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An Overview of the Deployment and Management of 5th Generation (5G) Wireless Network in Nigeria

[1]Michael E. Ogbonnaya, [2]Sunny Orike, [3]Barinyima Nkoi
[1-2]Department of Mechanical Engineering, Rivers State University
[3]Department of Computer Engineering, Rivers State University
michael.ekeoma@gmail.com

ABSTRACT

The purpose of this paper is to give a preview into the deployment and management of 5th Generation (5G) wireless network in Nigeria thereby addressing technical challenges of 5G deployment, assisting in the establishment of a 5G ecosystem, ensuring cost-effective implementation, management, and deployment in a timely manner in Nigeria. Data forecasting, and cost analysis were adopted for this study as the preferred tool to be used. It involved studying various network business deployment models, market demand and subscriber's growth, and the cost for deploying 5G network equipment's. The result showed that Infrastructure sharing based on Technology or based on Business/ownership are the preferred method for deployment cost reduction. Results obtained for subscriber's growth forecast using optimistic, normal, and pessimistic scenarios are 171.52%, 163.35%, 155.19% respectively for the next 10 years. Also, deployment cost was observed to varies with population density and projected coverage area as for the case of Port Harcourt and Ahoada which are 12,069,144,108 dollars and 143,680,287 dollars, respectively. This work will contribute to the knowledge of Nigeria government in the Telecommunication sector, network operators to fast forward the rollout of 5G network in Nigeria and its management to reduced cost for the benefit of the Nigeria user. Also, this study adds to the body of knowledge by addressing technical issues, contributing to the formation of a 5G ecosystem, and maintaining cost-effective and speedy rollout of the 5G network across the country.

KEYWORDS: 5th Generation Network, Data Forecasting, Deployment Models, Infrastructure Sharing, Subscriber's Growth.

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1.0 INTRODUCTION

According to historical patterns, a new generation of mobile communications technology is introduced every 10 years or so. (Wolter *et al*., 2017). The evolution of mobile communication started with the introduction of first Generation (1G) in 1981 and to the latest fourth Generation (4G) in 2009 (Prinima & Jyoti, 2016). The 5th generation (5G) of mobile networks is expected to be implemented into existing networks. in 2020. Every successive generation represents a steady interaction between interdependent stakeholders such as infrastructure equipment manufacturers, device makers, network operators, and end-users, and national, regional, global regulators and policymakers. The interaction concerns the assignment and allocation of new radio frequency bands, as well as the development of new standards by International Telecommunication Union (ITU), the development and manufacturing of new network equipment by equipment manufacturers, the investment in new infrastructures by the Network Operators (NO), the introduction of new mobile devices and their acceptance by consumers. This is a highly coordinated operation that necessitates a large investment and a well-aligned supply and demand to be successful.

Telecommunication providers and technology businesses all over the world are implementing Fifth Generation (5G) network solutions to solve the increasing demands for mobile data services and the Internet of Things (IoT) from consumers and industrial organizations. Fifth Generation (5G) mobile technologies provides the required data speed, capacity and low latency needed for the next generation of mobile These upgrades were developed to increase existing mobile networks (e.g., 2G, 3G, and 4G). Faster speeds, lower latency, increased capacity, and the ability to support new features and services are all projected to come with 5G networks (Fischer & Ringler 2015). 5G technologies were created to meet rising demand for mobile data (e.g., online gaming, TV streaming, Internet of Things, etc.) and are expected to meet current and future consumer expectations (e.g., industrial Internet of Things, self - driving cars). (Vetrivelan, 2015). It is also projected to benefit consumers in the following areas: Health - aiding the disabled, telemedicine, and industrial automation - automate processes, increase operational efficiencies, data analysis and economy - new revenues streams, new jobs etc. Experiences in the telecommunication sector has shown that Network Operator compete to provide modern technologies and better user-experience to the customers in other to capture the bulk of the revenues and customer loyalty. This has lead companies around the world to heavily invest in the new 5G technologies develop. Nigeria Governments and Policymakers are taking steps to encourage 5G development and deployment, recognizing the potential for economic gain.

The rollout and acceptance of 5G has the potential to provide Nigeria with long-term social and economic benefits. 5G is projected to transform how we connect with other people and machines, allowing for truly innovative use cases in a variety of fields. For example, autonomous driving and interconnected vehicles would improve safety on the road while also enhancing traffic management, resulting in fewer road accidents, traffic jams, and time spent traveling, all of which will lead to higher productivity and a healthier environment. 5G applications in healthcare, such as interconnected ambulances or remote personalized treatment, will help to make the healthcare system more responsive and less congested, as well as increase people's sense of safety in remote places. Furthermore, 5G will enable smart home apps and the Internet of Things, enhancing quality of life by boosting privacy and security at home, among other benefits.

