Draft Consultation Document

for

Deployment of Fifth Generation (5G) Mobile Technology in Nigeria

August, 2020

Table of Content

Contents

List of Figures 4~~6~~

List of Tables 5~~7~~

CHAPTER ONE 9~~11~~

1.0 Introduction 9~~11~~

1.1 Goal 9~~11~~

1.2 Background on 5G Technology 9~~11~~

1.3 Standalone and Non-Standalone 5G Network Infrastructure 10~~12~~

1.4 Justification for the 5G Plan 11~~13~~

1.5 The Need for a National 5G Plan 12~~14~~

1.6 5G Use Cases 12~~14~~

1.7 Spectrum Challenges 13~~15~~

1.8 Milestones and Deployment Strategy for 5G Technology 15~~17~~

1.9 5G Safety and Health Concerns 15~~17~~

1.9.1 Electromagnetic Spectrum, Safety and 5G Deployment 16~~18~~

1.9.2 Ionizing Radiation 18~~20~~

1.9.3 Non-Ionizing Radiation 18~~20~~

1.10 Global Trends in 5G Technology Development and Deployment 18~~20~~

1.10.1 Early 5G Deployment Trials Globally 19~~21~~

1.10.2 5G Commercial Launches Across the World 19~~21~~

CHAPTER TWO 21~~23~~

2.0 5G Network Deployment Strategies 21~~23~~

2.1 Introduction 21~~23~~

2.2 5G Deployment Infrastructure 21~~23~~

2.3 Driving Technologies 21~~23~~

2.4 Infrastructure Usage Scenario 22~~24~~

2.5 Usage Capabilities of 5G Networks 22~~24~~

2.6 5G Infrastructure 24~~26~~

2.6.1 Fibre Backhaul 24~~26~~

2.6.2 Deployment Plan 24~~26~~

2.6.3 Phase 1 5G Spectrum Release Timeline 25~~27~~

2.6.4 Planning Regulations 25~~27~~

2.7 5G Deployment Plans and Timelines for Selected Countries 26~~28~~
2.8 Nigerian 5G Deployment Plan and Timelines 26~~28~~
2.9 Nigerian 5G Trial 29~~31~~
2.10 Outcome of the Electromagnetic Radiation Test during the 5G Proof of Concept trial in Nigeria 33~~35~~
CHAPTER THREE 35~~37~~
3.0 Draft Plan for 5G Deployment in Nigeria 35~~37~~
3.1 Introduction 35~~37~~
3.2 Objectives of the Plan 35~~37~~
3.3 Thematic Areas 35~~37~~
3.3.1 Legal and Regulatory Framework 36~~38~~
3.3.2 Network Roll-Out 36~~38~~
3.3.3 Security 37~~39~~
3.3.4 Coverage and Capacity 42~~44~~
3.3.5 Spectrum Allocation and Assignment 43~~45~~
3.3.6 5G Technology Standards 50~~52~~
3.3.7 Use Cases and Emerging Communication Trends 50~~52~~
3.3.8 Digital Economy 51~~53~~
3.3.9 Health Safety and Environment 52~~54~~
CONCLUSION 53~~55~~
Areas of Engagement with Operators 54~~56~~
Public Consultation Guidelines 56~~58~~
REFERENCES 57~~59~~

List of Figures

Figure 1. 5G Usage Scenarios. Source ITU 11
Figure 2. Milestones in the definition of the 5G technology and specifications release (source Analysys Mason 2018) 15
Figure 3: Electromagnetic Spectrum Source: Encyclopædia Britannica, Inc. 16
Figure 4. Global 5G commercial deployment .Source: GSA 5G Market Snapshot August 2020 20
Figure 5: Usage scenario in 5G........ **Error! Bookmark not defined.**
Figure 6: Key capabilities of 5G Network 23
Figure 7: Relation between key capabilities and the three usage scenarios of ITU-R. 23
Figure 8. 5G spectrum Allocation timelines 25
Figure 9. Colour coding Used in the 5G Launch Source: Analysys Mason, 2018 26
Figure 10. Deployment plan and Timelines for Nigeria 26
Figure 11. Global Telecom Manufacturers market share Source 29
Figure 12. 5G Network Rollout timeline 37

List of Tables

Table 1: EM Radiation Designation 16
Table 2. The EM spectrum showing Photon energies for different frequencies 17
Table 3: Global 5G Deployment Statistics as of May 2020 27
Table 4. Test results from the Abuja Location 30
Table 5. Test results from the Calabar Location: 30
Table 6. Results obtained from the Lagos Location 31
Table 7. Results obtained from the Kano Location 31
Table 8. Test results from the Abeokuta location 32
Table 9. Test results from the Ibadan location 32
Table 10: ICNIRP 1998 Reference levels for general public exposure to electric and magnetic fields (unperturbed rms values). 33
Table 11: EM Radiation from 5G Trial Network 34
Table 12: Range of frequencies supported by FR1 .... **Error! Bookmark not defined.**
Table 13: Range of frequencies supported by FR2 .... **Error! Bookmark not defined.**
Table 14: 2100MHz 47
Table 15. 2300 -2400MHz 47
Table 16. 2.6GHz 47
Table 17. 3300-3400MHz 48
Table 18. 3.5GHz 48
Table 19. 3600-3700MHz 48
Table 20. 4800-4990MHz 49
Table 21. 24.25-27.5GHz 49
Table 22. 40.5- 43.5GHz 49

Nigerian Communications Communication

Vision Statement

A dynamic regulatory environment that ensures Universal Access to affordable and equitable service and supports the nation's economic growth

Mission Statement

To support a market-driven communications industry and promote Universal Access

Consultation Document on the Plan for 5G Deployment in Nigeria

This document defines the implementation plan for the deployment of 5G in Nigeria. It provides a background into the benefits of 5G technology and outlines the Commission's plans and strategies for a successful implementation of 5G in Nigeria. It presents guidelines for the relevant areas of the technology and the expectations of the Commission from the operators. This Plan takes into account the expectations of all the stakeholders in the communications industry in Nigeria.

EXECUTIVE SUMMARY

The Nigerian Communications Commission has a clear ambition to ensure that the Digital Economy Policy of the Federal Government is accomplished and one of the instruments for the realization of this Policy is the availability of a robust information and communication network in the country. The Commission having identified the unique benefits and the role 5G can play in accomplishing the objectives of the digital economy, has outlined a Plan that will facilitate the deployment of 5G Technology in Nigeria. The 5G communication technology is the next evolution of the mobile communications technology which is capable of creating new opportunities for growth in the economy by enabling new and dynamic business models and opening up new opportunities and markets. It also provides tremendous improvements in interpersonal communications with several innovations and services.

5G Technology will initiate several new changes in mobile connectivity with an enormous capacity to boost productivity and grow the economy. These are the key reasons behind the Commissions drive to ensure the deployment of 5G in Nigeria. Mobile technology has not stopped growing since the commercial implementation of the first telephone system in 1876. It is estimated that by the end of the year 2020, global mobile data traffic would reach a monthly rate of 30.6 exabytes, as compared to 3.7 exabytes in 2015. That is a compound annual growth rate of 53%. Each mobile communications technology brings with it, new capabilities that ultimately transform both work and interpersonal communications.

5G represents the fifth generation in mobile communications evolution and an incremental deployment is expected over the following decade. 5G is designed to be a system of systems that will bring flexibility to mobile, fixed and broadcast networks and support more extensive data requirements. The technology will impact on the way interactions are done by enabling in some cases unforeseen business models, enhanced lifestyles all resulting in increased productivity. Some of the technologies already being touted include automated cars and advanced manufacturing, Internet of things (IoT) which will enable thousands of connected devices, such as smart energy meters, work together and share information. These changes and innovation have enormous economic benefits. IHS Economics estimated that 5G would enable USD$12.3 trillion of global economic output in 2035.

This document outlines strategy that will enable the deployment of 5G Technology in such a manner that will be most beneficial to the Nation and the end users.

CHAPTER ONE

1.0 Introduction

1.1 Goal

The goal of the Commission is that Nigeria becomes one of the leading nations with 5G technology deployed in a manner that is beneficial to all the stakeholders and contributes maximally to the Digital Economy Policy of the Federal Government of Nigeria. To achieve this, Nigeria actively participated in the ITU-R study cycle under the Task Group 5/1 that dealt with the identification of the 5G spectrum in the mmWave band. Sequel to that, the Commission suspended an impending licensing of allocated spectrum in the 38GHz and 42GHz bands as well as suspending further licensing of the 26GHz band, due to the foreseen potential identification of some parts of these bands for 5G services.

Nigeria also participated in the evaluation of submitted/proposed Radio Interface Technologies (RITs) through the creation of Nigerian Evaluation Group under the auspices of the registered Independent Africa Evaluation Group within the ITU-R process. The 5G evaluation process was concluded in February 2020.

Nigeria undertook 5G trials in selected locations within the country in collaboration with an Operator. The Commission also has an ongoing engagement with the academia while at the same time funding 5G related research projects, all in a bid to ensure the nation is provided with the best in terms of research findings and policy input, to drive the implementation and deployment of 5G technology in Nigeria. These engagements are targeted at enabling the development of robust policies which will put Nigeria in the best place to contribute maximally to the digital economy drive of the nation. The specific targets of these engagements include the development of policies which have the potential of:

a. Accelerating the deployment of 5G networks in Nigeria,
b. Maximizing the productivity and efficiency benefits of 5G to the nation,
c. Creating new opportunities for Nigerian businesses at home and abroad and encouraging in-country investment.
d. Ensuring the operations of 5G networks are in conformity with international standards

1.2 Background on 5G Technology

5G technology is the current generation of mobile communications technology, and it is designed to exceed the preceding 4G networks with new capabilities and specifications equipping the technology to support new and innovative solutions and products.

The most popular 5G deployments around the globe have been in the (3.3-3.8) GHz band, which is used by other communication technologies. Other bands proposed for the 5G deployment includes frequencies in the sub 6GHz range and above 6GHz, with ranges between 24GHz to 86GHz, known as millimeter wave bands that were studied at the ITU-R. These new frequency bands will in addition to enhancing service delivery, create additional revenue to Government through licensing. 5G will leverage existing infrastructure when deployed in a Non-standalone architecture and subsequently progress to the Standalone architecture.

One of the most significant advantage of 5G is the higher bandwidths in some of the frequency bands identified for the technology. These high bandwidths will translate to its ability to transfer large volumes of data at extremely high speed and very low latency. These speeds are expected to reach 10Gbps which is ten times faster than the highest rates offered by the fibre to the premises networks. The most significant advantages of 5G are the sheer amount of data it can transfer and the extremely fast response.

A unique feature of the 5G which is the low latency will enable the utilization of 5G in critical control and remote health applications which were challenging with the 3G and 4G networks. The response time for 3G is usually rated for 100milliseconds while that of the 4G is rated for 30milliseconds. Comparing this with the 5G response time rated as low as one millisecond, provides an enormous opportunity for the development of real-time control applications. This rapid response time is made possible by the higher available bandwidth and spectrum efficiency of the technology, as applications can complete their data transfer and allow other applications to access the bandwidth. Critical applications which will benefit from these advantages include automation, particularly in the healthcare and mining sectors, massive Machine Type Communications, and the remote control of industrial processes such as oil and gas, farming and manufacturing.

A vital drawback of the high frequency bands is their susceptibility to atmospheric attenuation; thus, the cells must be very small micro or femtocells. While these cell sizes are small, the form factors of the base stations are even much smaller resulting in microcell BTS as small as tiny boxes on streetlight installations which can be powered by solar panels and batteries.

1.3 Standalone and Non-Standalone 5G Network Infrastructure

There are two infrastructure options for a 5G network, non-standalone (NSA) and standalone infrastructures. A non-standalone infrastructure relies partly on existing 4G LTE infrastructure and brings some new technology like 5G New Radio (NR).

According to the standards body 3GPP’s Release 15 from October 2019, NSA architecture has the 5G RAN and the 5G NR interface working together with existing LTE infrastructure and core network. This means while only LTE services are supported, the network has the capabilities offered by 5G NR, like enhanced mobile broadband.

Standalone infrastructure refers to a 5G network that does not rely on LTE networks and has its own cloud-native network core that connects to the NR. It is expected that network carriers will arrive at a standalone infrastructure after moving through an NSA infrastructure. Using an NSA approach allows carriers to offer 5G-like experiences while they build out the needed physical infrastructure of a 5G network.

According to the 3GPP Release 15, the standalone deployment option is composed of user equipment, the RAN — which includes the NR — and the 5G core network. The 5G core network relies on a service-based architecture framework with virtualized network functions.

1.4 Justification for the 5G Plan

While the contributions and achievements of the 3G and 4G technologies have been remarkable, the current and continuous increase in development of new technologies and devices with the accompanying new service requirements creates a need for the development of technologies that can meet these requirements. These requirements include faster connectivity, enhanced mobile broadband, higher data capacity, reduced latency and the infrastructure required to realize revolutionary innovations such as driverless cars etc.

The mobile data traffic in Nigeria is on an upward trajectory, increasing exponentially year on year. There is thus the need for an effective and cost-efficient network expansion to ensure optimal support for this traffic growth. Cisco predicted that by 2020, global mobile data traffic would have grown eightfold from 2015 to 2020, a compound annual growth rate of 53%. This assertion is based on the higher flowrate of data, the advent of new systems and technologies such as the IoT and smart cities. A recent World Economic Forum report concluded that 5G networks would contribute $13.2 trillion in economic value globally and generate 22.3 million jobs from direct network investments and residual services

Accenture in a 2017 study concluded that 5G could create USD500 billion in additional GDP and 3million jobs in the US through a USD275 billion investment by telecom operators. A similar study by the European Commission estimated that the benefit of 5G in Europe would reach EUR 113 billion per annum in four key sectors namely automotive, healthcare, transport and energy, creating 2.3 million jobs. A global study commissioned by Qualcomm also concluded that 5G would enable USD12.3 trillion of economic output by 2035 with the 5G value chain supporting 22 million jobs.

This outlook of 5G technology has led to different governments, operators, vendors and other players in the 5G value chain racing to realize the benefits of this technology by being the first to both deploy and commercialize the technology. Key application areas that will be driven by 5G are shown in figure 1 below.

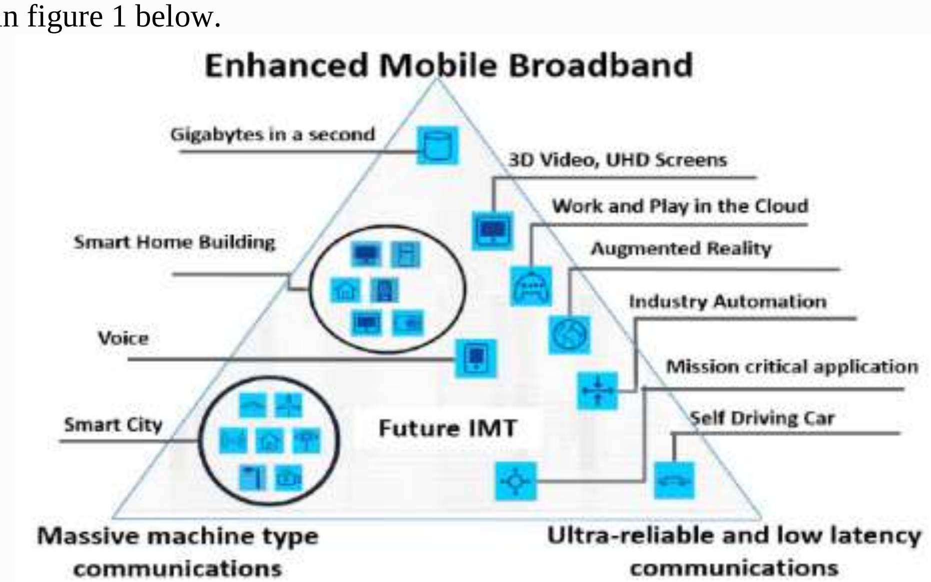

Figure 1. 5G Usage Scenarios. Source ITU

1.5 The Need for a National 5G Plan

In line with the strategy of the Federal Government of Nigeria for the acceleration of the National Digital Economy for a Digital Nigeria and the positioning of Nigeria as an early adopter of digital technology and a major participant in the growing global digital economy, the successful and timely deployment of 5G is crucial. It is expected to facilitate several emerging technologies, generate innovative new use cases, spur significant socio-economic growth, and job creation.

