Proposed Deployment of 5G Network in Nigeria: Problems and Prospects

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ABSTRACT

Nigeria has proposed to join the league of countries which have deployed 5G wireless network technology for communication purposes by 2022 and has already granted licences to two network providers to deploy same. Despite this bold commitment there are some hurdles which must be surmounted before this deployment can be feasible. Similar challenges have delayed the smooth rollout of this technology in other countries. This paper examines some of these challenges and proposes solutions. It also highlights some of the key benefits of 5G to Nigeria's social and economic development. A review of the existing mobile communications network in Nigeria was done using data sourced from the regulatory authorities as well as a study of related literature and steps taken by countries which have already deployed similar technology in order to provide suggestions on how the deployment and implementation of 5G in Nigeria can be successful and impactful on the nation and her citizens.

INTRODUCTION

5G refers to the 5th Generation technology standard for broadband cellular or mobile networks. It was introduced in July 2016 to succeed the previous 4G (4th generation) networks as part of the continuous evolution of mobile cellular wireless technology standards. Previous generations were classed as 1G, 2G, 3G representing the first, second and third generations of this technology. There were also variants like 2.5G, 2.75G, 3.5G and 3.75G representing improvements to a current generation of technology which could not fully constitute a new generation. [1]

Table 1 shows a comparison of the features of mobile wireless technologies by generation.

Table 1: Comparison of Mobile Wireless Technologies

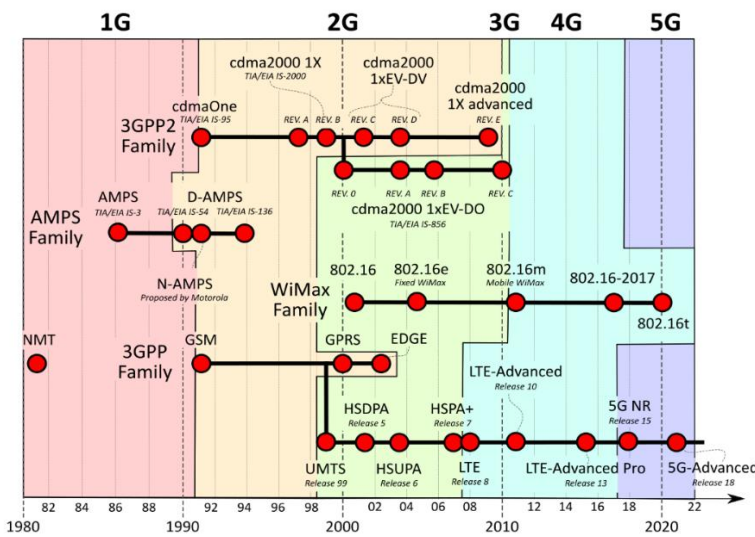| Features	2G	3G	4G	5G
Access method	TDMA	WCDMA	OFDMA	5GNR
Maximum downlink speed	10-150 Kbps	384 Kbps	100 Mbps	1-10Gbps
Maximum uplink speed	10-150 Kbps	28 Kbps	150 Mbps	1Gbps
Bandwidth	200 KHz	5 MHz	1.4-20 MHz	500MHz-2GHz

Figure I: Generations of Mobile Wireless Technologies (Wikipedia, 2022)

5G uses millimetre wave technology to transmit signals as opposed to microwave of earlier technologies and offers advantages such as lower latency period, higher connection capacity per square kilometre and higher data transmission rates. This technology is suitable for applications such as enhanced mobile broadband, ultra - reliable low latency communications and massive machine type communications. As shown in Figure 1, 5G technology has been under development since 2017 and is currently at the forefront of mobile wireless technology evolution.

Nigeria's mobile technology landscape has witnessed major innovations over the years even as the disruptive 5G technology sweeps across the globe. However, with the promise of providing the fastest network connectivity across all sectors, there seems to be a growing demand to upgrade telecommunications infrastructure urgently.

