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The Role of Optical Fibres Infrastructure in Reinforcing the Adoption of 5G Networks in Nigeria

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ABSTRACT: *Fibre optic backbone network is at the heart of most communication services in Nigeria. Most internet traffic passes in and out of the country since little internet content is hosted within the country itself. A wired backbone network is essential for high traffic between network nodes. Limited availability of high capacity backbone network in Nigeria is one of the factors underlying the limited growth of broadband in the country. The vision of 5G network in Nigeriarequires new technology to accommodate the denser deployment of access points, simultaneous transmission to direct towards the users, many GHz of unused spectrum at mm-Wave frequency and the design of new hardware to support the odd way of signal propagation.In this paper, a general overview of the role of optical fibres infrastructure in reinforcing the 5G cellular networks is viewed.The optical fibre highly support the fronthaul technology like advanced network, mmWave, Multi – RAT (Radio Access Technology), advanced MIMO (Multi-Input, Multi-Output), small cell access point, advanced D2D (Device-to-Device) and multiple access in the adoption of 5G networks in Nigeria.*

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I. INTRODUCTION

The Fifth-Generation mobile telecommunications technology (5G) is the latest incarnation in the evolution of mobile technology. The driving factors of this emerging mobile technology has the important tools that support 5G and the important requirements for 5G technology development and the enhancements of this technology as can be seen from Fig. 1 such as the data speed that increases 20 times when compared to 4G, increased network densityand very low latency (Landman, 2019) (Daengsi & Pornpongtechavanich, 2019). These improvements are expected to enable numerous new use cases, including autonomous vehicles, the industrial Internet of Things, and telemedicine (Agyapong, Mikio, Dirk, Wolfang, & Anass, Nov. 2014.).

5G will enable these improvements because it is designed to exploit not only low-band spectrum, which historically has been used for mobile voice and data services, but also mid- and high-band spectrum, while capitalizing on the propagation characteristics of the different spectrum bands (Akyildiz, Ian F., et al, 2016). Specimen of thesenew technology components are different ways of accessing spectrum and considerably higher frequency ranges, theinstigation of massive antenna configurations, direct device-to-device communication, and ultra-dense deployments (Baldenair, 2013).

It is assumed that 5G might replace optical fibre because it is capable of delivering speeds up to a gigabit to consumers using the millimetre wave spectrum bands (Landman, 2019).

However, this may not be achievable because this spectrum has extremely short wavelengths, which implies that signals would not travel very far before the signal loses strength and attenuates which would make superfast data transfer impossible (Landman, 2019).

In addition, because of the propagation mechanisms of the waves at these wavelengths, they would not be able to get through buildings and other obstacles (Daengsi & Pornpongtechavanich, 2019).

In the long run, the telecommunications companies would have to build new infrastructure, which will result in numerous base stations dotted all across our towns and cities. New solutions to the problems posed by the short wavelengths employed for 5G would be the introduction of picocells, which could have tiny antennas that can be masked and well hidden from public view and provide more coverage especially in areas of potential black spots (Landman, 2019).

Fig. 1:Position of cells in coverage gaps (Bjornson, 2017)

Picocells would very much complete existing macrocells and even microcells may be employed only in areas of the expected high density of users (Chandrasekhar, Andrews, & Gatherer, 2008).

It might therefore still be a good idea to continue with investments in optical fibres, which would complement the deployment of 5G network. That way, broadband superfast connections can be assured between base stations and customers. This would ensure areas of potential blackspots would get adequate coverage.

One of the key challenges for the modern telecommunication systems towards coping with the exponentially increasing demands is to efficiently integrate cutting-edge communication technologies. The bottleneck in the current telecommunication infrastructure can be found at the sector that interconnects the radio access domain to the network core, known as fronthaul (Lagkas, Klonidis, Panagiotis, & Tomkos). The adoption of high performance fiber optical networking constitutes the only viable solution and is expected to play a leading role in building the future fronthaul infrastructure. At the access part of the system, the growing need for mobility and agility while wireless traffic keeps skyrocketing is now answered by New Radio (NR) (Baldenair, 2013) (Lagkas, Klonidis, Panagiotis, & Tomkos) standards and modern radio access features, namely beamforming, millimeter wave links, small-cells, and massive Multiple Input Multiple Output (MIMO) transmissions (Lagkas, Klonidis, Panagiotis, & Tomkos). The seamless combination of the latest radio access and optical communication hardware technologies at the fronthaul domain along with the use of state-of-the-art network control and management techniques are expected to enable covering the notably elevated requirements of the overall 5G vision (Lagkas, Klonidis, Panagiotis, & Tomkos) (Sarigiannidis, Lagkas, Bibi, Ampatzoglou, & Bellavista, 2017). The 5G networks promise to cover all related requirements with their advanced specifications in terms of throughput and latency, however, this does not concern only the radio access part. Interconnecting the numerous mobile devices to the core network and efficiently driving the links through the fronthaul is an essential part of the overall architecture for the delivery of high-quality modern telecommunication services to vast numbers of users (Lagkas, Klonidis, Panagiotis, & Tomkos) (Sarigiannidis, Lagkas, Bibi, Ampatzoglou, & Bellavista, 2017).