However, the promise of 5G is coupled with a myriad of regulatory challenges that need to be addressed before 5G rollout, such as spectrum allocation and assignment, infrastructure challenges, right-of-way issues, network security, privacy, health and safety, and so on.

In March 2020, the Nigerian National Broadband Plan 2020 – 2025 was released, updating and building upon the previous Plan (2013 – 2018). The new Broadband Plan unveiled a detailed strategy for rapid rollout of broadband services across the nation and sets goals for effective coverage, minimum data download speeds in both urban and rural areas, and data pricing, but does not fully or directly address 5G deployment.

The success of 5G deployment and commercial operation in Nigeria will be highly reliant on a defined strategy. The priority is therefore to create a Plan that ensures the advancement of 5G while also addressing the challenges and issues that are specific to 5G deployment.

1.6 5G Use Cases

5G's characteristics will enable the implementation of innovative new technologies and services that can bring radical changes to industry, business, and everyday life. These include the following:

(1) Enhanced Mobile Broadband (eMBB)

Mobile broadband is the obvious primary application of 5G. It is expected that operators will deploy 5G across the country over time, providing subscribers with much faster broadband speeds and enhanced reliability.

(2) Internet of Things (IoT)

The Internet of Things (IoT) refers to a network of devices equipped with sensors, actuators, and processors communicating with each other in real time to serve a meaningful purpose. 5G makes this feasible due to its low latency (faster responsiveness) and high capacity (the ability to support the connection of huge numbers of devices at once).

IoT technology can be applied to innovations in various sectors such as:

i. **Healthcare:** IoT can enable remote monitoring of patients, the collection of medical data through multiple sensors, and the potential automation of initial responses to changes in patients' condition.

ii. **Agriculture:** Sensors can monitor soil and plant conditions and deploy unmanned agricultural equipment, water sprinklers, or drones carrying seeds, fertilizer, or insecticide as required.

iii. **Transportation:** IoT can be used for traffic control, fleet management, remote vehicle diagnostics, and even remote control of vehicles. Autonomous vehicles will rely on 5G and IoT to gather, process, and respond to information rapidly in real time.

iv. **Manufacturing:** The automation and real-time monitoring of manufacturing processes including production floor, troubleshooting, and quality control will be enhanced by IoT.

v. **Business:** Business Intelligence, Big Data Analytics, Supply Chain Management, Process Automation, and many more business-critical concepts will benefit from 5G and IoT.

vi. **Retail:** In retail, IoT can augment inventory management, customer tracking and engagement, consumer data gathering, and customer self-service.

vii. **Energy:** Energy companies are increasingly turning to IoT technologies to enhance their grid optimization, energy distribution, predictive maintenance, and remote asset management and monitoring.

(3) Mission Critical Services (MCS)

Mission Critical Services (MCS) are digital services requiring an extremely high level of reliability and ultra-low latency, with very little room for error or loss of connectivity, such as telemedicine, autonomous vehicles, autonomous drones, smart power grids, and manufacturing processes. 5G's characteristics will enable and enhance the deployment and operation of MCS.

(4) Virtual and Augmented Reality (VAR)

Virtual (VR) and Augmented (AR) Reality applications can be used for various purposes including education, training, design, marketing, engineering, troubleshooting, maintenance, simulation, healthcare, and much more.

These applications require the real-time processing of massive amounts of data to render intricate graphical scenes, recognize real world objects, superimpose relevant information, and make sense of the complex input mechanisms for interacting with the virtual or augmented environment. The low latency and elevated data capacity of 5G will help to eliminate the lag, stutter, and stalls typically experienced by users when using sophisticated VR and AR applications over current (4G) networks, providing a smooth and seamless user experience.

1.7 Spectrum Challenges

Networks are challenged by a wide range of conflicting requirements.
Broadly, technical challenges of 5G deployment could include:

(1) **Coverage and Propagation Characteristics**:

Propagation loss increases at shorter wavelengths, which translates into shorter communication ranges. The free space loss and building penetration loss are perceived as the main contributors to the path loss at mm Wave frequencies.

(2) **Output Power and Unwanted Emission**:

A major aspect related to output power and heat dissipation at mmWave frequencies is the inverse relationship between power capability and frequency, as reflected by the Johnson limit.

(3) **Attenuation Challenges**:

The significantly higher path loss and limited output power from the Power Amplifier (PA) are two aspects that required to be addressed to make the use of the identified bands (specially the mmWave segment) of 5G useful for practical applications. Overcoming these challenges emphasize the importance of the antenna characteristics at mmWave frequencies. Hence, advanced antenna solutions with high antenna array gain become a main enabler for operation at mmWave bands. This can be realized at the base station by active antenna systems (AASs), where the beamforming can be implemented in digital, analogue, or hybrid fashion between the two.

(4) **Filtering:**

Implementation of 5G base stations with AASs involves filters being embedded in the antenna arrays, and thus must fit into the relatively small antenna array. As filter size affects filter capabilities related to insertion loss and selectivity, the combination of filter and antenna design becomes a crucial implementation aspect. The available space for accommodating mmWave filters for reducing unwanted emissions is limited, particularly in mobile devices that are likely to support sub-6 GHz bands in addition to mmWave bands.

1.8 Milestones and Deployment Strategy for 5G Technology

The deployment strategies and milestones for 5G technology is shown in figure 2.

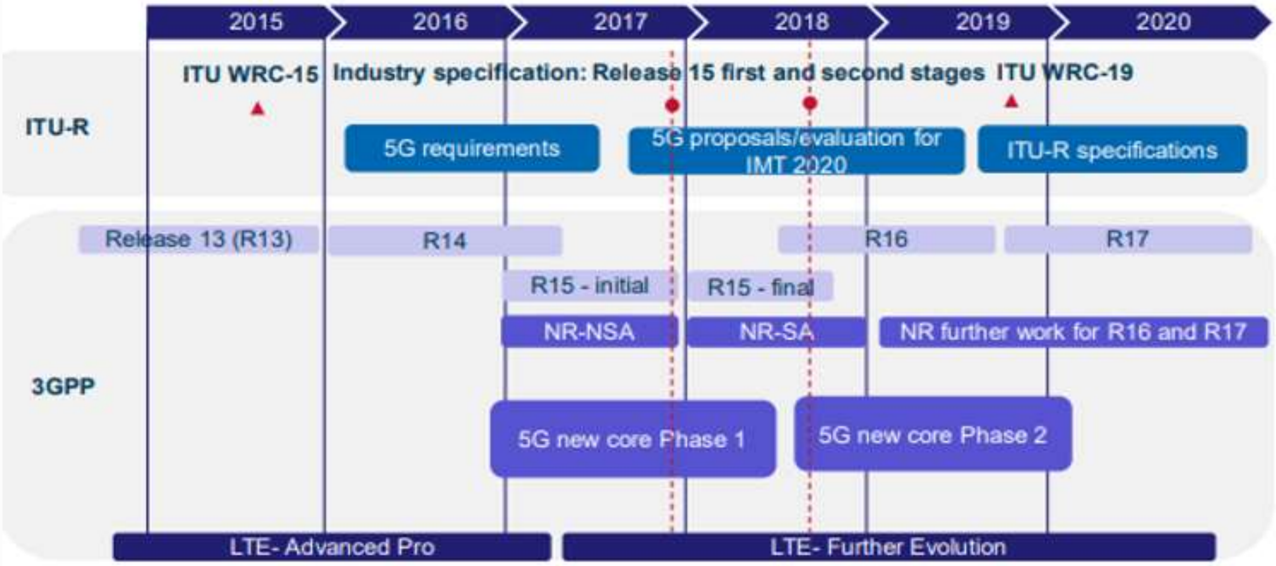

Figure 2. Milestones in the definition of the 5G technology and specifications release (source Analysys Mason 2018)

Regardless of the core network for 5G, 5G radio is to be deployed using several frequency bands. The key characteristics of the 5G NR are listed below. These characteristics will drive the spectrum need for mobile operators.

(1) At least ten times bandwidth increase over 4G (LTE-Advanced). This translates to over 1GHz spectrum for 5G NR deployment per operator for deployments in the mm-wave range.

(2) The use of new spectrum with wider contiguous frequency bands will enable operators to deploy service with better efficiency and lower latency (e.g. multiples of 100MHz carriers in the mid and high bands), low-bands (e.g. 600MHz, 700MHz and 800MHz including refarming of 2G, 3G and 4G spectrum.

1.9 5G Safety and Health Concerns

Scientific evidence from studies carried out by the Institute of Electrical and Electronics Engineers (IEEE), the United Nation Environment Program (UNEP) and the World Health Organization (WHO) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) all show that exposure to radio frequencies are safe and does not cause or initiate the occurrence of cancers.

Several studies have been undertaken for different portions of the Radio Frequency spectrum to support this position. A study involving over 40000 people exposed to radar frequencies for several years failed to identify any increased incidence of illness or mortality associated with the exposure to radio frequency emissions. Another study involving 1800 employees and 3000 of their dependents who were exposed to low level RF radiation at the US embassy in Moscow in 1978

(Study is old) showed that there was no adverse effect of their exposure to the radio frequency transmissions. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) a non-governmental organization formally recognized by WHO, also undertook several studies and issued guidelines for limiting exposure to electric, magnetic and electromagnetic fields (EMF).

The commission released updated guidelines for the protection of humans exposed to radiofrequency electromagnetic fields (EMFs) in the range 100 kHz to 300 GHz in May 2020. While these exposure limits are non-binding to countries, some have nevertheless adopted stricter limits than those recommended in the guidelines. The recommendation encourages countries to establish a common protective framework and inform the public of the health impact of electromagnetic fields, as well as to harmonize national approaches for measurement.

1.9.1 Electromagnetic Spectrum, Safety and 5G Deployment

The electromagnetic (EM) spectrum is the range of frequencies of electromagnetic radiation and their respective wavelengths and photon energies. It covers electromagnetic waves with frequencies ranging from one hertz to three hundred Exahertz (300 EHz). This frequency range is divided into separate bands, with waves in each of these bands having different characteristics and application areas. The electromagnetic spectrum is shown in figure 3.

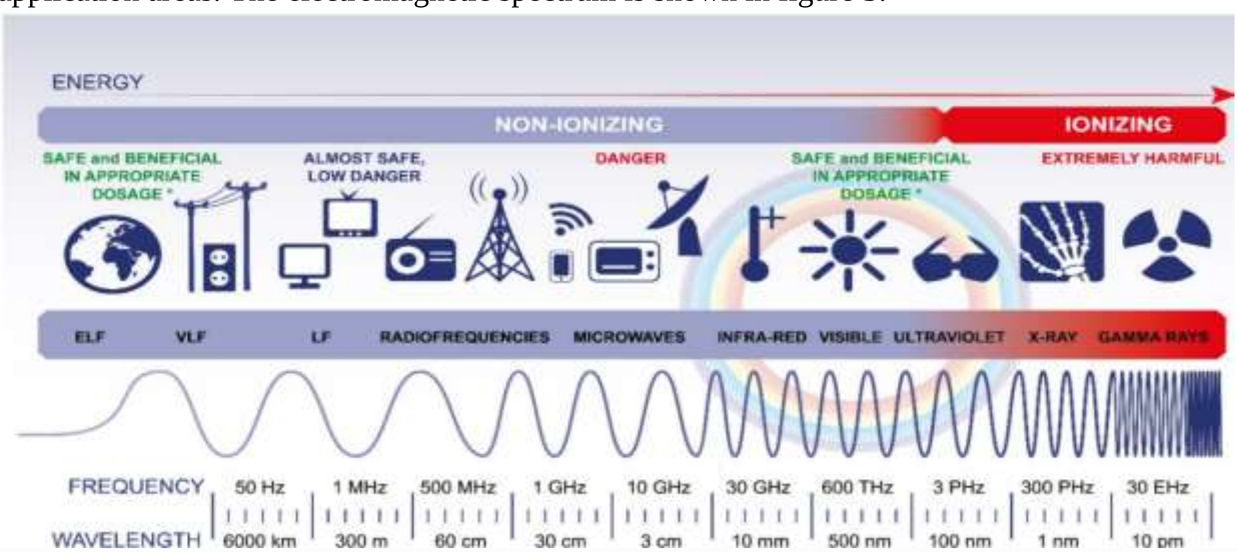

Figure 3: **Electromagnetic Spectrum Source: Encyclopædia Britannica, Inc.**

EM radiation deposits energy in two forms as it passes through biologic material: Excitation (Non-Ionization) and Ionization. Excitation describes the depositing of enough energy to raise an electron to a higher electron shell without ejection of the electron, whereas, Ionizing EM radiation has enough energy to eject one or more electrons from the atom. EM radiation spans an enormous range of wavelengths and frequencies generally divided into seven regions, in order of decreasing wavelength and increasing energy and frequency. The common designations are given in Table 1.

Table 1: EM Radiation Designation

Name	Class	Division	Energy
Extremely low frequency	ELF	Radio waves	Non-Ionizing
Super-low frequency	SLF	Radio waves	Non-Ionizing
Ultra-low frequency	ULF	Radio waves	Non-Ionizing

Voice frequency	VF	Radio waves	Non-Ionizing
Very low frequency	VLF	Radio waves	Non-Ionizing
Low frequency (radio	LF	Radio waves	Non-Ionizing
Medium frequency	MF	Radio waves	Non-Ionizing
High frequency	HF	Radio waves	Non-Ionizing
Very high frequency	VHF	Radio waves	Non-Ionizing
Ultrahigh frequency	UHF	Microwaves	Non-Ionizing
Super-high frequency	SHF	Microwaves	Non-Ionizing
Extremely high frequency	EHF	Microwaves	Non-Ionizing
Far-infrared	FIR	Infrared	Non-Ionizing
Mid-infrared	MIR	Infrared	Non-Ionizing
Near-infrared	NIR	Infrared	Non-Ionizing
Visible light	NUV	Ultraviolet	Non-Ionizing
Near-ultraviolet	NUV	Ultraviolet	Non-Ionizing
Extreme-ultraviolet	EUV	ultraviolet	Ionizing
Soft X-Rays	SX	Xray	Ionizing
Hard X-rays	HX	Xray	Ionizing
Gamma rays	Γ	Gamma rays	Ionizing

In EM Spectrum, the higher the frequency the shorter the wavelength, and the greater the energy carried by the wave known as photon energy. Table 2 shows the Photon Energy of the different frequency bands

Table 2. The EM Spectrum showing Photon Energies for Different Frequencies

Class	**Frequency**	**Wavelength**	**Energy**
ELF	3 Hz	100 Mm	12.4 feV
SLF	30 Hz	10 Mm	124 feV
VF/ULF	300 Hz	1 Mm	1.24 peV
VLF	3 KHz	100 km	12.4 peV
LF	30 KHz	10 km	124 peV
MF	300 KHz	1 km	1.24 neV
HF	3 MHz	100 m	12.4 neV
VHF	30 MHz	10 m	124 neV
UHF	300 MHz	1m	1.24 ueV
SHF	3 GHz	1 dm	12.4 ueV
EHF	30 GHz	1cm	124 ueV
FIR	300 GHz	1 mm	1.24 meV
MIR	3 THz	100 um	12.4 meV
NIR	30 THz	10 um	124 meV
Visible light	300 THz	1 um	12.4 eV
NUV	3 PHz	100 nm	124 eV
EUV	30 PHz	1 nm	1.24 keV
SX	3 EHz	100 pm	12.4 keV
HX	30 EHz	10 pm	124 keV
Γ	300 EHz	1 pm	1.24 MeV

1.9.2 Ionizing Radiation

Ionizing radiation is the type of radiation, traveling as a particle or EM wave that carries sufficient energy to remove tightly bound electrons from atoms or molecules, thereby ionizing an atom or a molecule.