The Internet is becoming increasingly relevant and indispensable in our daily lives. The operation and management of 5G network will require technical and high skill know-how for an efficient network. This will require the core five area of operations and management standard in Open System Interconnection (OSI) which was introduced in the 1980s according to ITU (2012). Fault management, configuration management, accounting management, performance management, and security management are the five functional areas (FCAPS). With 5G technology deployed and operational in our mobile network, we will experience seamless data service experience with exceptionally low latency. Operators will Concentrate on expanding existing 4G coverage in metropolitan areas by deploying tiny cells to densify the network. This will increase network capacity available for the customers, strengthen overall network quality and improve ground level coverage, as most of the new 5G sites will be implement in densely populated urban centres or cities.

MTN, 9Mobile, Airtel, and Glo are just a few of the Nigerian telecommunications providers that are always investing in their networks to provide quicker, more dependable service, expand network capacity to meet expanding data needs, and support new technology uses. According to industry studies and research (Qualcomm, 2014), a new technology solution develops every 10 years that delivers dramatically enhanced speeds, supports new features, and functions, and produces new markets and revenue for Mobile Network Providers (MNO). These technologies improve networks and devices to such an extent that they alter people's perceptions of mobile

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communications, and so represent the next generation of mobile technology. There have been five generations of mobile technology in the field of communications.
This research was conducted to review network deployment methods to facilitate infrastructure availability, deployment cost reduction, and to forecast subscriber's growth and analysis for the next 10 years.

2.0 MATERIALS AND METHODS

In the run-up to 5G, the deployment of 5G in dense metropolitan areas in Nigeria is an important investment opportunity for Mobile Network Operators. This study investigates and evaluate different models needed to reduce the investment cost required for a successful 5G deployment in Nigeria while ensuring that good quality of service is provided to the end user for best experience.

Mobile Network Operators are likely to focus on expanding existing 4G coverage and capacity in metropolitan areas in preparation for 5G by deploying 4G small cells or capacity sites on a continual basis. These will boost network capacity, improve coverage, and improve overall network quality, all of which will be required by 5G networks. Thanks to greater data demand on the 4G network, many of these deployments will take place in highly populated metropolitan centers or cities. 5G employs high frequency spectrum bands that have never been used in the access network by terrestrial telecom operators in the past to accomplish the technological criteria that 5G networks promised. Higher frequencies offer more bandwidth and thus better connectivity, but at the cost of a shorter propagation range. This short reach necessitates more stations to cover a given region with 5G than with earlier technologies, posing practical challenges in terms of power and backhauling. Additionally, there will be instances where additional antennas, such as tiny cells, must be installed within buildings or sites of high commercial interest, such as stadiums, concert halls, and shopping malls.

Until now, mobile virtual network operators have built their own proprietary networks to which they had exclusive access and subsequently offers services to end customers as well as wholesale access to other Mobile Virtual Network Operators (MVNOs). This is the most basic network deployment model on the industry. More advanced network deployment models are now in demand because of current trends and needs.

i. Single deployment model.

ii. Infrastructure sharing model.

2.1.1 Single Deployment Model

In single deployment models, the Mobile Network Operator bears all the cost of deploying the network which its then use to provide services to the end users and in return, earn revenue. They can also rent or sell a portion of the infrastructure/capacity to another ecosystem player. Nevertheless, other investors interested in Telecommunication sector might be willing to invest as a service provider (SP) i.e. (Co-location Provider) by building sites in lucrative locations and deploying the necessary infrastructure for the Mobile Network Operators to lease. This approach is used in places like malls, major government buildings, and stadiums where more network densification and expansion are required to satisfy capacity requirements. Figure 1 below shows a Single deployment model.

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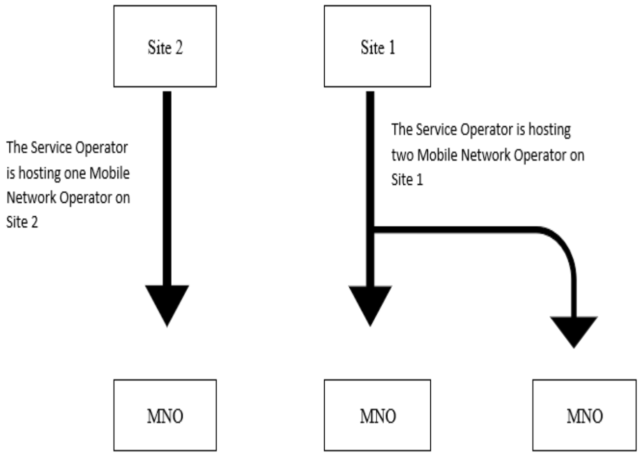

Figure 1 Single Deployment Model

Examples of Service Providers (Co-location Providers model) in the Nigeria Telecommunication sector includes ihstowers, America Towers Company (ATC), Swap Towers, Zyetechcom, Hotspot, etc. They operate on two especially important concepts:

i. Hosting the Mobile Network Operator.

ii. Colocation Service neutrality.