Recently, the Nigerian Communications Commission (NCC) granted licenses to two network providers, MTN Nigeria and Mafab Communications Limited to roll out 5G services, with effect from August 24, 2022. [2]

The fourth - generation mobile communication system includes TD-LTE and FDD-LTE, which is also the combination of the third generation mobile communication system (3G) and WLAN. The official name of 5G is IMT-2020, which is the fifth - generation mobile communication standard formulated by the International Telecommunication Union. As for the formation of 5G protocol, there is a unified standard in the industry field, instead of the multi-standard parallel standard in previous times. [3]

5G is committed to research in enhanced mobile broadband which can provide users with larger system capacity and faster wireless access rate, mass Internet of Things which can be applied to intelligent logistics, smart cities and even people's daily fitness as well as ultra - reliable low latency communications used in industrial production precision control, UAV (Unmanned Aerial Vehicle) remote monitoring and emergency personnel tracking, and it is believed that it will have a great impact on human life in the future. [4]

The 5G network architecture adopts SBA architecture, which is called Service Based Architecture. In fact, 5G network is a user-centered intelligent elastic network, which splits the original whole into several individuals with independent functions, and these individuals play their own roles.

Among the limitations of 4G is its use of a low frequency band, so when many people use a 4G network, there will be congestion, which will lead to lower rate. However, 5G uses a high frequency band. In this case, even if many people use a 5G network, there will be no rate reduction, and using high frequency can make better use of resources. In addition, the data download rate of 5G is as high as 10 Gbps, which is 100 times faster than 4G (about 100 Mbps). In addition, virtual industries such as VR, which have just become popular, are mostly based on 5G development. In addition, 5G network has the advantages of larger capacity, lower delay and stronger computing capability. [4]
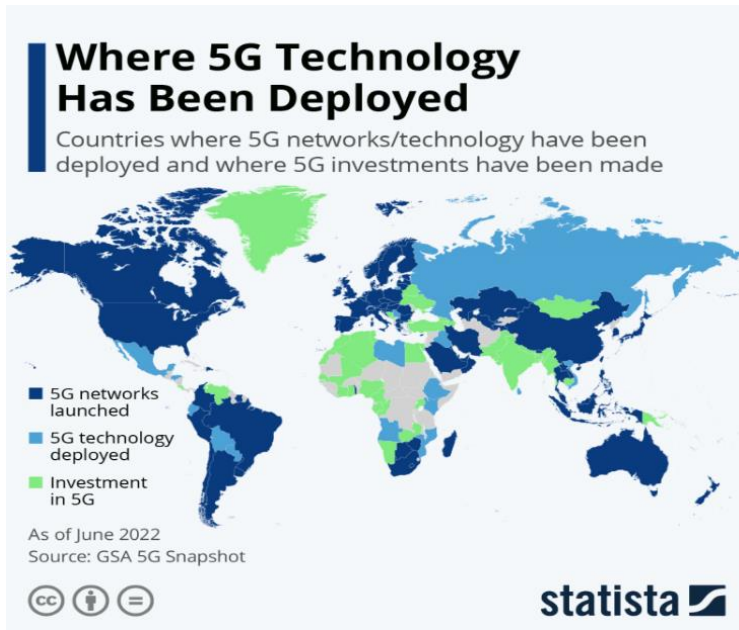
Figure 2: Deployment of 5g Networks Worldwide (Statista, 2022)

BACKGROUND OF THE STUDY

The map in Figure 2 shows the global deployment of 5G networks; obviously, Africa is far behind regarding overall deployment and investments in 5G technology. Some analysts predict that 5G will add an additional $2.2 trillion to Africa's economy by 2034. In the African continent Ethiopia, Botswana, Egypt, Gabon, Kenya, Lesotho, Madagascar, Mauritius, Senegal, Seychelles, South Africa, Uganda, and Zimbabwe are testing or deploying 5G. However, Africa's 5G first movers are facing teething problems that stand to delay their 5G goals. The challenges have revolved around spectrum regulation clarity, commercial viability, deployment deadlines, low citizen purchasing power of 5G enabled smartphones and expensive internet. [5]

Zouein (2021) classifies the issues preventing a complete development of mobile broadband in sub-Saharan Africa as mostly technical (deployment of a functional network), financial (price of subscriptions and smartphones) and geographical (how to cover the most remote rural areas). [6]

In recent years, South Africa made the most progress among African countries regarding the 5G technology, however due to spectrum availability and licensing issues it had to suspend the operation of its 5G network pending the resolution of these issues. According to the GSM Association (GSMA), most commercial 5G networks rely on spectrum in the 3.5 GHz range (3.5 GHz-4.2 GHz). [7] This is because it has been touted as the most suitable and appropriate frequency for deploying the 5G technology. The South African regulator ICASA believes it is time to focus its energy on the permanent licensing of spectrum — a decade-long problem that has plagued South Africa's telecommunications landscape.