The release of bound electrons leads to the generation of ions and free radicals. Within living cells, ions and free radicals interact with cellular machinery and cause DNA damage, which can ultimately lead to cells deaths.
X-Rays and Gama Rays fall within the ionizing radiation and can cause human exposure risk if it exceeds the controlled levels

1.9.3 Non-Ionizing Radiation

Non-ionizing radiation refers to any type of EM radiation that does not carry enough energy per quantum (photon energy) to ionize atoms or molecules, that is, to completely remove an electron from an atom or molecule that it interacts with and therefore won't be able to do damage to biological bodies, such as breaking chemical bonds in molecules.

Non-ionizing EM radiation does not have sufficient energy to produce charged ions when passing through matter. It can only cause excitation, which is the movement of electrons to higher energy states. Radiation with particle or Photon energies less than 33 eV, the energy needed to ionize water molecules is considered non-ionizing.

Radiowaves, Microwaves, Infrared and Ultraviolet with frequencies between 1Hz and 300 THz fall within the Non-Ionizing Radiation which does not have sufficient energy to cause human health hazard.

The 5G frequencies are between 450 MHz and 71 GHz, with Photon energies between 1.426 ueV and 29.76 ueV which is far below the highest frequency and Photon energies of 300 THz and 33 eV highest limit of Non-Ionizing radiations.

All countries have regulations which are enforced to control the emissions from RF transmitters. These regulations known as Type-Approvals, and conformance testing, are vigorously enforced by the Nigerian Communications Commission which ensures the regulation of the deployment of any RF transmitter or receiver equipment which can transmit signals to remain within the internationally established safe limits for users.

1.10 Global Trends in 5G Technology Development and Deployment

Different Countries have taken different approaches to participate in 5G technology. While some have focused on the development of 5G infrastructure, others have focused on the development of associated applications/technologies and services which either enhance the 5G experience or advances the 5G capabilities. A summary of the current ongoing or recently concluded trials of 5G and the associated technologies is presented in the following section.

While the NCC is desirous of deploying the 5G technology, there is a need to focus on the key strengths available in the country. The youth population and the Digital Economy Policy of Government presents an opportunity for Nigeria to focus on the development of innovating products and services which will be significantly enhanced by the deployment of the 5G Technology in Nigeria. Some of such approaches include, the setting up of technology hubs and the sponsorship of startup events and research projects for SMEs and academia to stimulate innovation among the youth and the research community in the country.

1.10.1 Early 5G Deployment Trials Globally

Some of the early 5G deployment trials include the following:

(1) **Japan**: The trial in Japan was planned for selected areas in Tokyo, and the aim was to evaluate the performance of prospective 5G technologies in a live environment. The country had scheduled to launch a 5G network in Tokyo on time for the summer 2020 Olympics.

(2) **South Korea:** Samsung and KT CORPORATION had completed early connectivity trials. The next phase upon the completion of these trials was the setting up of the first Mobile 5G trial at the Pyeongchang Winter Olympics for 2018. All three Korean mobile operators are expected to launch commercial 5G service before the end of the year 2020.

(3) **United States**: Verizon and AT&T approached the US Government for multi-year licences to run 5G tests.

(4) **China**: China Mobile, China Unicom and China Telecom all announced 5G testing with telecommunications vendors Huawei and ZTE.

(5) **Australia:** Telstra, in partnership with Ericsson, tested one of the world's first 5G Radio testbeds in Melbourne.

(6) **Sweden**: Telia worked with Ericsson to conduct trials in Kista, Sweden, over a live 5G network.

1.10.2 5G Commercial Launches Across the World

There are about ninety-two (92) commercial launches of 5G networks in Thirty-Eight (38) countries across the world spread across all regions of the world as at July 2020. The chart in Figure 4 shows the global deployment status of the 5G technology. There are currently 92 commercial deployments of 5G in 38 countries.

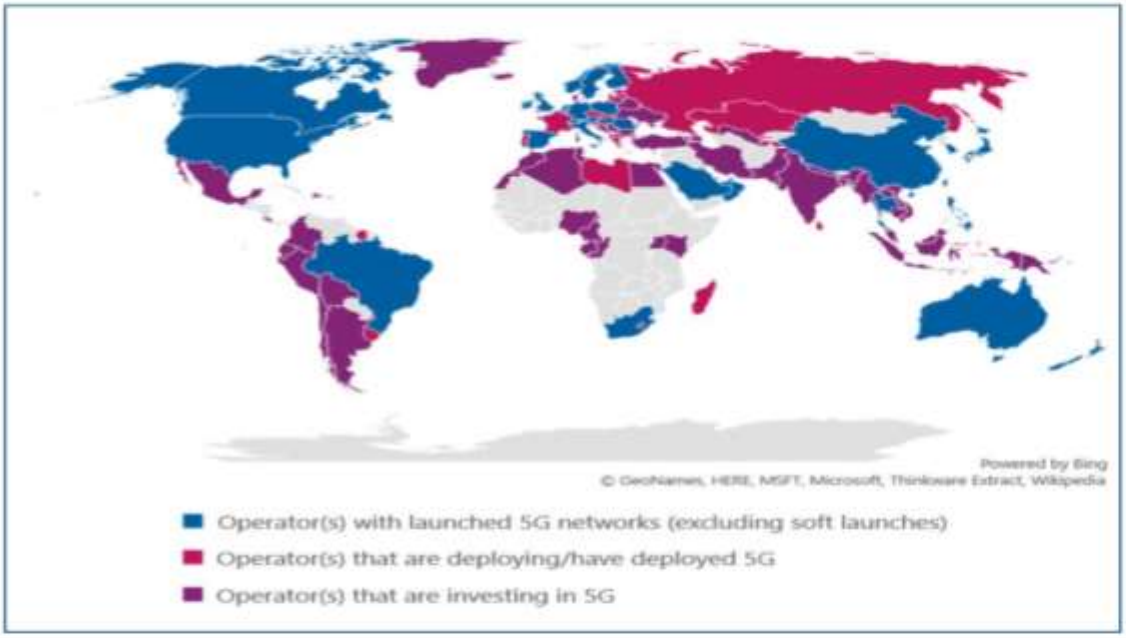

Figure 4. Global 5G Commercial Deployment
Source: GSA 5G Market Snapshot August 2020

CHAPTER TWO

2.0 5G Network Deployment Strategies

2.1 Introduction

5G network infrastructure is made up of macro- and micro base stations with edge computing capabilities. In a 5G network, network functions that typically run on hardware become virtualized, running as software. Before 5G networks reach their full potential and become self-sufficient, most carriers will be using existing 4G LTE radio access networks (RANs) augmented with some new antennas. This allows carriers to begin offering improved services while the new physical infrastructure is built.

2.2 5G Deployment Infrastructure

5G requires new infrastructure, including cell towers and antenna – known as small cells and distributed antenna systems (DAS) The cells could be any of:

- Macrocell - that covers a wide area
- Microcell - that covers a small urban or rural area
- Picocell - that covers a business-size premise and
- Femtocell - that covers a home or small business

2.3 Driving Technologies

Many new technologies have driven the development of 5G. However, the main ones are:

(1) **Virtualization**: The network element architecture is distributed internally onto specific types of blades that perform specific tasks.

(2) **Cloud Native:** This technology allows service providers to accelerate both the development and deployment of new services by enabling practices such as DevOps, while the ability to rapidly scale up or scale down services allows for resource utilization to be optimized in real-time, in response to traffic spikes and one-time events.

(3) **Containers**: This technology is used to optimize hardware resources to run multiple applications, and to improve flexibility and productivity. They are also used where low-latency, resilience and portability are key requirements; for example, in Edge computing environments.

(4) **Microservices**: these are an architectural and organizational approach to software development where rather than be developed in a monolithic fashion, software is composed of small independent services that communicate over well-defined APIs. It is often considered a variant of the service-oriented architecture approach. The overall aim with microservices architectures is to make applications easier to scale and faster to develop, enabling innovation and accelerating time-to-market for new features. They also, however, come with some increased complexity including management, orchestration and create new data management methods.

(5) **Automation**: One of the main drivers for the evolution of the core network is the vision to deliver networks that take advantage of automation technologies. Across the wider ICT domain, Machine Learning, Artificial Intelligence and Automation are driving

greater efficiencies in how systems are built and operated. Within the 3GPP domains, automation within Release 15 and Release 16 refer mainly to Self-Organizing Networks (SON), which provide Self-Configuration, Self-Optimization and Self-Healing. These three concepts hold the promise of greater reliability for end-users and less downtime for service providers. These technologies minimize lifecycle costs of mobile networks through eliminating manual configuration of network elements as well as dynamic optimization and troubleshooting.

2.4 Infrastructure Usage Scenario

ITU-R has defined three usage scenarios that form a part of the 5G recommendation. Inputs from the mobile industry and different regional and operator organizations were taken into the 5G process in ITU-R WP5D, and were synthesized into the three scenarios depicted in Figure 1

(1) **Enhanced Mobile Broadband (eMBB):** The continuous demand for mobile broadband increases due to new application areas that are emerging. This sets new requirements for what ITU-R calls Enhanced Mobile Broadband. Because of its broad and ubiquitous use, eMBB covers a range of use cases with different challenges, including both hotspots and wide-area coverage, with the hotspots enabling high data rates, high user density, and a need for very high capacity, while the wide area coverage stresses mobility and a seamless user experience, with lower requirements on data rate and user density. The Enhanced Mobile Broadband scenario is in general seen as addressing human-centric communication.

(2) **Ultra-reliable and low-latency communications (URLLC):** This scenario is intended to cover both human- and machine-centric communication, where the latter is often referred to as critical machine type communication (C-MTC). It is characterized by use cases with stringent requirements for latency, reliability, and high availability. Examples include vehicle-to-vehicle communication involving safety, wireless control of industrial equipment, remote medical surgery, and distribution automation in a smart grid. An example of a human-centric use case is 3D gaming and "tactile internet," where the low-latency requirement is also combined with very high data rates.

(3) **Massive machine type communications (mMTC):** This is a pure machine-centric use case, where the main characteristic is a very large number of connected devices that typically have very sparse transmissions of small data volumes that are not delay-sensitive. The large number of devices can give a very high connection density locally, but it is the total number of devices in a system that can be the real challenge and stresses the need for low cost. Due to the possibility of remote deployment of mMTC devices, they are also required to have a very long battery lifetime [56].

2.5 Usage Capabilities of 5G Networks

ITU-R defined a set of capabilities needed for technology to support the 5G use. The capabilities are identified through the inputs from regional bodies, research projects, operators, administrations, and other stakeholder organizations. This is fully documented in the IMT Vision recommendation. Total of 13 capabilities defined with eight regarded as key capabilities. The key capabilities are depicted in Figures 5 and 6.

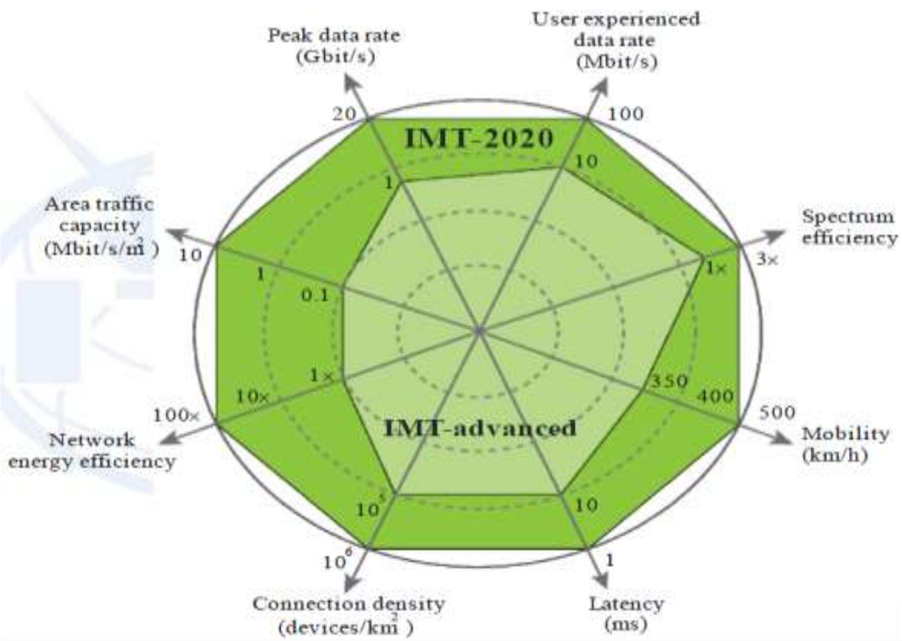

Figure 5: Key capabilities of 5G Network

Figure 5 illustrates the key capabilities together with indicative target numbers intended to give a first high-level guidance for the more detailed 5G requirements. As can be seen the target values are partly absolute and partly relative to the corresponding capabilities of 4G. The target values for the different key capabilities do not have to be reached simultaneously and some targets are to a certain extent even mutually exclusive. For this reason, Fig. 6 illustrates the importance of each key capability for realizing the three high level usage scenarios envisioned by ITU-R. It is to be noted that IMT – advanced is 4G while IMT – 2020 is another name for 5G.

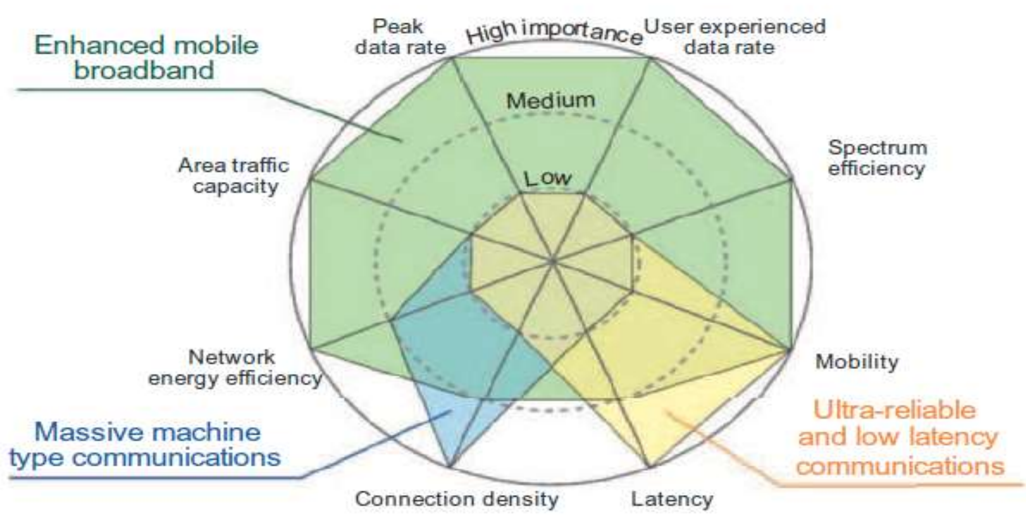

Figure 6: Relation between key capabilities and the three usage scenarios of ITU-R.

In addition to the eight key capabilities given in Figure 5, the other five additional capabilities are:

(1) **Spectrum and bandwidth flexibility**: Spectrum and bandwidth flexibility refers to the flexibility of the system design to handle different scenarios, and in particular to the capability to operate at different frequency ranges, including higher frequencies and wider channel bandwidths than today.

(2) **Reliability**: Reliability relates to the capability to provide a given service with a very high level of availability.