In single deployment models, service providers (SP) create and operate network infrastructures either on their own or through outsourcing, then offer these services to Mobile Network Operators. These services provided by the Service Provider (SP) helps the Mobile Network Operators to provide uninterrupted services to the customers at reduced cost and high quality of service (QoS). The aspect of "neutrality" relates to the hosting of telecommunication equipment that serves as a shared platform for various hosted clients. This Service Provider (Co-location Providers model) concept has been around for a while, and it is likely that it'll reach its full potential with 5G due to the following factors:

i. Due to the short coverage area of the frequency used for 5G and bandwidth needs, there is a need for improved coverage and connection in metropolitan areas.

ii. Private individuals and corporations' bodies are now more aware of the need to design and make provision for the deployment of mobile technologies when building new structures thereby serving as host.

iii. The Co-location model will serve 5G requirements for different use thereby reducing cost and ensure network reliability.

2.1.2 Infrastructure Sharing Models

Infrastructure sharing in the Telecommunication sector involves forming collaborations between Mobile Network Operators (MNO) and sharing network costs e.g., Radio Broadband, Antennas and Transmission cost in other to provide mobile connectivity to the end users at a relative low rate. Depending on the requirements and goal, infrastructure sharing can be passive or active. The telecommunications sector regulator Nigeria communication commission favours infrastructure sharing in some cases, but in others, the Mobile Network Operators enter commercial collaboration without regulatory involvement.

These are the advantages of infrastructure sharing.

i. CAPEX/OPEX reduction
ii. Expanding the network's reach more quickly (especially in rural area)
iii. Reduced carbon footprint

The disadvantages are:

i. Limited flexibility
ii. Capacity limitation

Passive network elements such as masts and cabinets are shared between operators in passive sharing. Active network elements such as antennas, transmission lines, and controllers are shared between operators in active sharing.

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Active sharing is a collaboration agreement between Network Operators. Traffic is routed to another operator's network without the operator investing in active infrastructure in the area. This type of sharing is commonly referred to as roaming, which can be either national or international. National roaming can be used by an operator to expand network coverage.

2.2 5G Subscriber's Forecast in Nigeria

The percentage of the total addressable market that a technology captures is measured using two metrics: population penetration and the percentage of the total addressable market that the technology captures. The three identified scenarios are optimistic, normal, and pessimistic.

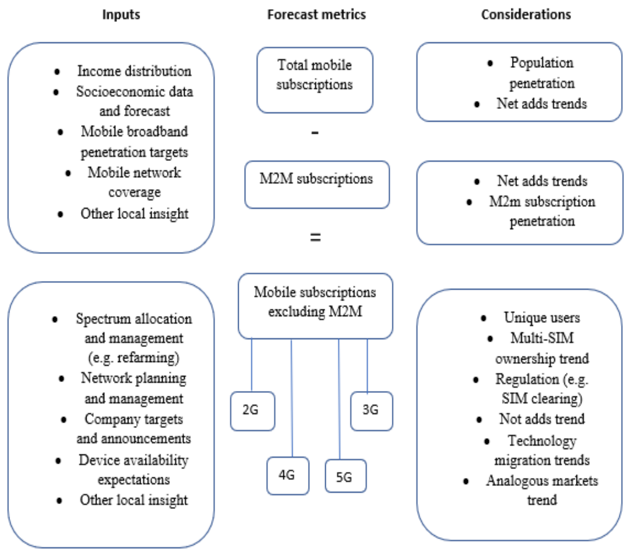

Figure 2 5G Subscriber's Forecast Components

The chosen mobile connectivity prediction technique involves phases such as data gathering, forecast drafting, data analysis, and forecast calibration, and it is based on numerous inputs, as shown in Figure 2 5G Subscriber Forecast Components, such as:

i. Income distribution in the populati on
ii. Data on the socioeconomic situation
iii. Targets for mobile broadband penetration
iv. Coverage of mobile networks
v. Network planning and management
vi. Market information from regulators and operators
vii. The availability of 5G-enabled devices.

According to statistics published by the NCC (2018), there were 172.8 million of mobiles subscribers in Nigeria. Table 1 shows the Evolution of the mobile Subscriber in the last 11 years. Based on this information, there has been a growth on subscriber's base for the past eleven years.

Table 1 Evolution of the Mobile Subscriber in the Last 11 Years (NCC, 2019)

Year	Subscriber's Number	Subscriber's Growth	Percentage Growth %
2008	64,296,117	10,222,147	15.90%
2009	74,518,264	13,829,762	18.56%
2010	88,348,026	7,538,688	8.53%
2011	95,886,714	17,309,237	18.05%
2012	113,195,951	14,410,678	12.73%
2013	127,606,629	11,536,981	9.04%
2014	139,143,610	11,873,634	8.53%
2015	151,017,244	3,512,536	2.33%
2016	154,529,780	-9,470,266	-6.13%
2017	145,059,514	27,811,580	19.17%
2018	172,871,094	11,899,620	6.88%

$$\text{Subscriber's Growth (SG)} = SN^{n+1} - SN^{n} \quad (2.1)$$

Where:

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NS = Subscribers Number

$^{n+1}$ = One year ahead

^{n} = Present year

$$\text{Percentage Growth (P.G.)} = \frac{\text{S.G. X 100}}{SN^{n+1}} \quad (2.2)$$

Where:

S.G. = Subscriber's Growth.