In sub-Saharan Africa, 3G mobile data traffic is still dominant and increasing, though the number of 4G subscriptions grew by 26 percent in 2021, according to the biannual report by Ericsson [8], strong growth is expected to continue in 2022 and majority of the traffic growth is expected to be in 4G, buoyed by the growing demand for mobile voice and data services and investment in telecom infrastructure as 4G is still at a low level of adoption in sub-Saharan Africa as a whole.

On a global scale China, South Korea, The United States, Spain, The United Kingdom, Canada, Australia, Saudi Arabia, Italy and Finland are the leading countries in terms of 5G deployments and users. [9] In China, despite a good start and roll out, there are still many challenges regarding future development. For core components including chips, mobile operating system and other basic software and hardware, Chinese companies still depend on imports, which has restricted the development 5G technology. Also, 5G-related construction, operation and maintenance costs are higher than 4G. The technology needs to be upgraded and optimized for various application scenarios. It is also necessary to boost cross-industry application.

German telecommunications operators secured 5G spectrum licenses in June 2019 and they started an aggressive commercial strategy to launch 5G services in the country's main urban areas. As a result of aggressive competition between operators 5G coverage was in excess of 20 million users at the end of 2021. [10]

Issues and Challenges Facing Operators of 5G Networks

5G infrastructure is quite extensive and challenging to deploy even in developed countries. Some of the issues and challenges facing operators of 5G networks are:

1. 5G network development infrastructure: Some of the infrastructure needed for 5G is already in place, such as towers and masts already in use as telecommunications infrastructure. But for 5G there is the need to add small-cell technology in densely populated areas, which will increase network capacity. 5G network infrastructure requirements involve mmWave frequencies, which can only cover a short distance. [11] Consequently an ultra-dense grid is needed with small cells and multiple antennas which are necessary to serve a specific area. 5G network expansion largely depends on the ability to install these small-cell base stations. Another additional need is that of testing devices and networking equipment for the 5G network.

2. Costs: Adding 5G network infrastructure components means that more hardware and supporting software

are necessary. Although many components of 5G technology build on 4G networks which enables operators to approach their infrastructure as more of an evolution. This also makes investment easier. By network refarming (reallocation) of their 3G spectrum, for instance, they can more easily upgrade the capacity of their 4G network, evolving to LTE features. This can put off having to make 5G investments right away. Another approach is network sharing which involves sharing both active and passive network equipment thereby reducing the cost of network ownership for service providers while also improving network quality.

3. 5G issues with backhaul: Fibre optic cable is the medium of choice for backhaul use in 5G and is replacing copper in many 4G installations, and its ideal for 5G given its connection rates and minimal end-to-end round-trip delay. However, more fibre has to be laid, and this is where deployment becomes a challenge in terms of costs and time and space.

4. Wave spectrum: Challenges with 5G include the ability to provide the necessary bandwidth to users with the devices capable of higher data rates. Using frequencies above six gigahertz enables networks to do this. However, high-frequencies entail problems with 5G. For starters, its range is short, which again, is why multiple small cells are needed to cover an area. Trees, buildings and other objects can obstruct signals, requiring cell towers to avoid signal path loss. The good news is, multiple-input, multiple-output (MIMO) technology has shown to expand the capacity of 5G connectivity and address these signal path challenges. MIMO deployment's design simplicity adds to its attractive features. Massive MIMO can service a multitude of mobile devices in tightly packed area at a single frequency. By implementing more antennas, a massive MIMO network resists signal interference and jamming.

5. 5G security concerns: 5G network security faces many challenges. For starters, much of 5G wireless telecommunications infrastructure is built on legacy technologies, such as 4G LTE networks. Any vulnerabilities already existing in those networks will threaten the security of 5G networks. With so much more data being relayed per unit time, thieves will find it worth their time to attempt data exfiltration. More components are also involved in the implementation of 5G technology, which increases the number of access points and network edges. 5G technology infrastructure typically relies on cellular towers, beamforming, small cells, and cellular devices. This increases the digital attack surface. Also, many of these components lack physical security measures. For example, a small cell mounted on the side of a building or on a tree is vulnerable to physical attacks.

