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Radio Propagation and the 5G Network in Africa

Adimula, I. A[*], Idowu, A. O.[**], Ojerheghan G. I.[***]
[*](Department of Physics, University of Ilorin, Kwara, Nigeria)
[**](Department of State Services, Abuja, Nigeria)
[***](Department of Physics, University of Ilorin, Kwara, Nigeria)

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Abstract:

Mobile networks have advanced from providing simple voice communications to supporting an array of data services ranging from email and simple SMS (short message services) to a plethora of different mobile apps. These apps and services range from games, maps and social media tools to mobile commerce, mobile banking, smart cars and wearable devices. The major difference to mobile services is the staggering growth in connected machines, which would outnumber human mobile subscribers by 2025. This is creating a more connected life where almost anything can be remotely monitored, controlled, upgraded and fixed. The historical evolution of the different generations of a network describes how human activities are interconnected with Internet-of-Things (IoT). Africa has a 5G network index of 4% as at the year 2020 even though there are radio frequencies for the 5G network, which denotes how the continent can fit in the dynamic cyberspace. The cost of infrastructure, lack of political will, low power supply and the likes may hinder the growth rate of this index.

Keywords:IoT, 5G network, mobile apps, SMS, wearable devices

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I. INTRODUCTION

The behaviour of radio waves as they travel or propagate from one point to another or into different parts of the atmosphere is called radio propagation. Radio waves are propagated from the transmitting antenna (Tx) to the receiving antenna (Rx). Antenna and wave propagation have a great role to play in wireless communication networks. An antenna can be defined as an electrical conductor or a system of conductors that radiates/collects (transmits or receives) electromagnetic energy into/from space. An idealized isotropic antenna radiates equally in all directions. There are three modes through which transmissions propagate wirelessly – line-of-sight, ground-wave and sky-wave propagation. The frequency of the underlying signals determines the particular mode of propagation. The line-of-sight propagation entails both the transmitting and receiving antennas to be within the line of sight of each other; sky-wave propagation uses reflection by both ionosphere and earth while ground-wave propagation follows the contour of the earth. For frequencies below 30MHz, AM radio is an example of ground-wave propagation while international broadcasts like Voice of America (VoA) is an example of sky-wave propagation. When the signal is above 30 MHz, neither ground-wave nor sky-wave propagation operates, thus the communication is through line-of-sight.

In wireless media, the propagation mechanism of signals uses three principles, which are reflection, diffractionand scattering.Reflection is said to occur, when the signal bump into a large solid surface, whose size is much larger than the wavelength of the signal, for instance,a solid wall.Diffraction is said to occur, when the signal bump into an edge or a corner, whose size is larger than the wavelength of the signal, for instance, an edge of a wall.Scattering is said to occur when the signal bump into small objects of size smaller than the wavelength of the signal.

One drawback of multipath propagation is that multiple replicas of signal propagation along multiple different paths arrive at different timesat any point. So the signal received at a point is not only limited by the inherent noise, attenuation, distortion and dispersion in the channel but also

the interaction of signals propagated along multiple paths.

Wireless communications systems consist of one or more "Antenna Sites", "Tower Sites", or "Cell Sites". The movement of these radio waves (which move at the speed of light) to and from these sites and devices is known as wireless signal propagation. Wireless communication can be used for wireless access to the internet, cellular telephony, wireless home networking amongst others. It has been revealed that there are three types of wireless networks. Firstly, the Wireless Wide Area Network (WWAN) in which users can use mobile phone signals which are provided and maintained by specific mobile phone (cellular) service providers and allow users to stay connected despite their proximity to access other networks. Secondly, the Wireless Local Area Network (WLAN) uses radio waves whose backbone network uses cables with one or more wireless access points connecting the wireless users to the wired network. Thirdly, the Wireless Personal Area Network (WPAN) which are networks that use Bluetooth technology being short-ranged. The range of WPAN is about 30 feet [1].

Radio spectrum is used to carry information wirelessly for a vast number of everyday services ranging from television and radio broadcasting, mobile phones and Wi-Fi to communications systems for the emergency services, baby monitors, GPS and radar.The Internet of things (IoT) was a phrase coined by Kelvin Ashton, an innovator and consumer sensor expert to describe the network of physical objects—"things"—that are embedded with sensors, software, and other technologies to connect data with other devices and systems over the Internet [2]. In the 1960s, the communication technology used was based on "press to transmit" system where users have to enable a transmission button and disable reception. This system constitutes two channels in which one channel was used for sending and the other one was used for receiving [3]. This system did not support simultaneous listening and talking, thus, Improved Mobile Telephone System (IMTS) was launched. The IMTS uses 23 channels ranging from 150MHz to 450MHz to eliminate the "press to transmit" system. The Advanced Mobile Phone Service (AMPS) was invented by Bell Labs and hence introduced the first generation (1G) cellular network in 1980 until it was substituted by 2G in 1992. The main difference between 1G and 2G is that 1G is analogue-based while 2G is digitally based. The physics behind the 1G network is that the geographical area is broken down into cells. Each cell is 10-25km away and has its base station. Though the length of the cell in IMTS is bigger than the cells in AMPS, the latter has proximity than the former. This has made the cells in AMPS to require less power to function well. The AMPS uses two 25MHz bands; one for transmission from the base to the mobile unit and otherwise. Each phone has a 32-bit number and a 10-digit phone number allocated to the phone's Programmable Read-Only Memory (PROM).

