmission capacity and cloud infrastructure to support 5G as detailed in Section 4.13, further competition in the provision of these critical support services should be facilitated in order to enhance affordability.

Objective Four: to determine what Nigeria needs to do differently or uniquely with regards to global and regional deployment of 5G

Recommendation 10

Spectrum should be made available and dedicated to FWA and enterprise/industry based on findings on these applications as detailed in Section 4.14 and 4.15. The NCC should be mindful of the growing use of FWA, and include such services in its spectrum roadmaps and demand analysis. For FWA, the use of 2.3. 2.6 and 3.5GHz spectrum bands may be considered while enterprise spectrum is considered to be best suited for the mmWave bands.

Recommendation 11

Having examined the requirements imposed by a range of other country regulators and Governments as detailed in Section 4.16, it is recommended that the NCC consider including a network rollout obligation in the 3.5 GHz spectrum license of say, 30 percent coverage of Nigeria's population within 3 years. This coverage commitment figure could be increased to 50 percent or more by possibly making available sub-1 GHz spectrum and re-farming legacy IMT spectrum for 5G.

In addition, the NCC should mandate minimum 5G download speeds as this is the case in a number of global markets. To secure the benefits of 5G for Nigeria and to be significantly faster than current speeds, the minimum could be prescribed as at least 30 Mbps for users within 3.5 GHz 5G coverage areas and rising over time.

Recommendation 12

Where spectrum is assigned through a market-based process, the NCC must ensure that participants have an incentive to bid according to their maximum willingness to pay, with no opportunity or incentive to collude with other bidders or coordinate their actions. It is generally desirable to choose an auction format that facilitates price discovery, has no exposure risk and has low complexity.

In assessing optimal spectrum auction format as detailed in Section 4.17, it is considered that while the Clock Auction and the SMRA share a number of characteristics in the Nigerian context, the Clock Auction is likely to be a better choice due to its reduced complexity and the additional flexibility applicable to the auctioneer in restricting certain information given to bidders during the auction that could be used by the bidders to tacitly collude among themselves.

Recommendation 13

Spectrum auctions are widely considered to be the most appropriate approach to assigning spectrum where demand exceeds supply, and this is usually the case with IMT spectrum bands. However, the administrative approach is more appropriate in some cases which can encourage 5G network rollout including investment in backhaul transmission to support higher end-to-end broadband speeds. The NCC should therefore, consider this approach in licensing mmWave spectrum.

Recommendation 14

The NCC should consider a downward review of the transactional costs on spectrum trading. As MNOs seek to put together contiguous spectrum across desirable bands by exploring spectrum trading, the significant charges discussed in Section 4.17.4 could affect the motivation of licensees who may be seeking to trade or put together a large contiguous spectrum block for 5G use.

Recommendation 15

To encourage 5G network rollout in Nigeria including investment in backhaul transmission to support higher end-to- end broadband speeds, it is critical that spectrum be priced at reasonable and sustainable levels in relation to discussions detailed in Section 4.17.6.

Recommendation 16

The NCC should consider facilitating the reduction of the tax burdens on MNOs. Going forward in terms of non-supporting multiple taxation and regulatory regimes detailed on Section 4.18, there is a strong argument that telecommunication investment in 5G and future innovative services should be encouraged by rationalizing and reducing the current taxation burden in Nigeria.

Recommendation 17

In order to facilitate small cell deployment and managing traffic in business districts/crowded areas, the NCC should in turn, facilitate the attainment of streamlined approval and permit processes for rights of way and relatively low application fees in order to make it economically feasible for wireless companies to deploy 5G small cell wireless facilities. Applicable issues have been discussed in Section 4.19.

Recommendation 18

To facilitate device affordability and availability, the NCC should align with global trends in terms of device supportability as detailed in Section 4.20. From an ecosystem perspective, the n78 (3.5 GHz) n78 (3.5 GHz) and n41 (2.6 GHz TDD) are the most supported 5G bands.