The high cost of laying optical fibre has been the greatest challenge to getting mobile networks deployed but this can be augmented by the use of 5G nodes with point-to-point microwave radio antennas (Landman, 2019).

Fibre optic backbone network is at the heart of most communication services. In Nigeria, most internet traffic passes in and out of the country since little internet content is hosted within the country itself (Solomon, B. Adekunle, and Moses Alokpa Fidelis, 2018). A wired backbone network is essential for high traffic between network nodes. Limited availability of high capacity backbone network in Nigeria is one of the factors underlying the limited growth of broadband in the country (Dahunsi, 2015).

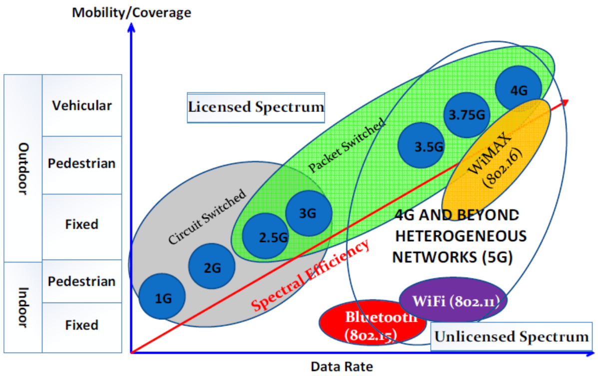

Fig. 2: Evolution of wireless technologies (Akhil Gupta, Rakesh Kumar Jha, 2015)

5G promises to provide faster speeds as such it is to make the wireless industry to be integrated with previous generations, just as 4G LTE networks support 3G devices (Attaran, Mohsen, 2019).Fibre is the cable of choice that supports low-latency and higher bandwidth level to ensure the transfer of real-time data collection (Landman, 2019).

II. THE VISION OF 5G NETWORKS IN NIGERIA

As was seen with the evolution from 1G to 3G but especially moving from 2G to 3G, a lot of extra investment is required to be made by the telecommunications companies. However, there were ingenious ways of improving the efficiency of the spectrum thus giving birth to improved technologies such as 2.5G (Landman, 2019) (Daengsi & Pornpongtechavanich, 2019).

3G has not completely satisfied user performance demands whereas 4G removed circuit switching and its wider frequency channels reduced the latency producedthis has led to a global business model where expenses are lower, and revenue from services is higher, due to the presence of more and greater services than 4G could provision for (Landman, 2019).

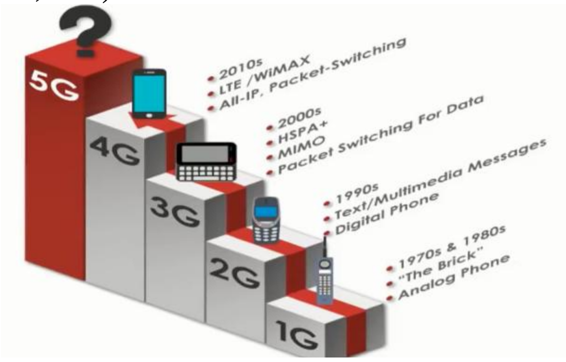

Fig. 3: Transition of generation with their technology

It is also claimed that migrating from 4G to 5G is not so much sustainable over the long term, as 4G is claimed to be approaching unsustainability faster than the industry experts predicted (Landman, 2019).
Nigeria has primary fiber optic backbone infrastructure presence in all the 36 state capitals and the Federal Capital Territory (FCT), with most fiber infrastructure concentrated in state capitals and a few urban centres (Dahunsi, 2015).