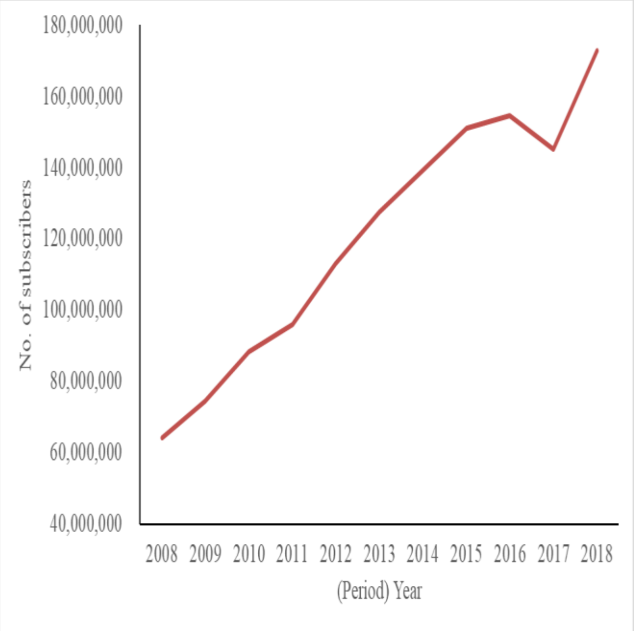

Figure 3 Mobile Lines Evolution Trend in Nigeria from 2008 to 2018

The normal scenario, the optimistic scenario, and the pessimistic scenario were used to make an estimate for the likely future number of subscribers based on these statistics from 2008 to 2018. The normal scenario considers that the mobile network operator subscriber's base continues to grow at average rate of 8%. Figure 3 Mobile Lines Evolution trend in Nigeria from 2008 to 2018.

2.2.1 Normal Scenario

In the normal scenario, it is expected that subscriber's growth will continue to grow at 10% every year as in the past 11 years. After 5G is launched commercially, coverage and device penetration are expected to grow. Using Linear regression equation (Douglas, 2012)

$$Y = a + bX, \quad (2.3)$$

where X is the explanatory variable and Y is the dependent variable. The slope of the line is b, and a is the intercept.

2.2.2 Optimistic Scenario

The following assumptions support the optimistic scenario: 5G will have to be commercially introduced in 2021 as telecom operators develop the necessary infrastructure, and its coverage will expand at a similar rate as 4G technology when it is deployed. From 2021 onwards, a wide range of 5G-enabled devices will be essential.

$$\text{Optimistic Scenario} = \text{N.S.} + [\text{N. S. X } 5\%] \quad (2.4)$$

Where:

N.S. = Normal Scenario

2.2.3 Pessimistic Scenario

In the pessimistic scenario, 5G uptake will be far slower than 4G, and operators' technical commitment will be small. In this scenario, 5G will be commercially available in 2021 or later, and coverage will expand at a significantly slower rate than it did when 4G was first introduced. Initially, only a small number of 5G-enabled gadgets will be available.

$$\text{Optimistic Scenario} = \text{N.S.} - [\text{N. S. X } 5\%] \quad (2.5)$$

Where:

N.S. = Normal Scenario

2.2.4 Mobile Subscribers Distribution

According to statistics released by the Nigerian Communications Commission, mobile phone penetration was 104.41% in the second quarter of 2019, with the following market shares for the various operators: 9mobile had 6.11% of the total

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market share, Airtel had 26.99% of the total market share, Glo had 26.51% of the total market share and MTN had 40.39% of the total market share. Table 2 shows the Market Shares for different Mobile Operators in Nigeria 2019 (NCC, 2019).

Table 2 Market Shares for Different Mobile Operators in Nigeria 2019 (NCC 2019)

Network Operator	No. of Subscribers	Percentage (%)
Airtel	53,705,705.00	26.99%
EMTS	12,163,330.00	6.11%
Glo	52,741,762.00	26.51%
MTN	80,350,564.00	40.39%

Further analysis of the mobile network customer's base market share representation in pie chart is shown on Figure 4 Market shares distribution for the different operators in 2019.