Recommendation 19

The NCC should consider establishing a regulatory sandbox as detailed in Section 4.22 as the 5G environment raises key questions about how policy makers and regulators in Nigeria should handle fast-changing technologies and industries. This may in turn foster change within the regulatory environment by guiding the NCC towards emerging structures and practices. It also provides well-defined testing fields which are transparent to authorities, allowing them to experiment within a protected regulatory framework

Objective Five: to provide an approach to addressing 5G EMF and public health concerns

Recommendation 20

In addressing 5G EMF and public health concerns, the NCC should consider the following:

I. The focus should be on building community knowledge and reinforcing that despite the public concern, health authorities have consistently declared 5G safe for use. A range of mediums, from traditional media to online methods should be used to disseminate the message;

II. The global approval of 5G and the benefits associated with its implementation are reasons to proactively kick-start deployment;

III. It is suggested that NCC should focus on information coming from both the health experts and the industry by working with the MNOs to disseminate the right knowledge to customers. It is important to continuously pay attention to global approaches and continue to undertake EMF measurements to monitor the overall trends in the long term;

IV. Testing 5G equipment and transmission to ensure they comply with national guidelines is recommended. Policy and regulations should be reviewed to ensure that they comply with current guidelines; and

V. Increased approval and adoption rates by the community help reduce the possibility of vandalism to 5G equipment and other telecommunications equipment.

Furthermore, the NCC should incorporate the Ministry of Health, NMA, Ministry of Communication & Digital Economy, ATCON and ALTON in a public enlightenment campaign with regards to 5G deployment towards re-assuring the public on the safety of the technology and that it is similar in terms of spectrum use with existing mobile services as outlined in Section 4.23.

LIST OF ABBREVIATIONS

3GPP	3rd Generation Partnership Project (uniting 7 standardization bodies)
4G	Fourth generation of broadband cellular network technology
5G	Fifth generation of cellular mobile communications
5GC	5G core network
5G NR	5G New Radio (the global standard for a new OFDM-based air interface)
ALTON	Association of Licensed Telecommunication Operators of Nigeria
ATCON	Association of Telecommunication Companies of Nigeria
ARPU	Average Revenue Per User
BSS	Broadcasting Satellite Service
BU-LRIC	Bottom-Up Long Run Incremental Cost
CA	Carrier Aggregation
CAPEX	Capital expenditure
CEPT	European Conference of Postal and Telecommunications Administrations
CPE	Customer Premises Equipment
DL	Downlink
DSS	Dynamic Spectrum Sharing
FDD	Frequency Division Duplex
ECOWAS	Economic Community of West African States
eMBB	Enhanced Mobile Broadband
EMF	Electromagnetic Field
EPC	Evolved Packet Core
ERGP	Economic Recovery Growth Plan (of Nigeria)
EU	European Union
FCC	Federal Communications Commission of the USA
FDD	Frequency Division Duplex
FIRS	Federal Inland Revenue Service

FTTX	Fiber to the x (x refer to the termination or delivery location)
FWA	Fixed Wireless Access
GCF	Global Certification Forum (for IoT certification)
GCN	Gateway Core Network Operator
GB	Gigabyte
Gbps	Gigabytes per second
GDP	Gross Domestic Product
GHz	Gigahertz
GPS	Global Positioning System
GSM	Global System for Mobile Communication (2G technology)
GSMA	The GSM Association (industry body that represents the interests of MNOs worldwide)
GSA	Global mobile Supplier Association
ICNIRP	International Commission on Non- Ionizing Radiation Protection
IMT	International Mobile Telecommunications
IoT	Internet of Things
ITU	International Telecommunications Union
ITU-RR	ITU Radio Regulations
LTE	Long Term Evolution
LTE-A	Long Term Evolution Advanced (upgraded version of LTE)
LTE-M	Long Term Evolution for Machines
M2M	Machine to Machine
MB	Megabyte
Mbps	Megabits per second
MHz	Megahertz
MIMO	Multiple-input and multiple-output
mMTC	Massive Machine Type Communication
mmWave	Millimetre Wave (for 5G currently focused on 24 to 28 GHz and other higher frequency bands)
MNC	Mobile Network Code

MNO	Mobile Network Operator
MOU	Memorandum of Understanding
MOCN	Multi-Operator Core Network
MORAN	Multi-Operator Radio Access Network
NBP	National Broadband Plan (for Nigeria)
NB-IoT	Narrow Band IoT
NCC	Nigerian Communications Commission
NEC	National Economic Council (of Nigeria)
NFMC	National Frequency Management Council (of Nigeria)
NigComSat	Nigerian Communication Satellite
NGF	Nigerian Governors Forum
NIWA	National Inland Water Ways
NMA	Nigerian Medical Association
NPV	Net Present Value
NSA	Non Standalone (mobile will setup call on LTE and add a new 5G carrier for data traffic)
OECD	Organization for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
OFDM	Orthogonal Frequency Division Multiplexing
OPEX	Operating expenditure
OTT	Over the Top
PCEA	Policy, Competition and Economic Analysis (A department in the NCC)
PPP	Purchasing Power Parity
PTCRB	PCS Type Approval Review Board
RAN	Radio Access Network
RF	Radio Frequency
ROI	Return on Investment
ROW	Right of Way
POC	Proof of Concept
RWI	Regulatory Watch Initiative (of the World Bank)