Table 1: Estimated Coverage of Fiber Infrastructure (F. M. Dahunsi, 2015)

Category	Area Description	Estimated Coverage
I	Fiber backbone to all state capitals and FCT	100% (37 of 37)
II	Metropolitan Area network in cities	10% (Mostly Lagos, Abuja and Port Harcourt)
III	FTTB. Fiber to the base station	10% of all base stations
IV	FTTC, Fiber to the cabinet, buildings or states	Unknown (e.g. 744 local government

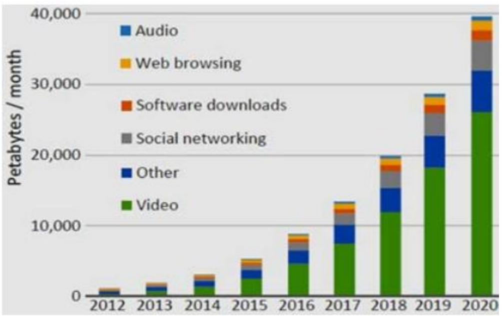

Fig. 4: World traffic forecast information (Daengsi & Pornpongtechavanich, 2019)

A. Denser Deployment of Access Point

In Nigeria, there are 151 million connections which are expected to rise to 210 million by the year 2025 with a mobile penetration of 49% of which smartphone adoption is 53 million (Daengsi & Pornpongtechavanich, 2019) (Nigerian communications commission,, 2018). As can be observed from Fig. 5, as of 2018 the 5G connections are very minimal. However, this is expected to rise to 8% by the year 2025. The Nigerian market is an emerging market with high potential for the adoption of 5G networks. 5G network will offer denser deployment of access points, as illustrated in fig. 6.

Galaxy Backbone built and operates the National Information and Communication Technology infrastructure Backbone (NICTIB) a cross-country optical fibre backbone. Its optical fibre coverage is expected to increase to 3441 km across the 41 cities in the North East, North West and South West of Nigeria (BTRAIN - Backbone Transmision Infrastructure, 2019).

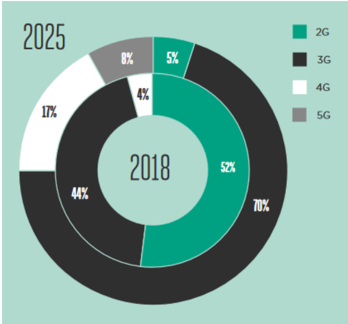

Fig. 5: Breakdown of mobile technology connections in Nigeria (Spotlight on Nigeria Delivering a digital future, 2018)

Optical fibre will support and improve higher cell density. More access points per km^2 will be easily achievable.

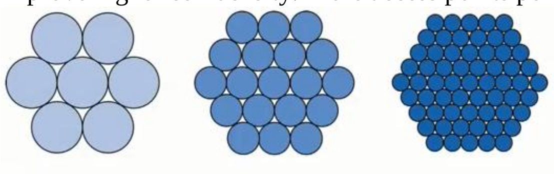

Fig. 6: Denser access point

The relationship between the wave frequency and antenna size is inversely proportional. Lower frequency signal needs a bigger antenna to transmit and receive, while higher frequency signals can work well with smaller-size antenna (Tiwana, Mohsin I., Stephen J. Redmond, and Nigel H. Lovell, 2012). Thus, millimetre wave makes it possible to have a lot of transmitters and receiver installed on a small size cell or panel.

B. Higher Spectral Efficiency

In Nigeria, It is very challenging to improve the spectral efficiency beyond the certain quantity of channel capacity (Ekpeyong, Moses E., and Joseph Isabona, 2011).

Increasing the transmit power turns out to be very expensive. Instead, deployment of optical fibre can support simultaneous transmission and making sure each have the same spectral efficiency. Many simultaneous transmissions directed towards the users (Xiao, Ming, et al, 2017).

In the previous generation, the wireless signals, if not omnidirectional, are spreading over a large area as they travel. Thus, signals tend to lose energy more quickly. Different user might interfere with each other if they are standing close. Beamforming makes the transmission between users and base or cell stations more directional (Ali, Ehab, et al, 2017). The higher density of beamforming leads to less interference and less energy consumption, and thus a faster data rare can be achieved with optical fibre infrastructure augmenting it, as shown in fig. 7.

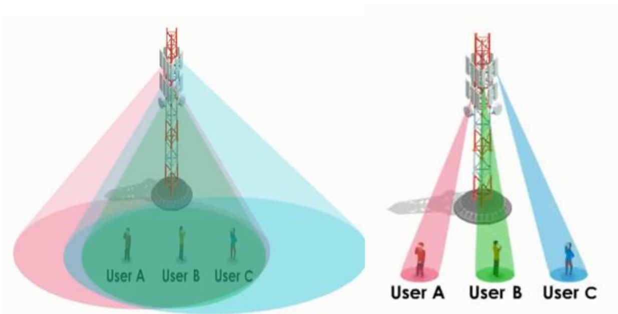

Fig. 7: Standard antenna and with beamforming (Bjornson, 2017)

$$\text{Capacity in } \frac{\text{bit}}{\text{s}} \text{ per km}^2 = \text{cell density in } \frac{\text{cells}}{\text{km}^2} \times \text{spectral} \frac{\text{efficiency} \ \text{in} \frac{\text{bit}/\text{s}}{\text{Hz}}}{\text{cell}} \times \text{available spectrum in Hz} \qquad (1)$$