5G doesn't change the fundamentals of security. As with 4G, end users will still have to address 5G security issues to protect their assets. The difference now is, lapses in security for 5G mobile wireless networks can have catastrophic results. That said, there are new vulnerabilities in 5G networks. Attacks on the 5G security

protocol can cause network segments to crash and launch denial-of-service attacks. [12]

Shivansh (2018) discusses the problems of 5G implementation that have to be addressed in India such as lack of regulatory bodies, last mile connectivity and lack of fibre infrastructure. Low data speeds and high data cost were also highlighted. The paper proposed the use of technologies such as mobile edge computing (MEC) to reduce network congestion as a solution to the implementation problems of 5G in India. [13]

According to Guy (2018), the specific barriers to successful network implementation in the UK include legislation, access to spectrum, affordability of sites, access to power, inconsistent approach by network providers, etc. [14] The ITU study group on the implementation of 5G in Europe indentified problems hampering the smooth implementation of 5G in Poland and proposed solutions some of which were:

(i)   Speeding and improving the investment process;
(ii)   Infrastructure maintenance cost reduction;
(iii) Availability of radio spectrum;
(iv)   Review of existing regulations; and
(v)   Ensuring network security.

The significance of this paper is to raise awareness on the various challenges confronting the rollout of 5G technology and the steps to address them based on the experiences of other countries which have commenced the operation of 5G networks. It also highlights some of the major benefits to be derived from a properly structured deployment of 5G in Nigeria. Data sourced from industry operators as well as the telecommunications regulator is also presented as the basis of analysing the current situation and proposing solutions to anticipated challenges.

State of 5g Rollout in Nigeria

The Nigerian Communications Commission (NCC) has said that the number of Nigerians connected to broadband, that is, high-speed internet increased to 83.3 million in May 2022. Data released by the Commission shows that telecommunications operators in the country added a total of 1.6 million new broadband subscriptions in the month. As of April, broadband subscriptions in the country stood at 81.6 million. The increase recorded in May brought the country's broadband penetration to 43.67%. [15] Initially, the government had set a target of 70% broadband penetration to be achieved by 2025.

A World Bank report has established that every 10% increase in broadband penetration in any country would improve its GDP by at least 4.6%. Hence, the rapid rollout of broadband services is expected to address various socio-economic challenges the country faces, including the need to grow its economy, expand the tax base, and improve digital literacy and educational standards. Data released by NCC in Figure 3 shows that the percentage contribution of the telecommunications sector to Nigeria's GDP has shown a relatively consistent upward rise from 2015 to 2021 especially with improvements in quality of service as well as internet penetration.
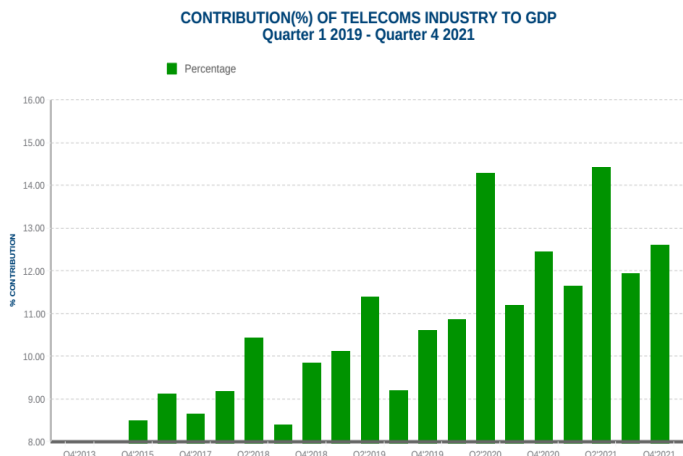

Figure 3: Percentage Contribution of Telecoms Sector to Gdp in Nigeria 2015 - 2021 (NCC, 2022)

Nigeria's mobile technology landscape has witnessed major innovations over the years even as the disruptive 5G technology sweeps across the globe. However, with the promise of providing the fastest network connectivity across all sectors, there seems to be a growing demand to upgrade telecommunications infrastructure urgently. Industry watchers observe that with the speed of technological penetration across the globe, Nigeria lags behind on the adoption of 5G especially as the process is confronted with some infrastructural deficits. [15]

Analysts opined that hitches such as access to spectrum, affordability of sites in both urban and rural areas, access to power, low speed data among others may act as inhibitors to the deployment of 5G in Nigeria. Also, the current 4G network infrastructure is not as pervasive and robust enough to allow for a seamless upgrade to 5G yet. [16]

With these overreaching barriers, many consumers and prospective users are still wondering how these will be tackled to pave the way for effective deployment of 5G technology and especially in fast-tracking the actualization plan for the national broadband between 2020 and 2025.