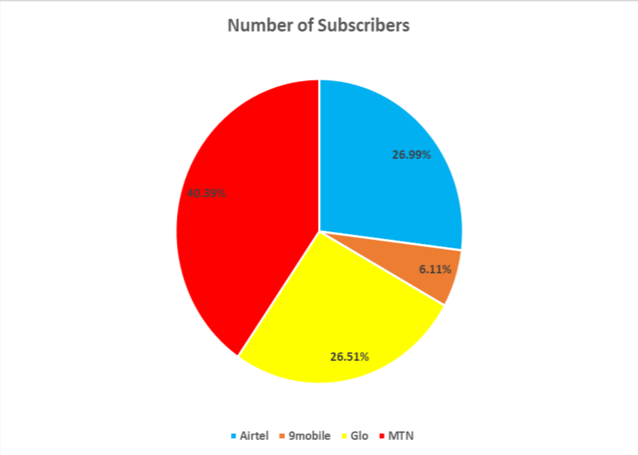

Figure 4 Market Shares Distribution for the Different Operators (NCC 2019)

2.3 5G Deployment Cost Methodology

We assumed that the Independent Tower Providers ITP will provide Tower services to the Network Operators with the existing contracts. This will reduce the total cost of Tower ownership (CAPEX) for the Network operators and due to the uncertainty surrounding the cost of 5G spectrum and Network radio equipment costs which will be provided by different equipment vendors at different pricing structure, they will be excluded from this analysis. The number of small cells and fiber necessary for network dimensioning are calculated based on the required coverage area, population size, and intercell cell-site distances. The dimensioning step's outputs are then used to calculate the overall CAPEX necessary to execute the 5G solution, which includes the radio access network, fiber, the main equipment room, implementation, and design.

2.3.1 Geographical Coverage

The coverage area of the network, which has an impact on the deployment cost and population to be served, is one of the most essential aspects for a business case in the telecoms sector. A city with a high population density and a tiny town/village with a low population density have both been examined. The following geographical areas are considered in this report:

i. Because of its high population density and great need for telecommunication services, the city of Port Harcourt was chosen. On a Google map, Figure 5 depicts the spread of 9mobile sites in Port Harcourt.

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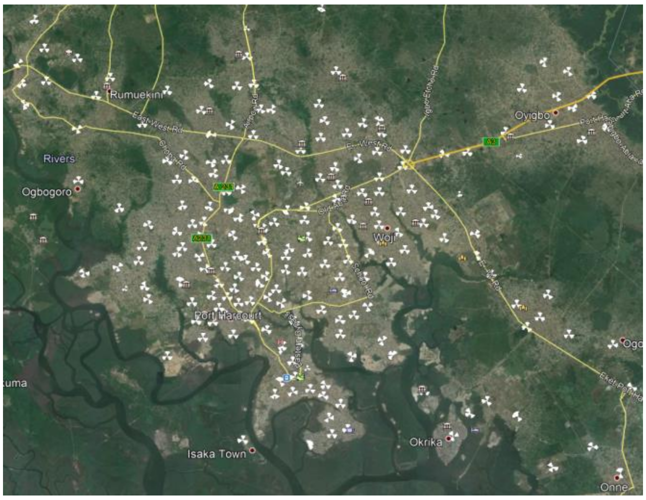

Figure 5 Port Harcourt Urban Cluster Site's Distribution

iii. Rural area. The small town/village of Ahoada was selected because of its low population density and low service demand when compared to the national average. Figure 6 shows 9mobile sites distribution in Ahoada on google map.

Figure 6 Ahoada cluster Site's Distribution

2.3.2 Population Coverage

The percentage of people in Port Harcourt and Ahoada who are covered by the mobile network and live within range of a mobile-cellular signal, regardless of whether they are subscribers or users. Population density of the two cities were calculated and inter-site distance for 9mobile sites were also obtained. Table 3 shows the population and territorial characteristic of Port Harcourt and Ahoada with geographical coverage, city name, surface area, population, population density and Inter-site distance.

Table 3 Total Population and Territorial Characteristics of Port Harcourt and Ahoada

Geographical coverage	Urban area	Rural area
City Name	Port Harcourt	Ahoada
Surface Area [km2]	369	352
Population	3,116,143	350,200
Density [pop/km2]	8,445	995
Inter-Site Distance (m)	500	1500

3.0 RESULTS AND DISCUSSION

3.1 Results of Infrastructure Sharing

Outcome of different scenarios of the research are discussed below.

3.1.1 Infrastructure Sharing Based on Technology

Non-electronic infrastructure at a cell site, including as power supply and control systems, as well as physical aspects such as backhaul transport networks, are shared through passive infrastructure sharing. This type can be further subdivided into site sharing, which involves sharing the physical locations of base stations. The transport networks from the radio controller to the base stations are shared in shared backhaul. The simplest kind of infrastructure sharing is passive infrastructure sharing, which may be deployed per site and allows operators to easily share sites while maintaining strategic competitiveness based on the sites shared. This type of sharing also makes operation easier because network equipment is kept separate. However, when compared to other types of sharing, the cost-saving potential of this type of

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infrastructure sharing is limited. The outcomes of passive and active infrastructure sharing on technology of all the components of the 5G network is shown in Table 4.

Table 4 Infrastructure Sharing Based on Technology.