C. Frequency Spectrum

For the purpose of frequency allocation, the world is divided into three regions. Nigeria falls within Region 1 (McHenry, Mark A., and Karl Steadman, 2004). Article 5 of the Radio Regulations deal with these frequency allocations which have been made from 8.3 kHz to 300 GHz. The adoption of 5G Networks requires an unused band on the spectrum. More transmission per second and it uses much higher frequencies (Nigeria Communication Commisssion (NCC), 2015).

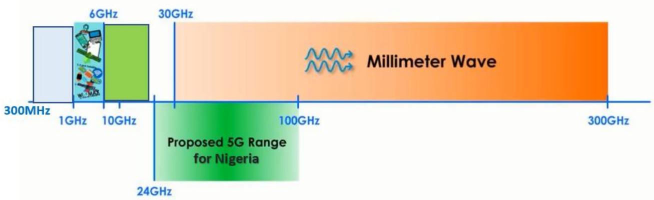

Fig. 8: Nigeria frequency spectrum

In Nigeria, radio frequency spectrum from 300MHz to 10.5GHz is very crowded. Many technologies use this range: Wi-Fi, 4G, 3G, L-band satellite, S-band and C-band, and etc.

The spectrum ranges from 30GHz to 300 GHz, known as millimetre wave, is less utilized. Thus, the range from 24GHz to 100GHz is proposed for the 5G network, which can be comfortably reinforced with optical fiber infrastructure, see fig. 8.

D. Latency

Latency refers to any form of delay incurred in processing network data, low latency result in small delay while high latency result in long delay time (F. M. Dahunsi, 2015). The 5G networks promise to cover all related requirements with their advanced specifications in terms of throughput and latency. Using the optical fibre to reinforcing the adoption of 5G network will cause a 5 ms (end-to-end) and 1 ms (over-the-air) (Lagkas, Klonidis, Panagiotis, & Tomkos).

III. BENEFITS OF OPTICAL FIBRE INFRASTRUCTURE TO REINFORCE THE 5G NETWORKS

Optical fibres infrastructure in reinforcing the adoption of 5G Networks will offer a higher bandwidth, immunity to electromagnetic radiation, increased security, not susceptible to adverse weather conditions, Low loss transmission (Rahman, Kejalakshmy, Uthman, Agrawal, Wongcharoen, & Grattan, 2009), Controllable Design (Rahman, Uthman, Kejalakshmy, Agrawal, & Grattan, 2011),Easier Splicing/Coupling between fibres and other optical devices (Uthman, Rahman, Kejalakshmy, Agrawal, Abana, & Grattan, 2012).

The millimetre wave, which 5G networks will accommodate offers certain advantages;

i. It is a new and less used band.
ii. Higher frequency wave carries much more data than lower frequency.
iii. Millimeter wave makes it possible to have massive MIMO antenna.

It has some disadvantages too. For example, higher frequency signals will have more collisions with obstacles in the air, and thus they tend to lose energy more quickly, as shown in fig.1. Hence, the need for optical fibre to reinforce the 5G Networks (Bjornson, 2017).

Low latency, (<1 ms), high throughput and low power consumption are the key parameters for successful deployment of flexible 5G mobile communications in a small call (3GPP, 2017). Furthermore, analog optical fronthaul has been suggested as the most efficient method to alleviate the large signal bandwidths required in centralized radio access network architecture (Konstantinou, Dimitrios, et al, 2019). It can therefore be seen the most promising solution will involve the deployment of both fiber optics and millimetre-wave technologies in developing 5G technologies in Nigeria.

IV. CONCLUSION

It may have been predicted that 5G could be a replacement for optical fibers. However, considering the past experiences encountered in terms of huge investments required and the economic implications with the migrations from 2G to 3G and more recently from 3G to 4G, as well as the fact that the short wavelength of 5G spectrum poses limitations, the continued investment in optical fibre will go a long way to complement and augment 5G adoption in Nigeria.

Optical fibre will support and improve higher cell density and more access point per km^2.

Adoption of 5G Networks with optical fiber would be driven by a lot of new technologies to a new level, such as the Internet of Things, games, Smart city, machine learning and so on. Hence, 5G is coming with a lot of potentials and possibilities with its reinforced optical fiber.

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