Socio-economic Impact of 5G Deployment

Nigeria like many other nations is in the race for the deployment of 5G technology. A successful implementation of this technology will improve internet connectivity in the country and provide an era of new and emerging technologies such as Internet-of-Things (IoT), Artificial Intelligence (AI) and Big Data to improve lives and standard of work as well as enhancing other policies that will translate Nigeria into a full digital economy.

In a report analysing the impact of 5G on the global economy in the post-COVID-19 world between 2020 and 2035, IHS Markit (2020) predicts that 5G can have beneficial societal impacts; particularly if individuals, businesses, and governments leverage 5G's potential to tackle pressing challenges. In order to fully realize these economic benefits, the various players in the 5G ecosystem will need to work together to advance this technology and fully deploy the potential use cases. Fortunately, a phased transition from 4G to 5G is possible, particularly given the long deployment cycle for 5G. Two important developments in network configuration (Network sharing and Dynamic spectrum sharing) can facilitate such a transition. [17]

What sets 5G apart from previous mobile standards is that it is not merely a product (or service) but also a platform; one upon which many use cases and new products will be built. Therefore, in time, 5G will not only improve connectivity, which will enable much more efficient use of time, talents and resources, it will also address several pressing needs including better management of natural resources, increased energy efficiency, increased delivery of education and healthcare, better monitoring of supply chains, and allowance for people and businesses to be more resilient during times of disruption and more productive in the long run.

5G can also play a potential role in realization of the UN Social Development Goals (SDGs). That is, there is a potential upside for many countries that accelerate their 5G deployment and digital transformation initiatives as they can reap greater benefits over time. A key to sustainable GDP growth is continual investment in infrastructure and Research and Development (R&D).

Countries that engage in continual and aggressive investment, especially in R&D, will increase the likelihood of establishing robust 5G value chains capable of serving both domestic and global markets. They will be well positioned to continually improve and strengthen the foundational technology base across a broad spectrum of technology firms, including but not limited to:

1. Network operators

2. Providers of core technologies and components

3. OEM device manufacturers

4. Infrastructure equipment manufacturers

5. Content and application developers.

Nigeria can reap the benefits of 5G deployment and development in areas (1) and (5) listed above in addition to the potential for job creation and reduction in unemployment especially as the IT sector continues to contribute an increasing share of Nigeria's GDP as seen from data provided by the NCC. [14]

In the early years, foundational R&D and network infrastructure deployments will dominate 5G investment activities. A second wave of investment will shift the focus towards development of applications and services that exploit the unique capabilities of 5G. An information services provider - IHS Markit estimates that by 2035 the 5G value chain alone will drive $3.8 trillion of economic output and support 22.8 million jobs. [17] Therefore Nigeria cannot afford to be left out of the 5G revolution.
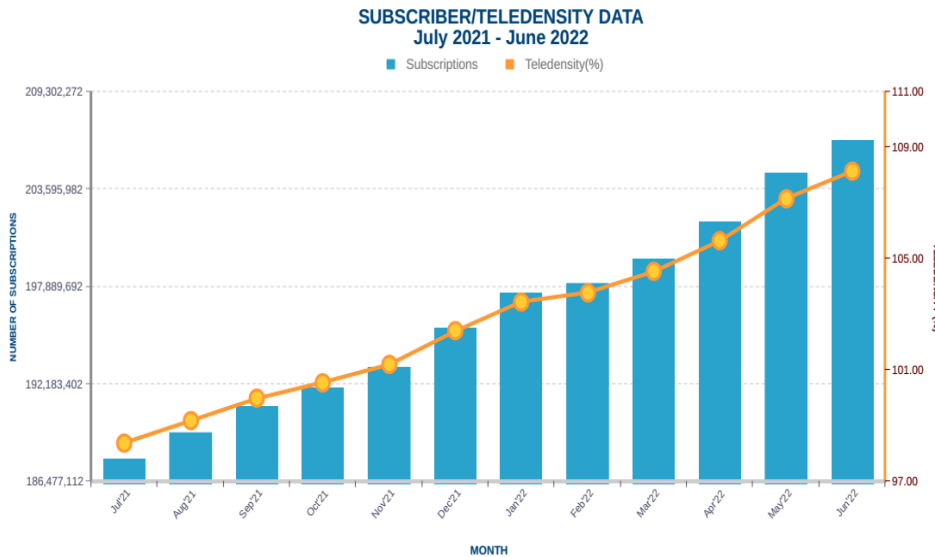