SA	Standalone (mobile can setup call on 5G)
SRVCC	Single Radio Voice Call Continuity Protocol
TDD	Time Division Duplex
TSNI	Technical Standard and Network Integrity (A department in the NCC)
TSLRIC	Total Service Long Run Incremental Cost
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunications Systems (3G)
URLLC	Ultra Reliable Low Latency Communication
USPF	Universal Service Provision Fund
VAT	Value Added Tax
VoLTE	Voice over LTE
WARC	World Administrative Radio Conference (preceding WRCs)
WARTA	West African Telecommunication Regulatory Authority
WHO	World Health Organization
WiMAX	Worldwide Interoperability for Microwave Access
WRC	(ITU) World Radio Conference

APPENDIX

Terms of Reference (Section 6 of Standard Request for Proposals for Lot-RD-13)

FEDERAL GOVERNMENT OF NIGERIA

STANDARD REQUEST FOR PROPOSALS

for the

CONSULTANCY STUDY ON "5G – THE EVOLVED TELECOMUNICATION TECHNOLOGY OF THE FUTURE

Lot- RD-13

Section 6. Terms of Reference

PROPOSAL FOR A STUDY ON "5G - THE EVOLVED TELECOMUNICATION TECHNOLOGY OF THE FUTURE"

1.0 INTRODUCTION

The future of any part of the vast, disorderly technology space is determined by the interplay between problems and opportunities that create customer demand and the technology developments that rebuild the framework of supply. The telecommunications industry is no exception. And despite the general vastness and disorder of the industry, a big part of the telecoms future will depend on how technology advances and intersect the problem- and opportunity-space.

From analogue through to LTE, each generation of mobile technology has been motivated by the need to meet a requirement identified between that technology and its predecessor. The transition from 2G to 3G was expected to enable mobile internet on consumer devices, but whilst it did add data connectivity, it was not until 3.5G that a giant leap in terms of consumer experience occurred, as the combination of mobile broadband and smartphones brought about a significantly enhanced mobile internet experience which has led eventually to the app-centric interface we see today.

More recently, the transition from 3.5G to 4G services has offered users access to considerably faster data speeds and lower latency rates and therefore the way that people access and use the internet on their mobile devices continues to change dramatically.

Fifth Generation (5G) wireless technology is the most recent, but yet-to-be-released mobile network that is causing a lot of excitement in the telecommunications industry. It is the next evolution in wireless data communications, promising higher bandwidth and data rates with improved performance, capacity and speed and a network that operates the world over, no matter where a user connects from.

It will ultimately replace the current 4G technology as it will be providing a number of improvements, one of which is the focus on erasing the differences between wire line and wireless networking to accommodate the exploding mobility of network users and also its use of unique radio frequencies to achieve what 4G networks cannot. The radio spectrum is broken up into bands, each with unique features as you move up into higher frequencies. Not only are they less cluttered with existing cellular data, they can be used in the future for increasing bandwidth demands, they're also highly directional and can be used right next to other wireless signals without causing interference. This is very different from 4G towers that fire data in all directions, potentially wasting both energy and power to beam radio waves at locations that aren't even requesting access to the internet.

5G also uses shorter wavelengths, which means that antennas can be small and still provide precise directional control. Since one base station can utilize even more directional antennas, it means that 5G will support over 1,000 more devices per meter than what's supported by 4G. What all of this means is that 5G networks will be able to beam ultra-fast data to a lot more users, with high precision and little latency.

In as much as the 5G wireless technology is the much awaited revolutionary technology, the deployment of the network may face a few challenges such as:

- Difficulty in laying of fiber which includes Right of Way and vandalization because 5G requires a high transmission in fiber.
- Availability of spectrum- There has to be frequency refarm to allow for 5G deployment.
- 5G works with MIMO (multiple input and multiple output) antennas which a lot of operators don't use at the moment as such, there will be need for antenna swap.
- How to manage number of online access which may vary from several hundred to several millions.