(3) **Resilience**: Resilience is the ability of the network to continue operating correctly during and after a natural or man-made disturbance, such as the loss of mains power.

(4) **Security and Privacy**: Security and privacy refers to several areas such as encryption and integrity protection of user data and signaling, as well as end-user privacy, preventing unauthorized user tracking, and protection of network against hacking, fraud, denial of service, man in the middle attacks, etc.

(5) Operational lifetime: Operational lifetime refers to operation time per stored energy capacity. This is particularly important for machine-type devices requiring a very long battery life (for example more than 10 years), whose regular maintenance is difficult due to physical or economic reasons.

(2) It is to be noted that the eight "key capabilities." are not necessarily less important than the five additional capabilities. The main difference is that the "key capabilities" are more easily quantifiable, while the remaining five capabilities are more of qualitative capabilities that cannot easily be quantified.

2.6 5G Infrastructure

Investment in 5G infrastructure will be largely made by the telecommunications industry. Nevertheless, government has a significant role to play in accelerating the deployment of 5G networks.

2.6.1 Fibre Backhaul

5G deployment is critically dependent on fibre backhaul. This is because the bandwidth, reliability, and low latency characteristics of the backhaul need to be able to match the cell sites to maintain seamless performance.

It is therefore essential that adequate fibre backhaul is available to support 5G deployment. Measures enabling the rapid and cost-effective deployment of pervasive fibre infrastructure must be entrenched. Right-of-Way charges should be harmonized or waived altogether. Furthermore, other attendant charges such as reinstatement costs should be harmonized and cost based. These will incentivize investment, in addition to enacting the relevant Funding and Incentives Recommendations of the Nigerian National Broadband Plan 2020 – 2025.

2.6.2 Deployment Plan

The Federal Government will provide an enabling environment for 5G deployment, but the MNOs will determine their own deployment Strategies subject to alignment to the approved polices and other regulatory instruments in force. However, the obvious strategy at this time would involve a phased approach.

Indications suggest that majority of operators in different markets will opt for a phased strategy, involving a Non-Stand Alone (NSA) approach for the early stage, a hybrid approach mid-term, and a Stand-Alone approach long term. This phase approach will accommodate device availability.

For the early stage of Nigerian 5G deployment strategy (2020 – 2021), a Non Stand-Alone approach will involve deployment of 5G equipment on some existing sites, supported by densified networks of small cells.

The mid-term stage (2021 – 2025) will involve a hybrid approach with new-build 5G sites added to the small cell networks. Depending on demand and ROI, this hybrid scenario may be seen by some as a long-term solution.
The long-term stage (post 2025) should see Stand Alone networks deployed and will require the largest infrastructure investment.

2.6.3 Phase 1 5G Spectrum Release Timeline

Securing spectrum for 5G is an antecedent for any Operator to commit serious investment to 5G infrastructure. This makes it imperative for the spectrum allocation and assignment process to be concluded as early as possible. The following timeline in figure 7 is therefore proposed as optimal:

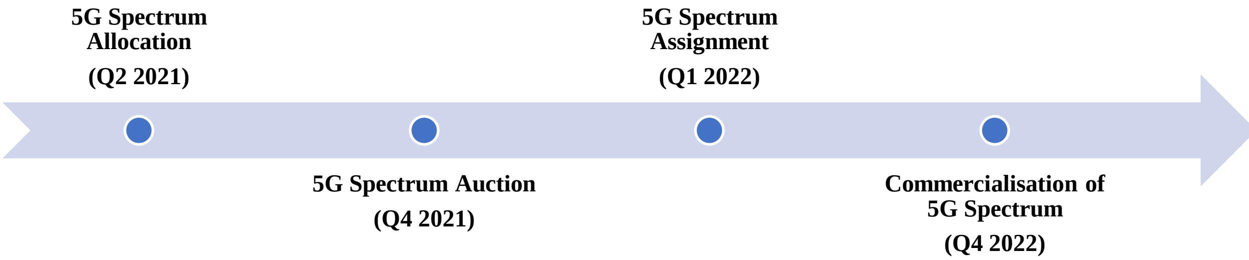

Figure 7. 5G spectrum Allocation Timelines

2.6.4 Planning Regulations

Many existing policies, regulations, and processes pertaining to the deployment of wireless networks were designed for previous generation networks.

With 5G, however, MNO network planning has become much more complex, with heavy reliance on small cells as opposed to large cell towers. Some of these cells may be located on street furniture or on buildings. Flexible and fit-for-purpose regulations will be required. Siting regulations and permits will need to be updated urgently to take this into consideration and help accelerate 5G deployment by easing previous restrictions that are no longer valid. Completion of the updates should be timed to coincide with the assignment of 5G spectrum.

The relevant building regulators and urban and town planning agencies should collaborate and ensure that buildings are designed to ensure ICT services are included in the building codes. The Commission will also engage in strategic collaboration with relevant agencies to explore lower deployment costs and encourage long term investments in communications infrastructure.

2.7 5G Deployment Plans and Timelines for Selected Countries

The following sections present charts on the 5G deployment plans and timelines for selected countries. These deployment decisions were made in 2018 with commencement dates of 2020. The critical components of these deployment plans shown in figure 8 include

(1) Government strategy and Roadmap document
(2) Government funding and backing program
(3) Mobile Network Operator (MNO) Launch
(4) MNO/Government Trials

Figure 8. Colour Coding Used in the 5G Launch Source: Analysys Mason, 2018

2.8 Nigerian 5G Deployment Plan and Timelines

The deployment plans and timelines for the Nigerian 5G deployment is shown in figure 9

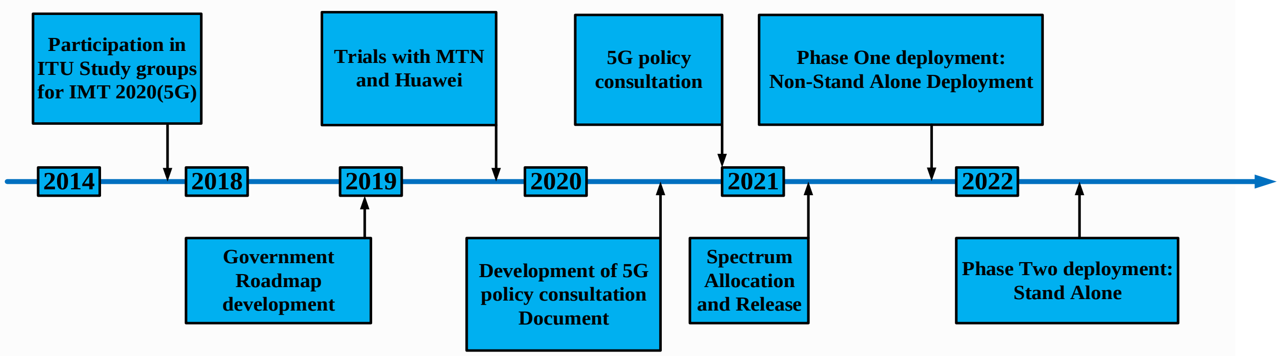

Figure 9. Deployment Plan and Timelines for Nigeria

The deployment plans for Nigeria is shown in figure 9. Nigeria envisages a two-stage deployment approach with the phase one deployment based on the Non-Standalone approach and the Phase two based on the Stand-alone approach. Phase one is planned to commence in 2021 and the phase Two deployment which will rely on new spectrum allocations is planned to commence in 2022.

The deployment plans and timelines in figure 9 shows that the adopted strategy, funding and technology trials are critical in planning the launch of the 5G technology.

There are commercial 5G networks already launched in several countries across the world as shown in Figure 8. Several other countries have also moved on to deploy 5G technology. Table 3 shows a list of the current global 5G deployments as at May 2020, the region and the operators responsible for these deployments.

Table 3: Global 5G Deployment Statistics as of May 2020

GLOBAL 5G NETWORK DEPLOYMENT								
S/N	**Country**	**Region**	**Sub region**	**Operator**	**Status**	**Launch date**	**Tech nology**	**Freq MHz**
1.	South Africa	Africa	Southern Africa	Vodacom	Live	May 2020	5G	3500
2.	Netherlands	Europe	Western Europe	VodafoneZiggo (Liberty Global / Vodacom)	Live	Apr 2020	5G	1800
3.	United States of America	Americas	Northern America	GCI	Live	Apr 2020	5G	600/700/ 850
4.	Hungary	Europe	Eastern Europe	Magyar Telekom	Live	Apr 2020	5G	3600
5.	Hong Kong; SAR China	Asia	Eastern Asia	3 (CK Hutchison)	Live	Apr 2020	5G	
6.	Hong Kong; SAR China	Asia	Eastern Asia	China Mobile	Live	Apr 2020	5G	
7.	United States of America	Americas	Northern America	T-Mobile (Deutsche Telekom)	Live	Apr 2020	5G	2500
8.	Hong Kong; SAR China	Asia	Eastern Asia	csl (HKT)	Live	Apr 2020	5G	3300
9.	Belgium	Europe	Western Europe	Proximus	Live	Apr 2020	5G	
10.	Japan	Asia	Eastern Asia	SoftBank	Live	Mar 2020	5G	2500
11.	Japan	Asia	Eastern Asia	KDDI	Live	Mar 2020	5G	
12.	Japan	Asia	Eastern Asia	NTT DOCOMO	Live	Mar 2020	5G	3700/450 0/28000
13.	Thailand	Asia	South-Eastern Asia	TrueMove H (True Corporation)	Live	Mar 2020	5G	2600
14.	Norway	Europe	Northern Europe	Telenor	Live	Mar 2020	5G	
15.	Canada	Americas	Northern America	Rogers	Live	Mar 2020	5G	2500
16.	United States of America	Americas	Northern America	US Cellular (TDS)	Live	Mar 2020	5G	
17.	Thailand	Asia	South-Eastern Asia	Advanced Wireless Network (AIS)	Live	Mar 2020	5G	2600
18.	United Kingdom	Europe	Northern Europe	3 (CK Hutchison)	Live	Feb 2020	5G	
19.	Philippines	Asia	South-Eastern Asia	Globe Telecom	Live	Feb 2020	5G	
20.	Qatar	Asia	Western Asia	Ooredoo	Live	Jan 2020	5G	
21.	Finland	Europe	Northern Europe	DNA	Live	Jan 2020	5G	
22.	Austria	Europe	Western Europe	A1 Telekom	Live	Jan 2020	5G	3500

23.	Latvia	Europe	Northern Europe	Tele2	Live	Jan 2020	5G	3500
24.	New Zealand	Oceania	Australasia	Vodafone	Live	Dec 2019	5G	
25.	Puerto Rico	Americas	Caribbean	T-Mobile (Deutsche Telekom)	Live	Dec 2019	5G	600
26.	Virgin Islands; US.	Americas	Caribbean	T-Mobile (Deutsche Telekom)	Live	Dec 2019	5G	600
27.	United States	Americas	Northern America	T-Mobile (Deutsche Telekom)	Live	Dec 2019	5G	600
28.	Romania	Europe	Eastern Europe	Orange	Like	Nov 2019	5G	
29.	China	Asia	Eastern Asia	China Unicom	Live	Oct 2019	5G	
30.	China	Asia	Eastern Asia	China Mobile	Live	Oct 2019	5G	
31.	China	Asia	Eastern Asia	China Telecom	Live	Oct 2019	5G	
32.	Ireland	Europe	Northern Europe	eir	Live	Oct 2019	5G	
33.	United Kingdom	Europe	Northern Europe	O2 (Telefonica)	Live	Oct 2019	5G	
34.	Hungary	Europe	Eastern Europe	Vodafone	Live	Oct 2019	5G	3600
35.	Finland	Europe	Northern Europe	Telia	Live	Oct 2019	5G	4500
36.	Saudi Arabia	Asia	Western Asia	Zain	Live	Oct 2019	5G	
37.	Austria	Europe	Western Europe	3 (CK Hutchison)	Live	Oct 2019	5G	
38.	Australia	Oceania	Australasia	Optus (Singtel)	Live	Oct 2019	5G	2300/3500
39.	Saudi Arabia	Asia	Western Asia	STC	Live	Sep 2019	5G	3500
40.	Austria	Europe	Western Europe	Magenta Telekom (Deutsche Telekom)	Live	Sep 2019	5G	
41.	Germany	Europe	Western Europe	Telekom (Deutsche Telekom)	Live	Sep 2019	5G	
42.	Qatar	Asia	Western Asia	Vodafone	Live	Aug 2019	5G	
43.	Ireland	Europe	Northern Europe	Vodafone	Live	Aug 2019	5G	
44.	Maldives	Asia	Southern Asia	Dhiraagu (Batelco)	Live	Aug 2019	5G	

Source: **GSMA**

Global Telecom Manufacturers Market Share

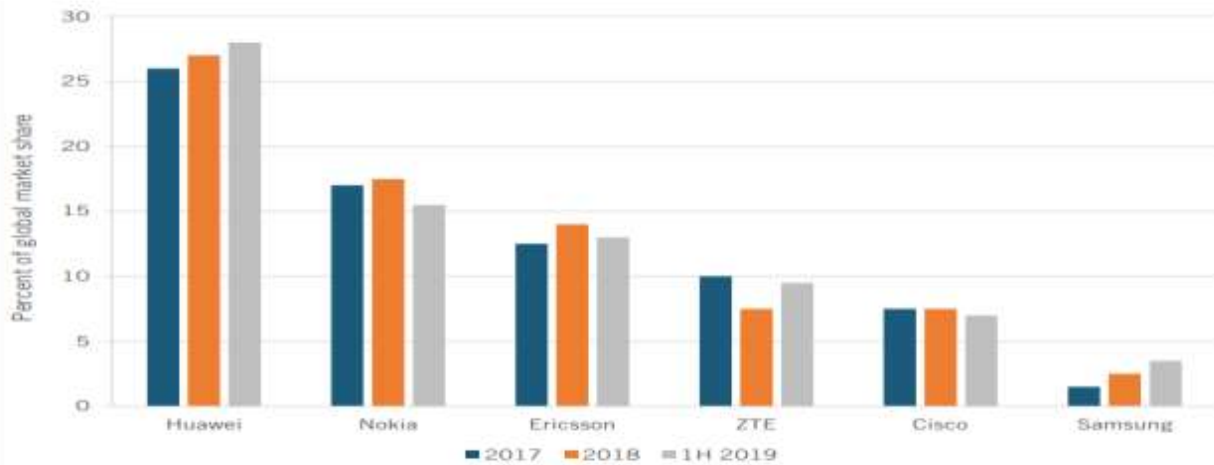

Figure 10. Global Telecom Manufacturers Market Share Source

The global distribution of 5G manufacturers is shown in Figure 10. Huawei currently leads the global market for 5G infrastructure manufacture.

2.9 Nigerian 5G Trial

A core step in the Commission's plan for the roll-out of the 5G network is a robust stakeholder engagement. A Proof of Concept (PoC) non-commercial technology trial was instituted with key industry stakeholders to undertake a Proof of Concept (PoC) for the 5G Technology in Nigeria. Six locations spread across the nation were selected for this trial, and the Commission allocated two candidate frequencies for these trials with the MTN Nigeria Communications serving as the Operator.

The locations selected are

(1) Abuja
(2) Calabar
(3) Lagos
(4) Kano
(5) Abeokuta
(6) Ibadan

The selected frequencies for the trials are the 3.5GHz and the 26GHz frequency bands. Key Network characteristics studied during the trials include

a. Throughput, Latency and Jitter measurements;
b. Co-channel interference impact on QoS;
c. Handover performance between access points (as applicable);
d. Type/models of 5G terminals used for the test;
e. Types of services (voice, data, video, etc.) and
f. Health and safety (EMF radiation level).