Key Assets	Passive				Active					
Operator	Site Sharing		Shared Backhaul		MORAN		MOCN		CN Sharing	
	MNO A	MNO B	MNO A	MNO B	MNO A	MNO B	MNO A	MNO B	MNO A	MNO B
Core Network	A	B	A	B	A	B	A	B	Shared	
Radio Controller	A	B	A	B	Shared		Shared		Shared	
Backhaul	A	B	Shared		Shared		Shared		Shared	
Base Station	A	B	A	B	Shared		Shared		Shared	
Site	Shared		Shared		Shared		Shared		Shared	
Spectrum	A	B	A	B	A	B	Shared		Shared	

Active infrastructure sharing refers to the network's electronic infrastructure, such as the radio access network (which includes antennas/transceivers, base stations, backhaul networks, and controllers) and core network (servers and core network functionalities). MORAN (Multi-Operator Radio Access Network), in which radio access networks are shared and each sharing operator uses dedicated spectrum, MOCN (Multi-Operator Core Network), in which radio access networks and spectrum are shared, and core network (CN) sharing, in which servers and core network functionalities are shared. MORAN and MOCN, like site sharing, can be deployed per site, allowing for strategic differentiation. However, network equipment operation must be shared (or at least difficulties must be discussed with participants), which adds to the complexity of sharing when compared to site sharing. Site sharing has a lower cost-cutting potential. Although a core network allows for higher cost savings, it is difficult to operate and retain strategic distinction. Table 5 below for comparison of infrastructure sharing based on technology. It is worth noting that core network sharing isn't very common, and just a few examples have been reported. The whole theoretical picture of infrastructure sharing is presented in this document by considering core network sharing.

Table 5 Comparison of Infrastructure Sharing Forms (Technology)

Sharing form	Pros	Coins
Passive Infrastructure Sharing	i. Significant CAPEX/OPEX savings ii. Lowered risk of site acquisition iii. Full differentiation and complete control of spectrum iv. Control over sites to be shared. v. No/little regulatory obstacles. vi. Essay migration to other sharing forms vii. Environmental benefits	viii. Availability of free space in existing sites (if existing sites are to be shared) ix. Similar cell planning may be required
MORAN, MOCN	x. Limited marginal CAPEX savings compared to Site sharing. xi. Substantial marginal OPEX savings compared to passive infrastructure sharing. xii. Control over base stations to be shared. xiii. Reduction of network footprint by operators	xiv. Regulatory approval necessary xv. Complexity of operation xvi. Requires long term commitment between operators. xvii. Difficult to exit from sharing agreement
Core Network Sharing	xviii. Further CAPEX/OPEX savings compared to MORAN/MOCN. xix. Significant investment can be diverted to services. xx. Maximum sharing for operators sharing existing infrastructure.	xxi. Regulatory approval necessary xxii. Complexity of operation and tight integration xxiii. Challenging to differentiate quality of service
National Roaming	xxiv. Significant CAPEX/OPEX savings xxv. Clear ownership of equipment xxvi. Differentiation based on service layer. xxvii. Low risk solution for both incumbent and new entrant	xxviii. Regulatory approval necessary xxix. Interconnection required. xxx. Reduced control over the network (e.g., outage of visited network can affect home network service) xxxi. End to end inter-PLMN QoS and inter-PLMN handover very challenging

Finally, national roaming is a form of infrastructure sharing that is not depicted in the diagram. National roaming refers to roaming arrangements that take place within a single country. For example, a 9Mobile Nigeria user may wander into MTN Nigeria's network when entering MTN Nigeria's non-overlapping service area, and vice versa. This form of sharing can save you money on the same level as or even

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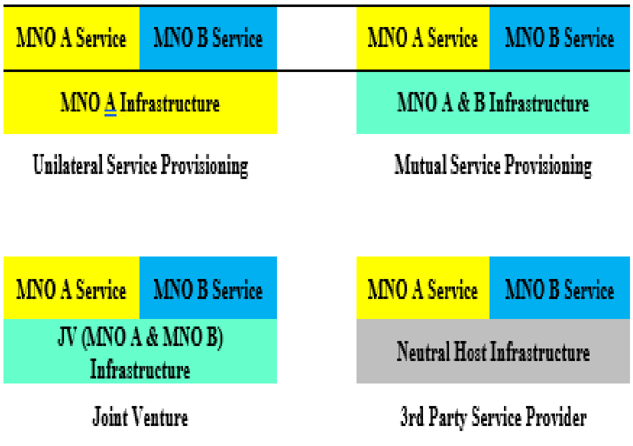
more than core network sharing. National roaming, on the other hand, is complicated (e.g., when to choose home network over visiting network based on signal quality), and there may be regulatory concerns about reduced competition.

NOTE 1: According to technological requirements, an MVNO can alternatively be thought of as a sort of infrastructure sharing arrangement in which the MVNO rents all the network infrastructure required. However, it was left out because the purpose of this text is to focus on the effective deployment and management of physical networks rather than the creation of virtual operators on top of them.

3.1.2 Infrastructure Sharing Based on Business/Ownership

The outcomes of infrastructure sharing on business ownership of all the components of the 5G network is shown in table 6.