This study will therefore measure the acceptability, reliability, energy efficiency of the 5G wireless technology and also how the transformational disruption will evolve or affect industries and economies.

2.0 OBJECTIVES/TERMS OF REFERENCE(TOR)

The overall objective of the study is to provide an insight into the study of 5G - The Evolved Telecommunication Technology of the Future. This study therefore, will have the following broad objectives;

1. To investigate and provide possible solutions for some of the key challenges that will face the deployment of the 5G cellular networks
2. To determine the reliability and energy efficiency of 5G cellular network
3. To device a means of which 5G cellular network can support more users, more devices, more services without a corresponding impact on cost
4. To determine what Nigeria needs to do differently/uniquely as regards to 5G deployment in Africa and the world.

3.0 SCOPE

The research shall cover a period of 20 weeks for intensive study, training and implementation so as to meet up or even precede the year 2020 target for deployment/implementation. The study will be nationwide, covering the 36 States of the Federation, with greater emphasis on areas of the states with concentration of traffic (business districts). Other emphasis to be focused on include:

1. Rapid increase in connected devices
2. The need to cope with total volume of traffic
3. New approach to deal with concentration of traffic in particular areas (business districts/crowd area services).
4. Internet of things (IoT)

4.0 DELIVERABLES

The Consultant will deliver the following documents in accordance with agreed timelines as indicated in the work plan:

1. An inception report to be submitted within four weeks of acceptance of Letter of Award. This inception report will detail the study approach/methodology and work plans with timelines including review meetings, in-house or out of office trainings where necessary, presentation periods following the submission of draft interim/progress reports and draft final reports. In the event that the inception report is unacceptable, the Commission reserves the right to cancel the award.
2. Interim/progress report before and after the completion of field survey.
3. Draft final report.
4. Final report.
5. The consultant shall submit five (5) copies of each of the approved final report and two electronic copies in Microsoft Office software format.
6. A publishable executive summary of the final report.

5.0 TIME FRAME (OR DURATION)

The study shall be executed within twenty weeks (20) effective from the date of award. An Inception Report must be submitted within four weeks of acceptance of award.

6.0 PAYMENT

1. 25% of agreed contract sum as first installment upon acceptance of Inception Report.
2. 40% of agreed contract sum as second installment on submission of Interim/Progress Report after completion of field survey and the Draft final report.
3. 35% being full and final payment of the greed contract sum on acceptance of the Final Report.

7.0 ADMINISTRATIVE ARRANGEMENTS AND RESPONSIBILITIES

While this study is underway the consultant shall;

1. Report directly to the Department of Research and Development of the commission and shall be responsible for alerting the commission on all major issues pertinent to the successful execution and completion of the study.
2. The consultant is expected to be available until the completion of the studies.

8.0 CONDUCT OF THE CONSULTANT

1. The Consultant shall be expected to carry out the assignment with the highest degree of professionalism and integrity.

2. The Consultant shall conduct their duties in an open and transparent manner and shall not hinder nor prevent the Commission from executing this or any other transaction included as part of industry development.
3. The Consultant will study all the guidelines and policies of the Commission with respect to the industry development initiatives and will be expected to ensure that the transaction is concluded with very strict adherence to such policies and regulations.
4. The Consultant shall not take any material decision concerning this study without the express permission of the Commission.
5. The Consultant shall not discuss, publish, or reveal any information regarding the study without the Commission's approval.

TECHNICAL EVALUATION CRITERIA

S/N	Description Of Criterion	Points	Score
i.	**Number of years of experience on similar works of the same magnitude (20 points)**	**20**	
	1-2yrs – 10pts		
	3-5yrs – 20pts		
ii.	**List of similar works performed in the last 3yrs (30 points)**	**30**	
	1-2 jobs – 20pts		
	3-4 jobs – 30pts		
iii.	**Professional Staff qualification and competence for the assignment (20 points)**	**20**	
	a) Post graduate degree in social science, Engineering, computer science – 10pts		
	b) Certification form reputable research institutions local or international – 10pts		
iv.	**Adequacy of Experience of key Personnel for the assignment (30 points)**	**30**	

	a) registration with relevant professional body (local) – 15pts		
	b) registration with relevant professional body (international) – 15pts		
TOTAL		**100**	