The reports from the trials are presented for each of the locations

(1) Abuja: Federal Capital Territory (FCT)

The following observations were made during the 5G PoC trial in Abuja

a. The trial demonstrated both Non-Standalone and Standalone networks Architectures;
b. The test involved making a call from a Voice over New radio (VoNR) topology (NSA) in Lagos to a Voice over LTE (VoLTE) topology (SA) in Abuja, and latency of 1sec was achieved;
c. An Artificial Intelligence (AI) penalty test was done using both the 4G and 5G network. Under the 5G network, the mechanical arm blocked the shot at a higher probability while under the 4G network, the mechanical arm blocked the shot at a lower probability; and
d. A holographic video call was made using the 5G network, and the participator felt wholly immersed in the conversation with live holograms.

The results obtained from the test are listed in Table 4

Table 4. Test results from Abuja Location

S/N	PARAMETERS	VALUES OBTAINED
1	Throughput	MTN used 800MHz bandwidth in the **26GHz** mm-Wave for 5G network and 20MHz bandwidth in the 3.5GHz band for the 4G LTE network to download a **2GB** movie. The movie downloaded within 17 secs on 5G (using 26GHz) and 5mins on 4G network (using 3.5GHz) with a Maximum Download (DL) throughput of **1.7Gbps** and **70Mbps** respectively.
2	Latency	Latency for voice over LTE (**VoLTE**) was **1sec** Latency for data was 170ms
3	Jitter measurements	**6ms**
4	Co-channel interference impact on QoS	MTN experienced some interference in **3410 – 3420MHz** from surrounding MTN existing TDD or WiMAX sites 20MHz re-farmed for the 5G.
5	Handover performance between access points (as applicable)	Not applicable as only one site was used.
6	Type/models of 5G terminals used for the test	Test user equipment used are as follows **Huawei MATE20X 5G Version** and **CPE H112-372.**
7	Types of services (voice, data, video, etc)	Tested voice, data and video call

(2) Calabar (Cross River State)

The trial in Calabar demonstrated Non-Standalone network architecture only. Bionic robot and holographic tests were conducted on the 5G network.

The results obtained from the test are listed in Table 5

Table 5. Test results from the Calabar Location:

S/N	PARAMETERS	VALUES OBTAINED
1	Throughput	A speed test result was achieved using 100MHz bandwidth on the 3.5GHz band with a maximum download speed of **2073Mbps** and an upload speed of **122Mbps**
2	Latency	Latency for voice over LTE (**VoLTE**) was **6.8ms** Latency for data was **167ms**

3	Jitter measurements	**3ms**
4	Co-channel interference impact on QoS	There was very little interference due to non-availability of any WiMAX or TDD sites.
5	Handover performance between access points (as applicable)	Not applicable as only one site was used.
6	Type/models of 5G terminals used for the test	Test user equipment used are as follows **MC801 CPE and ZTE Axon 10Pro**
7	Types of services (voice, data, video, etc.) to be tested as part of the PoC	Tested voice, data and video call

(3) Lagos (Lagos State)

The trial in Lagos used the Non- Standalone Network Architecture. A connected healthcare architecture was demonstrated using a 5G core network and a remotely located IP multimedia subsystem (IMS) server for voice and video connectivity. A doctor was able to effectively carry out a scan with the haptic glove over the 5G network.

The results obtained from the test are listed in Table 6

Table 6. Results obtained from the Lagos Location

S/N	PARAMETERS	VALUES OBTAINED
1	Throughput	The Lagos site with **20MHz** 4X4 **Multiple Input Multiple Output** (MIMO) in the 3.5GHz band achieved a download speed of **318Mbps** (dual connectivity of 4G and 5G) and a download speed of **209Mbps** (5G only). MTN couldn't conduct the PoC trial using the assigned 26GHz band due to Ericsson's inability to provide 26GHz equipment.
2	Latency	Latency for voice over LTE (**VoLTE**) was **1sec** Latency for data was **120ms**
3	Jitter measurements	**99ms**
4	Co-channel interference impact on QoS	MTN experienced some interference in **3410 – 3420** from surrounding MTN existing TDD or WiMAX sites 20MHz re-farmed for the 5G.
5	Handover performance between access points	Not applicable as only one site was used.
6	Type/models of 5G terminals used for the test	Test user equipment used are as follows **OPPO RENO 5G SKU1 Phone and Ericsson WNC POCKET Router**
7	Types of services (voice, data, video, etc.) to be tested as part of the PoC	Tested voice, data and video call

(4) Kano (Kano State)

The trial in Kano used the Non-Standalone network architecture;
The following results in Table 7 were obtained.

Table 7. Results obtained from the Kano Location

S/N	PARAMETERS	VALUES OBTAINED
1	Throughput	With a bandwidth of 40MHz in the 3.5GHz band, MTN was able to achieve a download speed of **515Mbps** and an upload speed of **21.8Mbps.**
2	Latency	Latency for voice over LTE (**VoLTE**) was **5-7secs** Latency for data was **173ms** MTN attributed this latency to the latency of the NSA architecture as well as the distance of the site to international gateways.
3	Jitter measurements	**4ms**

4	Co-channel interference impact on QoS	None
5	Handover performance between access points (as applicable)	Not applicable as only one site was used.
6	Type/models of 5G terminals used for the test	Test user equipment used are as follows **MATE20X 5G Version** and **CPE H112-372.**
7	Types of services (voice, data, video, etc.) to be tested as part of the PoC	Tested voice, data and video call

(5) Abeokuta (Ogun State)

The trial in Abeokuta used the Non-Standalone network architecture.

The following results in Table 8 were obtained:

Table 8. Test results from the Abeokuta location

S/N	PARAMETERS	VALUES OBTAINED
1	Throughput	MTN demonstrated using a 5G CPE and achieved a download speed of **563Mbps** and an upload speed of **45.7Mbps**
2	Latency	Latency for data was **19ms**
3	Jitter measurements	**4ms**
4	Co-channel interference impact on QoS	None
5	Handover performance between access points	Not applicable as only one site was used.
6	Type/models of 5G terminals used for the test	Test user equipment used are as follows **OPPO RENO 5G SKU1 Phone and Ericsson WNC POCKET Router**
7	Types of services (voice, data, video, etc.) to be tested as part of the PoC	Tested data only

(6) Ibadan (Oyo State)

The trial used Non-Standalone network architecture.

The following results in Table 9 were achieved:

Table 9. Test results from the Ibadan location

S/N	PARAMETERS	VALUES OBTAINED
1	Throughput	MTN demonstrated using a 5G CPE and achieved a download speed of **693Mbps** and an upload speed of **31.9Mbps**. A 4G phone was also connected to the 5G CPE using Wi-Fi, and a download speed of **376Mbps** was recorded.
2	Latency	Latency for data was **183ms**
3	Jitter measurements	**5ms**
4	Co-channel interference impact on QoS	Not applicable.
5	Handover performance between access points (as applicable)	Not applicable as only one site was used.
6	Type/models of 5G terminals used for the test	Test user equipment used are as follows **Huawei MATE20X 5G Version** and **CPE H112-372.**

7	Types of services (voice, data, video, etc.) to be tested as part of the PoC	Tested data only

2.10 Outcome of the Electromagnetic Radiation Test during the 5G Proof of Concept trial in Nigeria

This deployment of the 5G technology on the Electromagnetic Spectrum created a need for the study of the electromagnetic radiation levels which would be generated by the 5G infrastructure. These tests were conducted in accordance with the 1998 ICNIRP guidelines for general public exposure to time varying electromagnetic fields which were in force at the time of the trials. This reference levels are shown in Table 10.

Results of EMF radiation of the 5G Trial shown in Table 11 indicates that the highest radiation at 26 GHz millimeter wave at 5m away from source is 4.3 % and at 30m from the source is 0.142 %, while the highest radiation at 3.5 GHz at 5m away from the source is 11.4 % and at 30m away from the source is 1.9 % of ICNIRP Specification of 61 v/m for frequency range 2-300 GHz.

These results are far below the ICNIRP specification for protection of members of the public in the Guidelines and therefore suggest that no public health hazards are expected from the use of 5G in Nigeria.

Table 10: ICNIRP 1998 Reference levels for general public exposure to electric and magnetic fields (unperturbed rms values).

Frequency range	E-field strength ($V m^{-1}$)	H-field strength ($A m^{-1}$)	B-field (μT)	Equivalent plane wave power density S_{eq} ($W m^{-2}$)
up to 1 Hz	—	3.2×10^4	4×10^4	—
1–8 Hz	10,000	$3.2 \times 10^4/f^2$	$4 \times 10^4/f^2$	—
8–25 Hz	10,000	$4{,}000/f$	$5{,}000/f$	—
0.025–0.8 kHz	$250/f$	$4/f$	$5/f$	—
0.8–3 kHz	$250/f$	5	6.25	—
3–150 kHz	87	5	6.25	—
0.15–1 MHz	87	$0.73/f$	$0.92/f$	—
1–10 MHz	$87/f^{1/2}$	$0.73/f$	$0.92/f$	—
10–400 MHz	28	0.073	0.092	2
400–2,000 MHz	$1.375f^{1/2}$	$0.0037f^{1/2}$	$0.0046f^{1/2}$	$f/200$
2–300 GHz	61	0.16	0.20	10

[a] Note:

1. f as indicated in the frequency range column.
2. Provided that basic restrictions are met and adverse indirect effects can be excluded, field strength values can be exceeded.
3. For frequencies between 100 kHz and 10 GHz, S_{eq}, E^2, H^2, and B^2 are to averaged over any 6-min period.
4. For peak values at frequencies up to 100 kHz see Table 4, note 3.
5. For peak values at frequencies exceeding 100 kHz see Figs. 1 and 2. Between 100 kHz and 10 MHz, peak values for the field strengths are obtained by interpolation from the 1.5-fold peak at 100 kHz to the 32-fold peak at 10 MHz. For frequencies exceeding 10 MHz it is suggested that the peak equivalent plane wave power density, as averaged over the pulse width does not exceed 1,000 times the S_{eq} restrictions, or that the field strength does not exceed 32 times the field strength exposure levels given in the table.
6. For frequencies exceeding 10 GHz, S_{eq}, E^2, H^2, and B^2 are to be averaged over any $68/f^{1.05}$-min period (f in GHz).
7. No E-field value is provided for frequencies <1 Hz, which are effectively static electric fields. perception of surface electric charges will not occur at field strengths less than 25 kVm^{-1}. Spark discharges causing stress or annoyance should be avoided.

Table 11: EM Radiation from 5G Trial Network

LOCATION	**PARAMETERS**	**EM RADIATION (v/m) @**	**Maximum Exposure Measured Based on Speciation**
Abuja	BW = 800MHz F=26GHz band	5m = 1.47 30m = 0.245	The Maximum Radiated Value is 1.47 V/m@5m and 0.245V/m@30m. This is **2.4%@5m and 0.4%@30m** of ICNRIP Specification of 61 v/m at 2-300 GHZ Frequency
Lagos	BW = 20MHz F=3.5Ghzband	5m = 4.9 30m = 0.816	The Maximum Radiated Value is 4.9 V/m@5m and 0.82V/m@30m. This is **8%@5m and 1.3%@30m** of ICNRIP Specification of 61 v/m at 2-300 GHZ Frequency
Kano	BW = 40MHz F=3.5Ghzband	5m = 6.93 30m = 1.16	The Maximum Radiated Value is 6.93V/m@5m and 1.16V/m@30m. This is **11.4%@5m and 1.9%@30m** of ICNRIP Specification of 61 v/m at 2-300 GHZ Frequency
Calabar	BW = 100MHz F=26GHz band	5m = 2.6 30m = 0.087	The Maximum Radiated Value is 2.6 V/m@5m and 0.087V/m@30m. This is **4.3%@5m and 0.142%@30m** of ICNRIP Specification of 61 v/m at 2-300 GHZ Frequency
Abeokuta	BW = 60MHz F=3.5GHzband	5m = 8.49 30m = 1.41	The Maximum Radiated Value is 8.49 V/m@5m and 1.41V/m@30m. This is 5.4**%@5m and 0.86%@30m** of ICNRIP Specification of 61 v/m at 2-300 GHZ Frequency
Ibadan	BW = 60MHz F=3.5GHzband		The Maximum Radiated Value is 8.49 V/m@5m and 1.41V/m@30m. This is 5.4**%@5m and 0.86%@30m** of ICNRIP Specification of 61 v/m at 2-300 GHZ Frequency

CHAPTER THREE

3.0 Draft Plan for 5G Deployment in Nigeria

3.1 Introduction

The mobile technology space has witnessed major innovations and produced increasingly dynamic changes in communication services which have transformed human endeavors and activities globally. The transgenerational change in mobile technology is currently at the 5^{th} Generation stage which is a quantum leap from earlier generations of mobile technology.

The evolving nature of the 5G technology creates the need for a clear national Plan on how to deploy 5G technology towards achieving the best benefit for the nation and driving the 4^{th} Industrial revolution in Nigeria.

In line with the Commission's powers under Section 4(1)(q) of the Nigerian Communications Act (NCA) 2003, the Commission has taken steps to develop a Plan to guide the deployment of 5G technology in Nigeria.

3.2 Objectives of the Plan

The Plan on 5G focuses on creating an enabling environment for operators to plan and deploy 5G infrastructure and roll out services as efficiently as possible.

The following are the Plans objectives:

(1) To ensure efficient assignment of spectrum for deployment of 5G technology
(2) To create an enabling environment for additional investment in the industry
(3) To collaborate with relevant stakeholders to ensure nationwide availability of fibre and other backhaul infrastructure.
(4) To ensure effective deployment of 5G to cover major urban areas by 2025.
(5) To ensure the security of the 5G ecosystem and the protection of data.
(6) To ensure that international best practices and globally accepted standards and specifications are entrenched in Nigeria's 5G ecosystem.
(7) To create an enabling environment for innovation, digital entrepreneurship, and the proliferation of impactful 5G use cases.

3.3 Thematic Areas

The Plan focuses on the following thematic areas:

(1) Legal and Regulatory Framework
(2) Network Roll-out
(3) Security

(4) Coverage and Capacity
(5) Spectrum Allocation and Assignment
(6) 5G Technology Standards
(7) Use Cases and Emerging Technology Trends
(8) Digital Economy
(9) Health Safety and Environment (HSE)

3.3.1 Legal and Regulatory Framework

The unique and game-changing capability of 5G technology creates a need for a regulatory framework that will encourage operators to deploy services in compliance with the law and within the approved Policy framework. This regulatory framework should support both the deployment of 5G networks and take-up of 5G services. Key features of this framework will include the availability, allocation and timely assignment of radio spectrum, more favorable conditions for small cell deployments, investment incentives.

The adoption of net neutrality will go a long way in providing legal certainty with regards to 5G applications. Key benefits of net neutrality include equitable access to information, prevention of unfair, anti-competitive and discriminatory pricing practices, freedom of speech and promotion of innovation.

In order to ensure an efficient regulatory framework for deployment of 5G technology, the Commission shall:

a. Ensure the continuous development of a fit for purpose and flexible regulatory framework that keeps pace with the developments in the 5G telecommunications technologies to accommodate the rapid changes in the 5G telecommunications space.
b. Develop a regulatory framework that is positioned to address unique challenges of 5G infrastructure deployment such as investment barriers, lowering the cost of infrastructure deployment, encouraging long term capital investment in digital infrastructure and supporting coverage enhancements in collaboration with the relevant agencies of government.
c. Further invest in 5G Testbeds at approved institutions to improve the understanding of different regulatory regimes in which 5G applications and services will operate.

3.3.2 Network Roll-Out

The current race to deploy 5G networks is targeted at providing citizens with the benefits of the technology while at the same time enabling the activation of the digital economy. The 5G deployment timeline is shown in Figure 11.