Table 6 Infrastructure Sharing Based on Business/Ownership



The business ownership is classified into four different sharing agreements. Unilateral service provisioning is the first type of infrastructure sharing agreement, in which infrastructure ownership remains distinct (each firm owns its own network) and only one of the participating companies offers infrastructure to be shared. As a result, MNO A and MNO B's communications services (such as phone, SMS, and data) are supplied on MNO A's infrastructure. Mutual service provisioning is identical to unilateral service provisioning, except that two or more participating organizations share their infrastructure.

A joint venture is formed when firms in an agreement form a joint venture to own and operate networks, implying that the joint venture consolidates, owns, and operates the common infrastructure (but the companies do not directly own the infrastructure). It is worth noting that a joint venture can also function as a tower company, which owns towers and leases them to mobile operators. Finally, a third party service provider is a corporation that leases infrastructure to mobile operators but is not necessarily linked with them. This type is also known as a neutral host, and there are already successful instances on the market. Tower firms' own towers and lease them to mobile operators (e.g., IHS Nigeria, ATC Nigeria, Helios Nigeria, Swap Towers, and so on). From the start of the rollout phase, the neutral host agreement allows operators to share infrastructure. Operators can lease towers rather than build their own. Please see Table 7 for comparison of infrastructure sharing based on technology.

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Table 7 Comparison of Infrastructure Sharing Forms (Business/Ownership)

Sharing form	Pros	Cons
Service provisioning (Unilateral/mutual	i. Reduction in OPEX: removal of depreciation costs ii. Simpler to implement. iii. Ownership still with operator	iv. Co-ordination of operation v. Challenges in differentiation vi. Regulatory risks
Joint venture	vii. Reduced risk: fixed CAPEX is transferred to variable OPEX. viii. Reduction in OPEX: reduced O&M costs ix. Cut down CAPEX cost for new deployment. x. Control over diverting cost savings to operator	xi. Co-ordination of operation and network deployment plans xii. Challenges in differentiation xiii. Loss of strategic control and flexibility xiv. Difficult to exit. xv. Regulatory risks xvi. Transformational effort (e.g., setting up new organization)
3rd party service provider	xvii. Reduced risk: fixed CAPEX is transferred to variable OPEX. xviii. Reduction in OPEX: reduced O&M costs xix. Cut down CAPEX cost for new deployment. xx. Can objectively arbitrate dispute/issues	xxi. Loss of strategic control and flexibility xxii. Long lock-in and reliance on 3rd party xxiii. Lack of equity participation

Furthermore, each room/unit of space within a building must have a cell deployed and integrated to offer efficient indoor coverage to meet subscriber bandwidth demand. In this instance, the deployment of cells and connection of the cells of two to four operators would not only cost the mobile sector a lot of money, but it would also cause a lot of headaches for building owners (e.g., civil work and wire coordination). Operators may find it more cost-effective to share infrastructure in various locations throughout the deployment process, and to share maintenance and operations of shared equipment as a result. Building owners might become a third-party service provider, deploying, and operating the network that operators will lease.

3.2 Results of Subscribers Base Forecasting and Analysis

Below shows the forecast of 5G subscribers with optimistic, normal, and pessimistic growth scenarios for the next 10 years using forecasted growth of 10 percent every year according to average yearly growth projections. The telecommunication sector subscriber's growth rate for the next 10 years with average growth rate of 10% year over year in normal scenario (equation 2.3), the optimistic scenario considers that the operator will be expected to have 5% more subscribers than in the normal scenario (equation 2.4). In the pessimistic scenario the operator is projected to have 5% less subscribers than in the normal scenario (equation 2.5). Table 8 shows the Subscriber's Growth Forecast.

Table 8 Subscriber's Growth Forecast

Year	Optimistic Scenario	Normal Scenario	Pessimistic Scenario
2019	193,042,430.07	183,849,933	174,657,436.73
2020	204,113,189.70	194,393,514	184,673,838.30
2021	215,183,949.33	204,937,095	194,690,239.87
2022	226,254,708.96	215,480,675	204,706,641.44
2023	237,325,468.59	226,024,256	214,723,043.01
2024	248,396,228.22	236,567,836	224,739,444.58
2025	259,466,987.85	247,111,417	234,755,846.15
2026	270,537,747.48	257,654,998	244,772,247.72
2027	281,608,507.11	268,198,578	254,788,649.29
2028	292,679,266.74	278,742,159	264,805,050.86

In all the scenarios (optimistic, normal, and pessimistic) there are constant growth in mobile services market size. In the optimistic scenario, number of mobile subscribers is expected to grow by 171.52 percent in 10 years. In the normal scenario, number of mobile subscribers is projected to grow by 163.35 percent in 10 years and in the pessimistic scenario, number of mobile subscribers is projected to grow by 155.19 percent in 10 years. Figure 7 shows the Market Forecast Scenarios for the Network Operator.