Figure 4: Number of Mobile Subscriptions and Percentage Teledensity in Nigeria 2021 - 2022 (NCC, 2022)

IHS Markit also concluded that 5G deployments will positively affect virtually every industry sector. To put these findings in a broader context, it is essential to consider the secondary linkages across multiple industries for a given use case. For example, the availability of autonomous vehicles and drones will do more than stimulate sales of driverless cars and unmanned aerial vehicles to consumers. They will also be deployed in agricultural and mining applications ranging from surveillance of remote natural resources to autonomous transport of ores to self-driving tractors. They will be widely used in the transportation sector for driverless transport and delivery of commercial and consumer goods. Municipalities will integrate autonomous vehicles into their transit systems while using drones for monitoring functions. In manufacturing, autonomous vehicles will also be used in intra-plant stocking and retrieval systems. Finally, autonomous vehicles will also positively affect the insurance industry as vehicle accident rates decrease.

Sustainability and societal impacts of 5G

In addition to the substantial economic benefits, the ability to create sustainable solutions using the 5G platform can impact important social goals. Some of the social impacts of 5G could include:

- effectively leveraging 5G technology for public safety (e.g., rapid deployment of emergency personnel when a serious accident occurs).

- remote health monitoring and medical diagnostic capabilities that reduce testing needs and times and speed up treatment.

- helping underserved communities leapfrog existing technologies to gain affordable access to reliable high-speed internet service, or greater use of robotics for dangerous or repetitive jobs.

The above are in line with United Nations Sustainable Development Goals (UN - SDG) goals for Sustainable Communities, such as Quality Education, No Poverty, Decent Work and Economic Growth, Good Health and

Well-Being. Also, many research articles have discussed the environmental benefits of 5G which include lowering greenhouse gas emissions, better management of electricity consumption and better monitoring and mitigation of air and water pollution. International standards require 5G to use much less energy than 4G by using less power to transmit the same (or greater) amounts of data. This is 5G's favourable impact on SDG's Goal 3, good health and wellbeing.

In delivering quality education, having 5G fixed wireless broadband access in currently underserved communities could substantially mitigate education gaps and may also enable new innovations in education delivery that schools do not provide currently especially in the advent of tertiary institution strikes.

5G can also help to achieve SDG's Goal 6, clean water and sanitation, principally through connected water supplies that enable real-time, remote monitoring of water conditions.

5G also beneficially impacts on productivity, decent work and economic growth. A recent research study concluded that a 10% increase in mobile broadband adoption is associated with a 0.6-2.8% increase in a nation's GDP (Edquist et al., 2017). Just as 4G technology helped to usher in a new category of occupations called "app developers," 5G is also bound to create a number of yet-to-be-defined occupations. 5G offers several opportunities for entrepreneurs and businesses to innovate, thus contributing to SDG Goal 9 (industry, innovation, and infrastructure). Undoubtedly, indirect effects of these developments will touch other goals including poverty and hunger alleviation and responsible production and consumption. The low-latency and high data capacity of 5G will make several innovations possible, which will help advance the objectives of SDG 11 (sustainable communities), therein supporting more sustainable communities.

Potential Challenges faced by Nigeria in 5G Deployment

Despite the successful auction of licences by the NCC to two operators to commence operation of 5G services, the licensees may be faced with infrastructural, spectrum and some other challenges including importing some of the equipment required for the service rollout through vendors, as well as other hitches. [18] One of the licencees – MTN, in the first phase, hopes to cover five cities of Lagos, Abuja, Port Harcourt, Kano and Enugu. In terms of sites to be deployed in the first phase, MTN has prepared about 127 sites in Nigeria for a start and have conducted 5G trials.