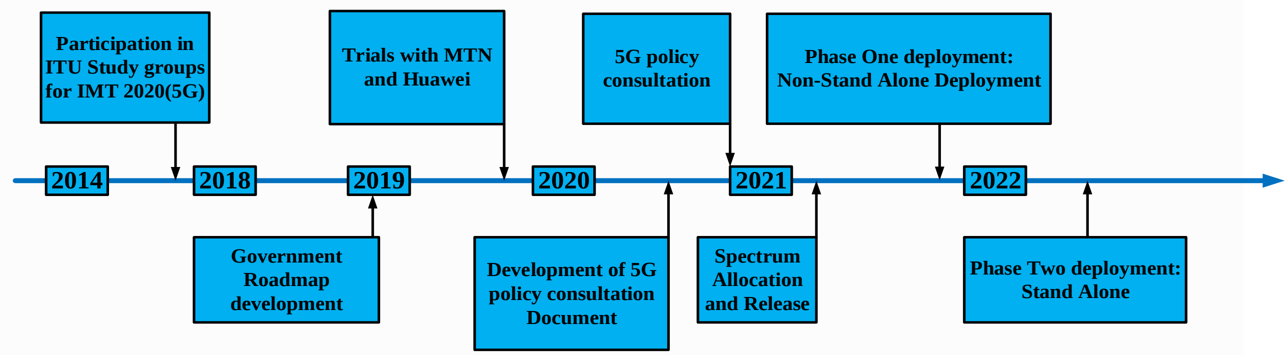

Figure 11. 5G Network Rollout timeline

The Commission's activities towards facilitating roll-out of 5G services shall be based on the following:

1. Creating an enabling environment for deployment of 5G technology: The Commission shall facilitate a private sector led deployment of 5G technology and roll-out of 5G technology. This shall be implemented by use of appropriate strategies which will include but not be limited to the following:
   a. Ensuring spectrum availability for 5G technology deployment
   b. Developing a roadmap that will allow the Commission to initiate a collaborative process across relevant bodies.
   c. Streamlining government processes for deployment of communication infrastructure
   d. Advocating for legislation that designates communications infrastructure as Critical National infrastructure
   e. Encouraging the use of fibre for 5G backhaul
   f. Developing standards for small cell size roll out

2. Enabling the utilization of the 5G deployments as part of the nation's broadband penetration plan.
3. Promoting strategic collaborations among relevant stakeholders for the setting up of testbeds and research hubs for 5G innovation and enabling contribution to global standards.
4. Ensuring optimal utilization of the cell sites by mandating compliance to the relevant infrastructure sharing regime.
5 Collaborating with the industry and academia to support and promote research in the development, testing and evaluation of new technologies and innovations

3.3.3 Security

5G networks in comparison to the existing networks and generations of the communications technology are fundamentally different. While all the previous generations mostly relied on hardware components which often get outdated very quickly, the 5G technology largely relies on the software and cloud infrastructure to "virtualize" network functions. Cloud services will play very critical roles in the 5G technology, and both the virtualization and 'cloudification' of network functions will unlock a myriad of new possibilities for managing and securing networks. Software-

Defined Networks will facilitate the creation of tailored virtual environments which will apply security controls customized to the data and devices used within the context. The increasing relevance of software in 5G is a key reason why the security of 5G is very critical.

The following are recommended input to the Plan for 5G deployment with regards to security:

1. Harnessing Software Innovation
2. Securing the 5G ecosystem,
3. Managing supply chain risk,
4. Hardening the cloud, and
5. Building 5G Governance.

The importance of these are indicated below:

1. Harnessing Software Innovation

With the critical role software will be playing in the backbone networks of 5G networks, innovative software-powered tools and techniques will reshape how 5G networks operate and this creates a huge need for security. Governments will be required to lead and set very high benchmarks to the operators for the security of these networks. Key technologies to be invested in include, Network Virtualization, Virtualized Radio Access Network, Open RAN technologies, Software- Defined Networking (SDN), Network Slicing, Cybersecurity and 5G Security Research and Development.

Investments should also be made in the piloting of these technologies to be able to test out the new security techniques such as segregation of suspicious traffic, protection of sensitive information, authentication of users and other fundamental security needs.

2. Securing the 5G ecosystem

The security of 5G network cuts across the 5G infrastructure and extends to the vast and dynamic ecosystem of devices connected to the system. Particular attention should be paid to the design, deployment, configuration and maintenance of 5G networks to ensure true end-to-end cybersecurity. The reliance of 5G on software makes the mitigation of risks of software vulnerabilities exceedingly critical. Best practices in software development and maintenance should be adopted by developers and vendors to ensure the software deployed on the 5G network is secure.

Encryption is one of the most vital tools for maintaining confidentiality and integrity of the vast volumes of data that will be moving through the networks. The Commission will ensure that operators deploy 5G networks in accordance with the relevant industry recommended encryption protocols

2(a) 5G Cybersecurity Risks

The evolution of the 5G network into a primarily software-driven system presents new vulnerabilities to cyber-attacks. Below are five ways these attacks have been enhanced.

1. The migration from a centralized hardware-based switching to the distributed software-defined digital routing creates difficulties with network monitoring for cyber-attacks. In previous generations of the communication network design, the hardware had chokepoints where cybersecurity threats could be controlled from. The software-based 5G networks present cybersecurity risks management difficulties as the network has moved away from centralized, hardware-based switching to distributed, software-defined digital routing as the cybersecurity management or chokepoints is pushed outward to a web of digital routers throughout the network, thus denying the potential for chokepoint inspection and control.

2. The virtualization of higher-level network functions usually performed by physical appliances further complicates the cyber vulnerability of 5G. These activities are based on the universal language of Internet Protocol and well-known operating systems. Whether used by nation-states or criminal actors, these standardized building block protocols and systems have proven to be valuable tools for those seeking to attack the networks.

3. The management of the network through software often through Artificial Intelligence exposes the system to the risk associated with an attacker gaining control of the software.

4. The large bandwidth of the 5G networks creates additional avenues of attack. The large number of low-cost, short-range, small-cell antennas deployed throughout urban areas become new hard targets. The use of 5G's Dynamic Spectrum Sharing capability in which multiple streams of information share the bandwidth in so-called "slices" creates a varying degree of cyber risk in each slice. When software allows the functions of the network to shift dynamically, cyber protection must also be dynamic rather than relying on a uniform lowest common denominator solution.

5. The advantage of IoT support in 5G also creates a cybersecurity risk. The connection of tens of billions of hackable smart devices (actually, mini-computers) to the network referred to as IoT, ranging from public safety things to battlefield things, to medical things, to transportation things all come with their vulnerability. A case of one of these types of attacks was reported by Microsoft where Russian hackers penetrated low-cost IoT devices to gain access to the networks they were connected to. The hackers then identified the secured IoT platforms and implanted their exploitation software. The fifth-generation networks thus create a greatly expanded, multidimensional cyberattack vulnerability. This new network architecture requires a similarly redefined cybersecurity strategy.

2(a)i 3GPP Security Provision

The 3GPP Releases provide for the security of the 5G networks. 3GPP specifications ensures the following securities:

1. Security architecture
2. Secure protocols
3. Authentication & authorization
4. Security assurance
5. Extendable authentication framework (EAP) for Subscriber authentication
6. Integrity protection of user plane mandatory on User Equipment (UE) and gNB

7. Data Confidentiality and Integrity.
8. Protection against changes of data Integrity,
9. Protection against changes of data Confidentiality and protection of data (at rest, in transit and in use).

The various Releases in 5G have several protocols addressing the following:

1. Mitigation of issues resulting in security breach or incident and Risk mitigation measures in operations of deployed networks.
2. Secure operational procedures, e.g. segregation of duties, use of least privilege and logging
3. Monitoring of performance security functions, vulnerability management. and detection of attacks
4. Response and recovery after breach
5. Solid network design with security and resilience in mind
6. Configuration of security parameters, hardening
7. Secure hardware and software components
8. Secure development processes
9. Version control and secure software update

Proactive action would require regulatory guidelines or frameworks and effective audits will be instituted to ensure these standards are effectively implemented by 5G network providers. Security in 5G networks and deployments is standardized (by 3GPP), where the user data is encrypted and decrypted in different functions in the 5G network.

The Plan of the Commission in managing the security risks associated with the 5G shall include but not limited to the following

1. The Commission shall in collaboration with relevant agencies:
   a. assess risks and identify the core security principles of the 5G infrastructure.
   b. promote secure and reliable 5G infrastructure by regularly assessing the economic and national security and other risks to this infrastructure, including defining and maintaining the relevant core security principles for this infrastructure.
   c. continually monitor the economic, national security, core security principles which includes the best practices in cybersecurity, supply chain risk management, and public safety for the nation's 5G infrastructure and other risks posed by the vulnerabilities and cyber threats to the 5G infrastructure for proactive action.
   d. ensure that transactions involving information and communications technology or services from or by entities owned by, controlled by, or subject to the jurisdiction or direction of a foreign nation that poses an undue or unacceptable risk to the national security of Nigeria and her allies are prohibited.
   e. leverage on relevant security report to address potential and operational risk from suppliers of 5G infrastructure.
2. The Commission will participate actively in the development and implementation of International 5G security principles through bilateral and multilateral collaborations with relevant partners.
3. The Commission shall develop frameworks that ensure 5G vendor diversity to minimize risk exposure.

4. The Commission shall ensure that the 5G networks are deployed with a fit for purpose security architecture to ensure data protection and privacy.
5. Strengthen domestic policies and actions that will promote local content within the industry.
6. Promote regulatory frameworks that prevent 'vendor lock-in'

3. Manage Supply Chain Risk

Effective supply chain risk management practices limit vulnerabilities and ensure the networks are secured by applying risk-based frameworks. Risk management entails understanding risk through the identification of likely threats, vulnerabilities and potential consequences, tailoring mitigation strategies to risks, and prioritizing actions based on the most relevant and potentially impactful risks. Consistency and compatibility of regulations and alignment to globally accepted technical standards enable continuous innovation. Standards-based risk management should be adhered to in the management of risks associated with the 5G networks.

Select recommendations for managing supply chain risk include the following:

a. Communication networks and services should be designed with resilience and security in mind. They should be built and maintained using international, open, consensus-based standards and risk-informed cybersecurity best practices. Clear globally interoperable cybersecurity guidance that would support cybersecurity products and services in increasing resilience of all stakeholders should be promoted.
b. Every country is free in international law, to set its national security and law enforcement requirements, which should respect privacy and adhere to laws protecting information from improper collection and misuse.
c. Laws and policies governing networks and connectivity services should be guided by the principles of transparency and equitability, taking into account the global economy and interoperable rules, with sufficient oversight and respect for the rule of law.
d. The overall risk of influence on a supplier by a third country should be taken into account, notably in relation to its model of governance, the absence of cooperation agreements on security, or similar arrangements, such as adequacy decisions, as regards data protection, or whether this country is party to multilateral, international or bilateral agreements on cybersecurity, the fight against cybercrime, or data protection.

The supply chain Plan should adopt a risk-based approach which advances interoperability, transparent and fair supply chain, Government-Industry collaboration and innovation across the supply chain. It should also have robust mechanisms for dispute resolution.

4. Hardening the Cloud

The critical role of the cloud in the 5G network roll-out is evidenced in the following vital applications areas.

a. Enabling rapid deployment of security mitigations

b. Dynamic assignment of computing resources to meet security and resource demands
c. Greater overall network resilience.

A secure and trustworthy cloud environment is required to maximize these benefits and application areas of the cloud. Adopting risk-based cloud security policies which are aligned with globally recognized standards is a crucial requirement for securing the cloud. Cloud network segmentation along with data types and locations must be used.

Risk-based approaches are recommended as they ensure optimal security outcomes while maintaining necessary flexibility and adaptability to providers to meet customer and security needs within the specific context in which they operate. Examples of international standards include the International Organization for Standardization (ISO) 27000 series or the Service Organization Controls (SOC). This provides a clear, repeatable basis for assuring and evaluating cloud security.

The adoption of several and varied implementation models of different cloud service providers also places a demand for the establishment of 5G security policies which clearly defines the requirements for such deployment. The Infrastructure-as-a-Service or Software-as-a-Service are some typical deployment models that will be used in the 5G network deployment.

5. Effective 5G Governance

Effective governance for 5G deployment will provide firm security control and robust technical support for its implementation. For effective operation of 5G networks, there will be a need for cooperation between nations and between different government agencies within countries. The use of open standards with built-in security should be encouraged. These standards will ensure that 5G governance is flexible and coordinated across the different stakeholders.

Open standards promote interoperability by providing transparency and consistency in implementations and enabling technologies from one vendor to communicate with those of others. This is at variance with proprietary standards which are closed and support only proprietary systems from the same manufacturer.

5G technology will play critical roles in several sectors cutting across numerous industries such as communications sector, the transportation sector (where 5G will enable broader adoption of autonomous vehicles and support cutting edge fleet management), the health care sector (where 5G will support life-critical medical devices), the financial sector (where 5G will underpin online financial transactions) amongst other new and upcoming use cases. There is need for synergy amongst relevant regulatory agencies to ensure effective mechanism for enforcing a unified approach to service delivery concerns.

3.3.4 Coverage and Capacity

5G network has the potential of facilitating the attainment of the goals of the Nigerian National Broadband Plan 2020-2025 and also the objectives of the National Digital Economy Policy and Strategy of the Federal Government. This capacity can only be achieved by ensuring that more locations in the country are provided with coverage.

As at December 2019, coverage data shows that most rural areas only have access to 89.8% 2G networks coverage, while 3G has a coverage of over 74%. The data-centric 4G had only about 37% of the population covered at the same time, with less than 10% connections leading to mobile internet penetration of about 32%. 5G can increase broadband delivery while lowering the price of broadband due to the large bandwidths available to the standard.

The Commission will adopt the following strategy in ensuring 5G coverage to the nation:

1. integrate 5G networks in the attainment of the national broadband plan.
2. ensure that 5G networks are deployed to provide the recommended levels of connectivity and coverage and meet the approved quality of service metrics.
3. encourage demand-driven deployment by ensuring that high consumption areas for data such as Educational and Health Institutions in the network roll-out and coverage plan for the 5G deployment.

3.3.5 Spectrum Allocation and Assignment

5G Network deployment will rely on the availability of sufficient radio spectrum at the low, medium and high-frequency bands to provide for the different use cases and applications. While some of these frequencies will be newly assigned for 5G network deployment, others will have to be re-farmed from other existing communication services.