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Faster data speeds, population growth, device growth (internet of things), and extremely low latency offered by 5G technology will improve the user experience while using 5G services for a variety of use cases, including Virtual Reality (VR) and Augmented Reality (AR) gaming, seamless video calling, and Ultra-high Definition (UHD) videos. Over the projection period, increasing demand for high-speed data connectivity for a unified Internet of things (IoT) applications like smart home energy management is expected to accelerate the adoption of 5G services. Furthermore, the rising focus of 5G system integration providers on forming relationships with telecom carriers is expected to boost 5G service uptake.

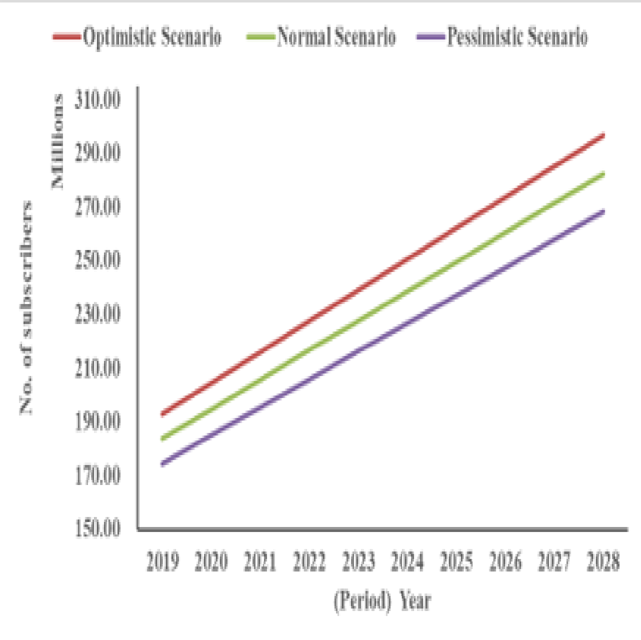

Figure 7 Market Forecast Scenarios for the Network Operator

3.3 Result of 5G Deployment Cost

To estimate the cost of deploying a 5G network solution Port Harcourt and Ahoada. Port Harcourt chosen as scenario 1 (large, dense city) and Ahoada chosen as scenario 2 (small, less dense city). In both cities, it is assumed that they have existing mobile network so only Radio equipment, Licence, Installation and Commissioning is required. Table 9 shows CAPEX Cost for Scenario 1 and Scenario 2 required to deploy 5G network can cost from Naira 143 million for a small city to 12 billion for a large, dense city like Port Harcourt. Note that a larger, metropolitan city puts a higher strain on the mobile network, and therefore requires smaller inter-site distance and a less dense city like Ahoada.

Table 9 CAPEX Cost for Scenario 1 and Scenario 2

City Name	Port Harcourt (Scenario 1)	Ahoada (Scenario 2)
Projected Number of 5G Sites for 9mobile	252	3
Equipment Cost (₦)	41,581,592	41,581,592
Installation and Commissioning (₦)	5,735,837	5,735,837
Software License (₦)	576,000	576,000
CAPEX per site (₦)	47,893,429	47,893,429
Total Cost (₦)	12,069,144,108	143,680,287
Surface Area [km2]	369	352
Population	3,116,143	350,200
Density [pop/km2]	8,445	995

The most major cost element in both scenarios 1 and 2 is equipment expenditures, as shown by a breakdown of the cost components. Each operator's total CAPEX will differ based on population, population density, existing network coverage, and the anticipated 5G coverage area. Furthermore, the cost of fiber deployment will be lower in cities where dense fibre networks or ducts are readily available and easy to access. Backhaul costs will be significantly lowered where wireless backhaul is more cost-effective than fiber. There will be less demand for micro-cells in cities where the existing macro network density is strong (e.g., Port Harcourt). Similarly, mobile operators with huge spectrum assignments don't need to use as many micro-cells to densify their networks.

4. CONCLUSION

This research discussed the telecommunication network evolution from 1st Generation of mobile communication technology to 5th Generation technology. The key infrastructural issues of deploying 5G networks were examined, and recommendations were made, including but not limited to the following: CAPEX investment requirement, Infrastructure requirement e.g., Fiber optic ducts and frequency spectrum licencing. Infrastructure sharing was identified as the method for cost reduction in deployment of 5G network in Nigeria. This will be achieved by either technology base sharing or business/ownership sharing arrangement. Infrastructure sharing will go a long way in reducing the cost of deployment and management of 5G network in Nigeria which will help lower investment requirement from operators.

Telecommunication subscriber's growth forecast and analysis done for the next 10 years using the linear programming tool shows that there will be constant possible growth for the next 10 years. Using optimistic, normal, and pessimistic scenarios forecasting method, the following mobile subscriber's growth were obtained for each scenario 171.52%, 163.35%, 155.19% respectively in 10 years.

Cost of deploying 5G in Port Harcourt and Ahoada was estimated using CAPEX per site and number of sites in the cluster. These provide insight into the expected cost estimate of deploying 5G with respect to the projected population and clutters.

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