Of great concern is the huge capital outlay needed for rollout of sites as building a site costs between $100,000 to $150,000 excluding some other costs such as security and human resources among others meaning that setting up a site would cost about $220,000. Therefore, the 127 sites planned for the first phase of 5G deployment should cost MTN about $27.9 million. [16]

According to NCC (2021), the 5G eventual licensees will have a rollout obligation plan spanning 10 years, beginning from the date of award of the licence. Between the first and second year of the licence, the operators are expected to roll out service in, at least, one state in each geo-political zone. From the third to fifth year, they are obligated to cover all the zones. Between six to ten years, they should cover all the states in the country, according to guidelines set out in the Initial Memorandum. The spectrum lot won by each bidder will be assigned on a nationwide basis covering all the 36 states of the federation and the Federal Capital Territory (FCT) on a subsisting policy on "use-it or lose-it" concerning the use of assigned spectrum. Indeed, in other climes where operators have deployed 5G, it costs an average of $750 million to roll out the service most of which is wireless capital expenditure (CAPEX).

While some analysts predict that 5G will add $2.2 trillion to Africa's economy by 2034, the Global System for Mobile telecommunications Association (GSMA) disclosed that 5G roll-out for the top 10 cities in Nigeria would require an estimated 6,000 base stations to be deployed at a cost of up to $500 million. To succeed with the deployment, operators must focus on phased deployment to test the success before expanding it to other territories. [16]

It is important also for the government to reduce spectrum cost to encourage more network operators to participate in the 5G rollout in order to speed up the rate at which the network coverage can be expanded. The

government should also encourage terrestrial fibre deployment by removing bottlenecks surrounding Right of Ways (RoW) and multiple taxations especially by local authorities.

In some African countries which have already commenced the operation of 5G networks (e.g. Kenya), the challenges revolve around spectrum regulation clarity, commercial viability, deployment deadlines, low purchasing power of 5G-enabled smart-phones and cost of data. Findings showed that the cheapest smart-phone with a 5G-enabled in the continent goes for about $300, which is very expensive for the average African. [19]

Some of the problems that Nigeria may encounter on its trajectory to 5G deployment are itemised below:

(1) Inadequate Fibre Cable Penetration primarily as a result of:

- Right of Way (RoW) issues

- Cable destruction during road construction, expansion and maintenance.

- Unstructured fibre network deployment.

(2) Device Challenges

(3) Frequency band and availability of spectrum challenges

(4) Need for skilled professionals

(5) Less market of 5G-enabled devices

(6) Managing expenses involved in 5G network deployment

(7) Regulatory Environment

(8) Security and privacy concerns

(9) Poor Electrical Power Supply

(10) Poor Civil Infrastructure

Proposed Solutions to these Challenges

Approach for 5G network deployment

First of all, operators need to have a strategy for 5G network deployment. Secondly, after deciding on the strategy, their approach towards implementing this strategy decides the future of deployment process. Based on the spectrum networks they have, and the densification and coverage they need, operators develop their deployment model and approach that is ultimately required for targeting specific 5G use cases. Further, 5G network deployment challenges include use of mm Wave frequencies and 5G small cells in a huge amount and will require a new approach to 5G network deployment and its regulatory standards.

(1) Improved Fibre Infrastructure: For 5G implementation in Nigeria the role of improved Fibre network is very important. Instead of increasing the cost of RoW, State and Local governments should assist Telecom providers by giving RoW waivers and provision of tax incentives. This will encourage massive rollout of fibre infrastructure which can be used as a backhaul infrastructure due to its high reliability and ability to deliver ultra-high capacity traffic. Alternative infrastructure ownership models, either sharing both physical networks and spectrum could also be explored.

(2) Equipment challenges are quite inevitable as most of the equipment and devices required for 5G network deployment are to be imported. The government could come to the aid of operators by making

forex easily accessible to them to be able to purchase this equipment from their vendors.

(3) Spectrum for 5G: To reap the benefits of 5G there should be availability of spectrum. The first line of action for the development of 5G in Nigeria should be to establish spectrum policy that will guide the allocation of spectrum to major players in the industry. NCC has identified two sets of spectrum to be released: one set which will form the initial 5G deployment; and one set which will provide further capacity and capability. The large number of potential operators means that the limited spectrum available must be divided into small blocks. One of the biggest challenges that the NCC faces is the number of spectrum bands it is looking to award and the number of operators who may be interested in bidding for these. Finally, the quality of service of 5G connections depends on the amount of contiguous spectrum available to an operator.