Table 12: Range of frequencies supported by FRI

FREQUENCY BAND	UPLINK	DOWNLINK	DUPLEX MODE
n1	1920 – 1980 MHz	2110 – 2170 MHz	FDD
n2	1850 – 1910 MHz	1930 – 1990 MHz	FDD
n3	1710 – 1785 MHz	1805 – 1880 MHz	FDD
n5	824 – 849 MHz	869 – 894 MHz	FDD
n7	2500 – 2570 MHz	2620 – 2690 MHz	FDD
n8	880 – 915 MHz	925 – 960 MHz	FDD
n12	699 – 716 MHz	719 – 746 MHz	FDD
n20	832 – 862 MHz	791 – 821 MHz	FDD
n25	1850 – 1915 MHz	1930 – 1995 MHz	FDD
n28	703 – 748 MHz	758 – 803 MHz	FDD
n34	2010 – 2025 MHz	2010 – 2025 MHz	TDD
n38	2570 – 2620 MHz	2570 – 2620 MHz	TDD
n39	1880 – 1920 MHz	1880 – 1920 MHz	TDD
n40	2300 – 2400 MHz	2300 – 2400 MHz	TDD
n41	2496 – 2690 MHz	2496 – 2690 MHz	TDD
n50	1432 – 1517 MHz	1432 – 1517 MHz	TDD
n51	1427 – 1432 MHz	1427 – 1432 MHz	TDD

n66	1710 - 1780	2110 – 2200 MHz	FDD
n70	1695 – 1710 MHz	1995 – 2020 MHz	FDD
n71	663 – 698 MHz	617 – 652 MHz	FDD
n74	1427 – 1470 MHz	1475 – 1518 MHz	FDD
n75		1432 – 1517 MHz	SDL
n76		1427 – 1432 MHz	SDL
n77	3.3 – 4.2 GHz	3.3. – 4.2 GHz	TDD
n78	3.3 – 3.8 GHz	3.3 – 3.8 GHz	TDD
n79	4.4 – 5.0 GHz	4.4 – 5.0 GHz	TDD
n80	1710 – 1785 MHz		SUL
n81	880 – 915 MHz		SUL
n82	832 – 862 MHz		SUL
n83	703 – 748 GHz		SUL
n84	1920 – 1980 MHz		SUL
n86	1710 – 1780 MHz		SUL

Table 13: Range of frequencies support by FR2

FREQUENCY BAND	UPLINK	DOWNLINK	DUPLEX MODE
n257	26.5 – 29.5 GHz	26.5 – 29.5 GHz	TDD
n258	24.25 – 27.5 GHz	24.25 – 27.5 GHz	TDD
n260	37 – 40 GHz	37 – 40 GHz	TDD
n261	27.5 – 28.35 GHz	27.5 – 28.35 GHz	TDD

From Table 12, Frequencies in FR1(Frequency Range 1) support both Time – Division – Duplexing (TDD), Frequency – Division – Duplexing (FDD) and Supplemental Downlink/uplink (SDL UL/DL), while FR2(Frequency Range 2) and Table 13 support only TDD. For TDD both the device and the base station use the same frequencies when transmitting, but they are synchronized to use different time slots to avoid interference. On the other hand, in FDD, the device and the base station use different frequencies for their respective transmissions. FDD is only supported on "Mid/low bands", not on "high bands" for which TDD is always used. SDL combines with Spectrum in other bands.

1. 5G Frequency bands

Spectrum use is international and the allocation of frequencies for 5G is backed by treaty and done at the International Telecommunications Union's World Radio Conferences level to take advantage of economy of scale for network equipment and device manufacturers. Spectrum proposed for the 5G network deployment are presented in Table 12 and Table 13.

2. Legacy Spectrum

Legacy spectrum in this context refers to spectrum identified for IMT in previous World Radiocommunications Conferences (WRCs) of the International Telecommunications Union (ITU), and currently being utilized by other technologies for different services other than 5G. Some of such bands are mainly being used by operators around the world for Non-Stand Alone (NSA) 5G deployments. Some of these bands might need to be re-farmed and/or re-planned for 5G roll-out in Nigeria.

3. List of Legacy Spectrum

The list of Legacy Spectrum that could be used for 5G deployments based on available standards, core, access and end-user equipment support are listed below.

700 MHz Band:	703-733 / 758-788 MHz
800 MHz Band:	790-821 MHz / 832-862 MHz
900 MHz Band:	880-915 / 925-960 MHz
1500 MHz Band:	1427-1517 MHz
1800 MHz Band:	1710-1785 / 1805-1880 MHz
1800 MHz TDD:	1890-1910 MHz
2100 MHz Band:	1920-1980 / 2110-2170 MHz.
2.3 GHz Band:	2.3-2.4 GHz
2.6 GHz Band:	2.5-2.69 GHz
3.3 GHz Band:	3.3-3.4 GHz
3.5 GHz Band:	3.4-3.7 GHz
4.9 GHz Band:	4.8-4.99 GHz

4. The Spectrum/Bandwidth requirement for 5G Deployment

Spectrum bandwidth requirement for the deployment of 5G system to meet the IMT-2020 usage scenarios of enhanced mobile broadband (eMBB), Ultra-Reliable Low Latency Communication (URLLC) and massive Machine Type Communication (mMTC), varies. A contiguous bandwidth of 80 – 100 MHz per operator is recommended, in the low and mid spectrum bands. While bandwidths of 400-1000 MHz contiguous spectrum are recommended per operator in the high (millimeter wave) bands.
In Nigeria, these requirements can be achieved in the Mid Bands with re-farming / re-planning. It can also be met in the High Bands without any further work apart from additional allocation to be made by the NFMC.

According to Global Suppliers Association (GSA), the bands are known to be most supported at the moment by announced 5G devices are n78 (3300-3800 MHz), n41 (2496-2690 MHz), n79 (4400-5000 MHz), and n77 (3300-4200 MHz) respectively in that order.

5. Newly Identified Spectrum for IMT2020

These are Millimetre wave Spectrum that were identified in WRC-19. They will also be made available for Stand Alone (SA) 5G deployments in Nigeria.

a. 24.25-27.5 GHz Globally harmonised

b. 37-43.5 GHz Global
c. 45.5-47 GHz
d. 47.2-48.2 GHz
e. 66-71 GHz Global

All these are covered by 3GPP Release 15 which provides support for New Radio (NR) Frequency Range 1 (FR1) and Frequency Range 2 (FR2), from 450-7125 MHz and 24250-52600 MHz respectively, except 66-71 GHz to be supported by Release 17 scheduled to be completed in September 2021.

The spectrum listed below are part of spectrum identified in WRC-19 which are globally harmonised for the deployment of 5G:

a. 24.25-27.5 GHz
b. 37-43.5 GHz
c. 66-71 GHz

The above bands are available and not assigned to operators at the moment except the 26 GHz band where an operator currently has an assignment of 2 slots of 2 X 28 MHz each in the old plan which is FDD. The new plan on this band is TDD so the operator will be vacated and the band licensed based on the new TDD plan.

The first phase of the release of millimetre wave Spectrum in Nigeria will be 24.25-27.5 GHz and lower part of 37-43.5 GHz (38 GHz) starting from 37 GHz to 40.0 GHz.

The new plan on the 26 GHz band is TDD. With Guard band of 250 MHz on each side, this will be assigned to Four 4 operators with maximum of 750 MHz each.

The plan for the 38 GHz band (3GHz) is TDD. With Guard band of 250 MHz on each side, this will be assigned to Four 4 Operators with maximum of 625 MHz each.

Subsequent phases will consider other bands including those not globally allocated as they become more matured and equipment more available.

The bands below are not globally harmonised, but identified for the deployment of International Mobile Telecommunications (IMT) by footnote in which Nigeria is included:

a. 45.5-47 GHz
b. 47.2-48.2 GHz
c. 3300-3400 MHz
d. 4800-4990 MHz

6. Spectrum for First Phase of 5G Deployment in Nigeria

In the first phase of 5G deployment in Nigeria, all/some parts of the bands below are prioritized for release, recovery, re-farming and/or re-planning in line with global trends. These bands are:

a. 2100 MHz Band
b. 2300-2400 MHz
c. 2600-2690 MHz
d. 3300-3400 MHz

e. 3500-3600 MHz
f. 3600-3700 MHz
g. 4800-4990 MHz
h. 24.25-27.5 GHz
i. 37.0 – 43.5 GHz

7. Spectrum for Second Phase of 5G Deployment

The second phase shall consider the release of all or some parts of the bands listed below, based on New Radio support, maturity and device availability:

a. 1427-1518 MHz
b. 45.5-47 GHz
c. 47.2-48.2 GHz
d. 66-71 GHz

8. Current Status of the Spectrum Bands

Table 14: 2100MHz

2100 MHz				
Operator A	Operator B	Operator C	Operator D	2 X 20 MHz
2 X 10 MHz. Nationwide	2 X 10 MHz Nationwide	2 X 10 MHz. Nationwide	2 X 10 MHz. Nationwide	Available Nationwide except Lagos with 2 X 10 MHz

There are two slots of 2 X 10 MHz each available nationwide, except in Lagos where one leg in one of the slots is being used by a legacy operator that will vacate the band in December 2021. These 2 X 20 MHz Spectrum will be re-planned in conjunction with spectrum in other bands and licensed for 5G.

Table 15. 2300 -2400MHz

2300-2400 MHz			
Operator A	Operator B	Operator C	Operator D
20 MHz Nationwide Deployed	20 MHz Nationwide Not Deployed	30 MHz Nationwide Deployed in Lagos	20 MHz in Lagos, FCT and Rivers. Deployed in Lagos

Based on the Use-it-or-Lose-it Policy, and the compliance to their respective roll-out obligations on this band, the additional spectrum will be made available with the enforcement of the Plan. This will make available 70 MHz nationally except Lagos where 50 MHz will be available. These Spectrum slots when recovered will be re-planned in conjunction with spectrum in other bands and licensed for 5G.

Table 16. 2.6GHz

2.6GHz				
Operator A	Operator B	Operator C	2 X 10 MHz	Operator D
2 X 30 MHz Nationwide Deployed	2 X 20 MHz Nationwide Deployed	2 X 10 MHz Nationwide	Vacant Nationwide	1 X 40 MHz Offered for compensation

		Not deployed to be recovered		

There are 2 X 70 MHz FDD and 40 MHz TDD in this band.
Considering the importance of this spectrum for the deployment of 5G in Nigeria and the fact that a new entrant that does not have spectrum in other bands particularly Low band (Bands below 1GHz) will not be able to deploy services using this Spectrum band efficiently. The 2 X 20 MHz FDD and the 1 X 40 MHz will be recovered. This will make available 2 X 20 MHz FDD and the 1 X 40 MHz to be re-planned in conjunction with spectrum in other bands and licensed for 5G.

Table17. 3300-3400MHz

3300-3400 MHz
100 MHz Vacant Nationwide

This band is free and is one of the Spectrum bands announced to have support for 5G devices.
It will make available 100 MHz bandwidth that would be planned in conjunction with other Spectrum bands for the deployment of 5G.

Table 18 3.5 - 3.6GHz

3.5 GHz			
Operator A	Operator B	Operators C	Operator D
1 X 30 MHz	1 X 30 MHz	1 X 25 MHz	1 X 30 MHz
Nationwide Deployed	Deployed in Lagos to be recovered in other states	Operators to be required to evolve to 5G	To be recovered Nationwide

The 3.5 GHz (3.4GHz – 3.6 GHz) is 200 MHz in quantum. In Nigeria, this is shared between the telecommunications operators and Nigerian Communications Satellite service with 120 MHz and 80 MHz respectively. Only one operator has a. 30 MHz national license. The rest have licenses in at most three states and deployed only in Lagos state, and some without any deployment at all. Based on the enforcement of Use-it-or-lose-it Policy, two additional slots of 1 X 30 MHz, i.e. 60 MHz bandwidth, will be recovered and re-planned in conjunction with other Spectrum bands and licensed for 5G. All the remaining non-national operators occupying one slot of 25MHz on the band shall be required to evolve to 5G services delivery. The 80 MHz being used by the Nigerian Satellite will be available at the end of life of the Satellite which will be due in six years. This will, therefore, be made available for 5G in subsequent phases.

Table 19. 3600-3700MHz

3600-3700 MHz
100 MHz
To be Re-farmed

This Spectrum band also has some portion of it being used by Nigerian Communication Satellite. There are also V-SAT operators in the band. A maximum of 80 MHz is expected to be re-farmed and re-planned for 5G in line with the worldwide harmonization of this band for 5G deployment. This spectrum would need to be re-farmed from Satellite use.
This will give an additional 80MHz to be planned in conjunction with other spectrum bands for the deployment of 5G.

Table 20 4800-4990MHz

4800-4990 MHz
190 MHz Available

This band is one of the spectrum bands announced to have support for 5G devices. It is although not globally harmonized but identified by a footnote which includes Nigeria.
The 190 MHz bandwidth will be planned in conjunction with other available bands to license for 5G

Table 21. 24.25-27.5GHz

24.25-27.5 GHz
3.25 GHz Available

This spectrum is currently available and licensed by the Commission on an FDD mode. Only one operator has a license in the band for point- to- multi-point service delivery. The 5G plan on the band is on TDD mode. The spectrum shall be re-farmed and re-planned for 5G.
The 3.25 GHz bandwidth available in this band will be re-planned in conjunction with other Spectrum bands to be licensed for 5G.

Table 22. 40.5- 43.5GHz

40.5 – 43.5 GHz
3.0 GHz Available

This spectrum is currently available. A portion of it is allocated to the Commission but not assigned to any operator. A reallocation will be required for the right portion 40.5 – 43.5 GHz

9. Unlicensed Spectrum

Consideration would be given to the use of unlicensed spectrum to complement 5G deployments in the 5/6 GHz and 60 GHz bands for the implementation of Wi-Fi and Wi Gig.
The Commission's responsibility is to facilitate the release of appropriate and available 5G spectrum in the low, mid and high spectrum bands. The spectrum allocation for the 5G technology shall ride on the following plan:

The Commission will:

a. drive the process to ensure that the required spectrum for 5G standard is made available in the most appropriate and timely manner to enable investments, innovation and competition in the development of 5G services for the benefit of consumers and businesses
b. develop measures that support the increased flexibility (in how the spectrum can be used) within the spectrum regulatory regime.
c. ensure the maximum utilization of these spectra by providing timelines for its deployment while enforcing “Use-it or lose-it Policy”**.**
d. encourage the full implementation of the Spectrum Trading Guidelines issued by the Commission.

3.3.6 5G Technology Standards

The global collaborations supporting the development of the 5G standards will be driven by market needs and be developed by the standards bodies using the bottom-up approach. Governments will be able to contribute to these developments by collaboration with the relevant private sector organs.

The critical strategy that will be engaged to drive the Commission's contribution to the technology and standards growth of 5G in Nigeria include the following:

1. continue to engage the relevant stakeholders in the private sector and the academia to contribute to the standards and also ensure that Nigeria's needs are captured in these standards.
2. support SMEs and the academia in generating innovative technologies and applications and promote the take-up and commercialization of their ideas
3. partner with relevant agencies such as TETFUND, and the Digital Bridge Institute for the setting up of 5G testbeds at DBI campuses to facilitate research in the 5G technology and contribute to the advancement of the 5G standards.
4. promote the involvement of SMEs in 5G standards development.
5. enable and encourage the participation of relevant stakeholders at ITU events and harness the contribution from these stakeholders in putting together the position of the country at these meetings.
6. support the development of intellectual property in the 5G communications technology space by funding research and technology trials with the academia and SMEs

3.3.7 Use Cases and Emerging Communication Trends

A vital advantage of 5G technology is the number of use cases it will enable and the emerging technologies it will facilitate. With its ability to provide wireless broadband services at Gigabit speeds and data connections well above 10 Gigabits per second, latency below five milliseconds and the capability to exploit any available wireless resources (from Wi-Fi to 4G) and to handle millions of connected devices simultaneously).

The technology will support the development of new applications which will connect devices and allow innovative applications and business models due to its software virtualization abilities. Examples of new technology areas to be facilitated by 5G include enhancements in application areas such as Internet of Things (IoT), Artificial Intelligence (AI), Robotics, Drones, Advanced Communication Systems, Cloud, 3D Printing, Mixed Reality, Simulation / Imaging and Gamification. These application areas will impact and create new improvements in areas such as Manufacturing, Transportation, Public Services, Health and Social Works, Agriculture, Energy, Logistics, Media and Entertainment, Mining and Quarrying, Machinery and Equipment, Automotive, Education, Information and Communication, Urban Infrastructure, Consumer experience, Sports, Semiconductor Technologies etc.

The Commission will

1. encourage stakeholders to provide innovative solutions and partner with relevant agencies to facilitate the adoption of these technologies
2. support the development of innovative solutions based on the use cases of the 5G technology by funding hackathons, research fairs and startup hubs
3. collaborate with relevant agencies of Government to support SMEs and provide suitable enabling environments that foster innovation and creativity
4. continue to collaborate with the academia and research institutions to fund research proposals that encourage the development of innovative solutions.
5. liaise with relevant government agencies to drive the utilization and commercialization of locally developed innovative solutions riding on the 5G technology through applicable legislation and policies.
6. undertake studies and develop regulations that ensure that the emerging technologies are not utilized to create applications that can put the network and consumer data at risk
7. continue to work with relevant agencies to ensure that all devices connected to the networks are configured with the required security protocols
8. explore synergies between digital communications, energy and other strategic infrastructures. This is to align regulations in telecoms and other utilities, particularly in power, to facilitate synergic investments between these types of infrastructures and industries.