Therefore, the NCC must choose between:

(1) Providing spectrum to every operator so there is a level playing field, or

(2) Allocating spectrum in large blocks to provide consumers with the highest possible speed and quality, with the consequence that not all operators will be granted spectrum.

To mitigate against these issues, it is important that the NCC clears as much spectrum as quickly as possible and provides clear indications of when and where further spectrum will be made available. There is also room for spectrum trading but subject to approval of the Nigerian Communications Commission (NCC). In the new rule set by NCC for spectrum trading unveiled last year, the Commission said, to trade, a seller must have held the spectrum for a minimum of one year, as against the previous requirement of two years. Both the seller and buyer must also have sound regulatory and financial standing with the Commission for a minimum of three years consecutively prior to their engagement.

Another concern is spectrum prices. A recent study shows that spectrum prices in developing countries is on average, more than three times higher than that of developed countries Thus, the cost of spectrum could be a major factor that will make a difference in 5G roll-out in Nigeria.

(1) Creating Enabling Environment: The government should play a greater role in encouraging investors to invest in the industry with less constraints. The issue of insecurity in the country should be tackled. There is also the need for training of personnel to be conversant with the operation of the new technology.

(2) Development of supporting infrastructure: To achieve the goal of deployment by year 2022 the supporting infrastructure which will facilitate the rollout must be in place. Highways, bridges, rural roads, canals and utilities must be in place to support the expansion of telecommunication services to underserved populations. Also, the new base stations will require power supply. There is therefore an urgent need to improve on the generation capacity as well as the transmission and distribution networks to reduce the burden of operators having to provide their own power supply for their cell sites.

(3) Encouragements to investors and operators: It is quite obvious that 5G networks involve huge investment in technology and palliatives or subsidies or tax holidays to the investors and operators will serve as an encouragement for them to take up the challenge of rapid deployment.

(4) Removing cumbersome Regulatory Barriers: 5G rollout throughout the country will involve the use of small cell technology. This feature makes this technology suitable for wider geographical coverage and network densification. In some countries excessive restrictions on operators have slowed implementation of small cells. Such should be avoided in Nigeria to allow cost- effective rollout of small cells especially cities where 5G services are initially expected to be in high demand.

(5) Funding in Research & Development. Nigeria should have a sector specific Research and Development program for the telecommunications sector in view of its strategic importance to Nigeria's socio-economic development. 5G technology is still being researched on extensively and Nigerian needs to

develop skills and scopes to produce its own software and hardware rather always import from abroad. Development of indigenous technology and solutions should also be encouraged.

(6) Security Aspects and Challenges: 5G network has its own security challenges arising from its adoption of advanced technologies to fulfil its envisioned goals. Security threats revealed by three major technologies incorporated by 5G namely Software Defined Networking (SDN), Network Function Virtualization (NFV), and Internet of Things (IoT) make it quite vulnerable to hacking and denial of service attacks. [20] In order to tackle these envisioned challenges Nigeria can adopt the following approaches:

(i) Training of security experts. Investment in education and training of IT workers as well as security experts to handle the security challenges of 5G as it is not affordable and sustainable to import skilled

manpower and IT personnel always.

(ii) Developing strong infrastructure to protect the 5G network from security challenges like vandalism and destruction. CCTVs or drones can be used for remote monitoring of sensitive sites and locations on the 5G network.

(iii) Introducing cybersecurity education. A range of IT security education should included in the curriculum of primary, secondary as well as tertiary education institutions. In view of the rise in number of data subscriptions with the deployment of 5G, it is necessary that these users have a basic to intermediate understanding of the security issues in cyberspace and how to be sufficiently protected when using such services.

CONCLUSION

As is evident in this review, many countries throughout the world have had different challenges that have affected the implementation and operation of the 5G technology. Some of these countries have overcome their challenges and others are still in the process. Also, as Nigeria is currently deploying 5G technology, this paper has highlighted some of the challenges that may hinder the rollout and operation of 5G technology to include infrastructural, security, regulatory and skilled manpower challenges as well as steps that can be taken to mitigate them considering the experiences of countries which have already deployed these networks. The paper proposed that a comprehensive strategy for the deployment of 5G networks should be developed through synergy between the telecoms regulator, network operators and the government of Nigeria as well as stakeholders in the telecommunications and ICT sector. The immense benefits of 5G deployment to Nigeria's economy through increase in GDP, creation of jobs and expansion of the digital economy and space were also discussed.

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