3.3.8 Digital Economy

Nigeria, with a population distribution having 70% of the citizens being less than 30years presents an opportunity which if not properly managed, can result in a substantial national challenge in the years ahead. The best approach at maximizing this population distribution is by equipping the youths with the right digital skills to help them become job creators and not job seekers.

The Commission will

1. collaborate with relevant agencies such as NITDA and the startup ecosystem to facilitate the advancement of digital literacy among the youth. This will be done by the setting up of startup hubs, promoting training programs and funding innovative solutions within the Nigerian Tech space.
2. drive the Nigerian National Broadband Plan by working with relevant agencies to ensure that broadband is deployed to crucial demand drivers such as tech hubs and research institutions.
3. invest in programs that support digital literacy training and skill acquisition for the youths in the country
4. collaborate with Operators, the National University Commission, the National Board for Technical Education and other relevant higher education regulatory bodies to help facilitate broadband penetration in the campuses of the higher institutions in Nigeria
5. develop and support an Idea-to-market innovation program where startups are mentored until their ideas and innovation are commercialized.
6. act in a bid to help with the acceleration of economic growth post-COVID 19 induced slowdown, support short-term investment into the digitalization of

public services to encourage private investment that may drive the economic recovery.

7.

3.3.9 Health Safety and Environment

Health and Public safety are very critical concerns associated with the deployment of Radio frequency-based technologies. The World Health Organization and other relevant International agencies focused on public health and safety have developed and published guidelines for the safe deployment and operation of these technologies. 5G technology falls within these technologies as such there is a need for continuous awareness and enlightenment to assure the public of the safety of the technology so as to encourage its uptake and prevent the conspiracy theorists from spreading false information and fear among the public.

The Commission shall

1. ensure that all equipment to be installed for the deployment of 5G meet the approved health protection certifications through the appropriate regulatory frame works.
2. undertake regular public awareness campaigns to keep the public up to date with health and safety related information on the 5G technology.
3. ensure that deployment and installation of 5G equipment conforms with international best practices ensuring public safety is given the highest priority.
4. ensure the utilization of controlled deployment of base stations and using the infrastructure sharing model to optimize the use of cell site locations and minimize duplication of infrastructure

CONCLUSION

Spectrum-space@ncc.gov.ng.

This Plan consultation document outlines strategies that Nigeria will adopt to facilitate the deployment of 5G Technology. It outlines critical strategies that will be engaged to enable the nation derive maximum benefits from the technology, while promoting public-private participation. The Commission will continue to engage with all relevant stakeholders in the country and also maintain active participation at the different global fora to ensure that the benefits of the technology are maximized in Nigeria. This Plan is a living document and will be updated as the need arises.

Areas of Engagement with Operators

1. Supply chain issues for hardware deployment: How do you want to manage the global rejection of Huawei 5G infrastructure?
2. What Roll out strategy would you recommend to ensure maximum uptake to demand drivers
3. Channel refarming issues: What approach should be taken to refarm existing frequencies and also reclaim unused frequencies from failed operators
4. Relocation of 3G and 4G to other areas for 5G rollout.
5. What Plan do you recommend to cater for compatibility of deployments across 3G, 4G and 5G and between different operators
6. Security training
7. Development of in-country talent
8. Development of test beds for 5G

QUESTIONS

Q Nos	**Questions**
Q1	What standard/s should Nigeria adopt for 5G deployment and why?
Q2	What Percentage should be placed as this Cap?
Q3	What other measures (if any) may be considered to prevent vendor monopoly?
Q4	Should there be additional concerns with online security on 5G networks over and above what currently exists with existing networks? If yes, what are your suggested measures to address the concerns?
Q5	What additional security measures (if any) in addition to the measures built into existing 5G standards do you consider is required to further strengthen security of 5G networks
Q6	Taking into consideration, the current status of the mid and high bands stated above, and the recommended bandwidths for 5G delivery based on standards. What is the minimum bandwidth that should be allowed for 5G deployment and made available, per operator in Nigeria, in the mid and high frequency bands?
Q7	Is the requirement, to connect all new 5G sites with Fibre appropriate?
Q8	Is the proposal for Nigeria to adopt ICNIRP 2020 Guidelines for 5G deployment as stated above in appropriate?
Q9	Which Licencing Method do you propose for 5G Spectrum?

Public Consultation Guidelines

1. Please submit comments on the proposed spectrum for 5G. If you have any alternative views or suggestions, please state them and include justification.
2. Please submit comments on the proposed licensing method. If you have any alternative views or suggestions, please state them and include justification.
3. Please submit any suggestions or concerns you may have about updating planning regulations for 5G deployment.
4. Please submit any suggestions you may have about how government can create a more enabling environment for infrastructure deployment.
5. Please submit comments on the use of Fibre for 5G backhaul. If you have any alternative views or suggestions, please state them and include justification.
6. Please submit comments on 5G network security. Are the 3GPP standards adequate? What additional security measures (if any) are required? Please include justification.
7. Please submit comments on the proposed vendor percentage cap for 5G. If you have any alternative views, concerns, or suggestions, please state them and include justification. Please suggest a threshold for the percentage cap if you agree with the premise.
8. Please submit any suggestions or concerns you may have about the physical security of 5G infrastructure to be deployed.
9. Please submit suggestions for how to create an enabling environment for innovation, digital entrepreneurship, and the proliferation of impactful 5G use cases by private sector actors.
10. Please submit any other comments or concerns you have on 5G deployment in Nigeria, and make constructive suggestions. Please include justification for any suggestions submitted.

REFERENCES

1. National Strategy to Secure 5G of the United States of America. March 2020
2. PLAN. Shaping Europe's digital future. 5G for Europe Action Plan. European Commission 19th December 2019 https://ec.europa.eu/digital-single-market/en/5g-europe-action-plan
3. 5G in Australia: getting up to speed with the future of mobile. https://www.theguardian.com/technology/2019/jul/28/5g-in-australia-getting-up-to-speed-with-the-future-of-mobile
4. Next Generation Mobile Technologies: A 5G Strategy for the UK. Department for culture, media and sport. United Kingdom 7th March 2017
5. David Abecassis, Chris Nickerson and Jannette Stewart. Global race to 5G- Spectrum and Infrastructure Plans and Priorities; Final Report for CTIA Ref 2012033-101. April 2018
6. An Industrial 5G Spectrum Plan for Europe Vodafone Public Plan Paper. November 2019
7. 5G Deployment State of Play in Europe, USA and Asia. IN-DEPTH ANALYSIS Requested by the ITRE committee. European Parliament. Plan Department for Economic, Scientific and Quality of Life Policies Directorate-General for Internal Policies Authors: Colin BLACKMAN and Simon FORGE PE 631.060 – April 2019
8. BSA Software Alliance https://www.ntia.doc.gov/files/ntia/publications/bsa-06252020.pdf June 2020
9. The Global Race to 5G. Cellular Telecommunications and Internet Association (CTIA) April 2018
10. Open Internet. Regulations Regulation (Eu) 2015/2120 Of the European Parliament and Of the Council of 25th November 2015
11. NICOL TURNER LEE. GLOBAL CHINA. NAVIGATING THE U.S.-CHINA 5G COMPETITION April 2020 https://www.brookings.edu/wp-content/uploads/2020/04/FP_20200427_5g_competition_turner_lee_v2.pdf
12. Doug Brake. A US National Strategy for 5G and Future Wireless Innovation Information Technology & Innovation Foundation. APRIL 2020
13. ITI's 5G Plan Principles for Global Planmakers. www.itic.org. https://www.itic.org/Plan/ITI_5G_Plan_Principles.pdf
14. A National Spectrum Strategy to Lead in 5G. CTIA.org https://www.ctia.org/national-spectrum-strategy.
15. A guide to 5G network security. Ericsson 2018. https://www.ericsson.com/48fcab/assets/local/news/2018/10201291-04_gir_report_broschure_dec2018_webb_181212.pdf?_ga=2.242974469.62579656.1595174236-549078100.1595174236
16. White Paper: 5G wireless access: an overview. Ericsson https://www.ericsson.com/en/reports-and-papers/white-papers/5g-wireless-access-an-overview
17. White Paper. Security in 5G RAN and core deployments. Ericsson. 2020 https://www.ericsson.com/en/reports-and-papers/white-papers/security-in-5g-ran-and-core-deployments
18. White Paper. Artificial intelligence and machine learning in next-generation systems. Ericsson 2020. https://www.ericsson.com/en/reports-and-papers/white-papers/machine-intelligence
19. White Paper. 5G security - enabling a trustworthy 5G system Ericsson 2020. https://www.ericsson.com/en/reports-and-papers/white-papers/5g-security---enabling-a-trustworthy-5g-system

20. White Paper. 5G systems - Enabling the transformation of industry and society. https://www.ericsson.com/en/reports-and-papers/white-papers/5g-systems--enabling-the-transformation-of-industry-and-society
21. Dalibor Vavruška Petr Očko How to approach 5G POLICIES. Ministry of Trade and Industry. June 2020 https://www.mpo.cz/assets/cz/e-komunikace-a-posta/elektronicke-komunikace/koncepce-a-strategie/2020/6/How-to-approach-5G-POLICIES.pdf
22. National Security Strategy for 5G: Findings & Recommendations on Meeting the 5G Challenge. Trilateral Cyber Security Commission 2nd December 2019. https://spfusa.org/wp-content/uploads/2019/12/TCSC-National-Security-Strategy-for-5G-Dec-2019.pdf
23. Fifth-Generation (5G) Telecommunications Technologies: Issues for Congress. Congressional Research Service R45485 January 2019 https://crsreports.congress.gov.
24. 5G, Standard-Setting, and National Security. Harvard Law School National Security Journal. https://harvardnsj.org/
25. The FCC's 5G FAST plan. https://docs.fcc.gov/public/attachments/DOC-354326A1.pdf
26. ICNIRP Statement on Health Issues Related to the Use of Hand-Held Radiotelephones and Base Transmitters. Health Physics 70(4):383-387; 1996.
27. ICNIRP Guidelines for Limiting Exposure to Electromagnetic Fields (100 KHZ TO 300 GHZ) Health Phys 118(5): 483–524; 2020
28. Effects of 5G wireless communication on human health. EPRS | European Parliamentary Research Service March 2020
29. Electromagnetic Fields (EMF) Electromagnetic Fields and Public Health. Base stations and Wireless Technologies. World Health Organization May 2006
30. Martin Blank & Reba M. Goodman. Electromagnetic fields and health: DNA-based dosimetry, Electromagnetic Biology and Medicine, 31:4, 243-249. 2012
31. J. T. Watts, "A Framework for an Open, Trusted, and Resilient 5G Global Telecommunications Network," The Atlantic Council, 2020.
32. B. A. Soglo, "White paper on 5G Plan implications in Sub-Sahara Africa," Intel Corporation, 2019.
33. GSMA, "5G Spectrum: GSMA Public Plan Position " 2020.
34. ITI, "ITI's 5G Plan Principles and 5G Essentials for Global Planmakers,", 2020.
35. M. L. Brown, S. H. Chang, S. D. Delacourt, R. B. Engelman, M. J. Gardner, A. M. Gomez, D. A. Gross, and A. J. Reynolds, 5G and Government: A Regulatory Roadmap: Wiley Law, 2020.
36. P. Sethi and S. R. Sarangi, "Internet of Things: Architectures, Protocols, and Applications," Journal of Electrical and Computer Engineering, vol. 2017, 2017.
37. R. Arias, M. Deshmukh, I. Mauro, D. O'Halloran, M. Spelman, H. Galal, and N. Ratan, "The Impact of 5G: Creating New Value across Industries and Society," World Economic Forum Whitepaper, 2020.
38. K. Schwab, The fourth industrial revolution: Currency, 2016.
39. F. Sadeski, K. Kaoucou, X. Potau, A. Gilwald, and R. Gupta, Study on unlocking the potential of the fourth industrial revolution in Africa: African Development Bank, 2019.
40. W. Coetzee, F. Mekuria, and Z. d. Toit, "Making 5G a Reality for Africa," Ericsson, with Council for Science and Industrial Research (CSIR), 2018.
41. K. Campbell, L. Cruz, B. Flanagan, B. Morelli, B. O'Neil, S. Teral, and J. Watson, "The 5G economy: How 5G technology will contribute to the global economy," in IHS Economics and IHS Technology: IHS Markit, 2019.

42. GSMA, "Study on Socio-Economic Benefits of 5G Services Provided in mmWave Bands," 2018.
43. FMoCDE, "National Digital Economy Plan and Strategy (2020 - 2030)," Federal Ministry of Communications and Digital Economy, 2019.
44. L. Hardell and R. Nyberg, "[Comment] Appeals that matter or not on a moratorium on the deployment of the fifth generation, 5G, for microwave radiation," Mol Clin Oncol, vol. 12, pp. 247-257, 2020.
45. L. Chiaraviglio, A. Elzanaty, and M.-S. Alouini, "Health Risks Associated with 5G Exposure: A View from the Communications Engineering Perspective," arXiv preprint arXiv:2006.00944, 2020.
46. NCC, "NCC clears doubts over 5G, COVID-19 and Security." vol. 2020: Nigerian Communications Commission, 2020.

GLOSARRY OF TERMS

Acronym	**Meaning**
FMoC&DE	Federal Ministry of Communications and Digital Economy
NCC	Nigerian Communications Commission
NITDA	National Information Technology Development Agency

GBB	Galaxy Backbone
NigComsat	Nigerian Communications Satellite
NIPOST	Nigerian Postal Services
NBC	Nigerian Broadcasting Commission
GSMA	GSM Association
MNOs	Mobile Network Operators
ISPs	Internet Service Providers
NDEPS	National Digital Economy Plan and Strategy
NNBP	Nigerian National Broadband Plan
ITU	International Telecommunication Union
WHO	World Health Organization
UNEP	United Nation Environment Program
ITU-R	International Telecommunication Union - Radio
ITU-T	International Telecommunication Union - Telecommunications
IEEE	Institute of Electrical and Electronic Engineers
3GPP	Third Generation Partnership Project
ICNIRP	Internal Commission for Non-Ionizing Radiation Protection
ISO	International Standard Organization
NCA	Nigerian Communications Act
PoC	Proof of Concept
IMT - 2020	International Mobile Telecommunications - 2020
5G	Fifth Generation Technology
SA	Standalone
NSA	Non-Standalone
4G-LTE	Fourth Generation Long Term Evolution
WiFi	Wireless Fidelity
WiGig	Wireless Gigabits
mmWave	Millimetre Wave
RF	Radio Frequency
EMF	Electromagnetic Fields
FR1	Frequency Range 1
FR2	Frequency Range 2
RIT	Radio Interface Technology
5G NR	5G New Radio
5G RAN	5G Radio Access Network
SDN	Software Defined Networks
SON	Self-Organizing Networks
DAS	Distributed Antenna System
AAS	Active Antenna System
IaaS	Infrastructure as a Service
NaaS	Network as a Service
FDD	Frequency Division Duplex
TDD	Time Division Duplex
MCS	Machine Critical Services
eMBB	Enhanced Mobile Broadband

URLLC	Ultra-reliable Low Latency Communication
mMTC	massive-Machine Type Communication
IoT	Internet of Things
MEC	Multi-Access Edge Computing
NFV	Network Function Virtualization
SBA	Service-Based Architecture
API	Application Program Interface
ML	Machine Learning
AI	Artificial Intelligence
VR	Virtual Reality
AR	Augmented Reality
LAN	Local Area Network
WAN	Wide Area Network
MAN	Metropolitan Area Network
HSE	Health, Safety and Environment