II. BRIEF HISTORY OF GENERATIONS OF NETWORKS

The first generation (1G) network was invented in the 1980s and it could only do voice calls with a push-button for the two-way analogue communication with a maximum speed of 2.4kbps. During the 1G network era, dropped calls were prominent. All of these changed when the 2G digital communication was introduced.The brief history of generations of the network is tabulated in Table 1 below.

Table 1: Brief History of Generation of Networks

	Year of Introduction	Technology	Acess System	Switching Type	Internet Service	Bandwidth	Frequency	Application
1G	1980	AMPS	FDMA	Analog	None	2 kBps	30 kHz	Voice calls
2G	1993	GSM	TDMA, CDMA	Circuit switching for voice and packet switching for data	Narrowband	2 MBps	1.8 GHz	Voice calls, SMS
3G	2001	WCDMA	CDMA	Packet switching except for air interference	Broadband	14.4 - 64 MBps	1.6 - 2 GHz	Video conferencing, mobile TV, GPS
4G	2009	LTE, WiMAX	CDMA	Packet switching	Ultra broadband	2000 MBps - 1 GBps	2 - 8 GHz	High speed application, mobile TV, wearable devices
5G	2018	MIMO, mm Waves	OFDM, BDMA	Packet switching	Wireless World Wide Web	1 GBps and higher	3 - 30 GHz	High resolution video streaming, remote control of vehicles, robots and medical procedures

III. THE INTERFERENCE OF RADIO WAVES ON 5G NETWORKS

The radiofrequency (RF) Technologies used by the 5G network are Software Defined Radio (SDR) and Cognitive Radio (CR). Software Defined Radio uses a software package to administer all the functions used in wireless communication. Everything from RF and channel selection, to handoff and logging, is handled independently by the software program. RF Technologies Cognitive Radio uses software as well but can store and react to the users dominate needs and typical environment. This is achieved by either pre-set codes or an algorithm created by the software manufacturer. Radio propagation – the electromagnetic phenomenon discovered by Henrich Hertz in the late 1880s. It is how energy travels through a given medium. The medium can be air, water, aired cable, fibre optics and the like. Radio signals travel at the speed of light through the air – 186,282 miles per second. The only significant difference cellular systems and conventional landlines are the radio link that connects the wireless network to the cell base station. The propagation of wireless signals is Omni-directional at different frequencies. In the process of radiating through free space, they can either be refracted when they bend through the atmosphere or reflected when they bounce off due to obstructions or diffracted when they bend around obstructions.

5G uses the rarely used radio millimetre bands in the 30 GHz to 300 GHz range. Testing of 5G range in mmWave has produced results approximately 500 meters from the tower. Using small cells, the deployment of 5G with millimetre wave-based carriers can improve overall coverage area. Combined with Beamforming (directing signals in a particular direction), small cells can deliver extremely fast coverage with low latency. Low latency is one of 5G's most important features. 5G uses a scalable orthogonal frequency-division multiplexing (OFDM) framework. 5G benefits greatly from this and can have latency as low as one millisecond with realistic estimates to be around 1 – 10 seconds. 5G is estimated to be 60 to 120 times faster than the average 4G latency. Active antenna 5G encapsulated with 5G massive Multi-In Multi-Out (MIMO) is used for providing better connections and enhanced user experience. Big 5G array antennas are deployed to gain additional beamforming information and knock out propagation challenges that are experienced at mmWave frequency ranges. Further, 5G networks clubbed with network slicing architecture enables telecom operators to offer on-demand tailored connectivity to their users that are adhered to Service Level Agreement (SLA). Such customised network capabilities comprise latency, data speed, latency, reliability, quality, services, and security. With speeds of up to 10 Gbps, 5G is set to be as much as 10 times faster than 4G. The 5G enabled-devices do communicate with base stations by transmitting and receiving radio waves within some specific frequency bands. 5G networks will incorporate the existing 4G Long-Term Evolution (LTE) technology, but a new radio technology also will be introduced that meets all the extended capability demands of 5G. To increase the capacity of the mobile networks and support very high data rates, 5G will extend the range of frequencies used for mobile communication. This includes new spectrum below 6 GHz, as well as spectrum in higher frequency bands up

to 100 GHz. There are two types of frequency range (FR) used in the 3rd Generation Partnership Project (3GPP); the sub 6 GHz range is called FR1 and millimetre wave range is called FR2. The 5G network uses the FR2(mm Waves). The values of the two Frequency Range are shown in Table 2 below.

Table 2: 5G Frequency Range (FR)

5G frequency range	Designation of 5G frequency range
450 MHz - 6000 MHz	FR1
24250 MHz - 52600 MHz	FR2

IV. THE AFRICAN 5G NETWORK INDEX

This is the ratio of countries with 5G network to the entire countries in Africa. In the global scale, out of the 193 UN-recognized countries, only 34 countries have 5G network as at November 2020 [4] as shown in Table 3 below. The Global 5G Network Index is 18%.

Table 3: Countries in the World with 5G networks

EUROPE	NORTH AND SOUTH AMERICA	MIDDLE EAST AND AFRICA	ASIA AND OCEANIA
Austria	Suriname	Bahrain	Australia
Estonia	Trinidad & Tobago	Kuwait	China
Finland	US	Lesotho	Maldives
Germany	Uruguay	Oman	New Zealand
Hungary		Qatar	South Korea
Ireland		Saudi Arabia	
Italy		South Africa	
Latvia		UAE	
Lithuania			
Monaco			
Poland			
Romania			
San Marino			
Spain			
Sweden			
Switzerland			
UK			
17	**4**	**8**	**5**
50%	**12%**	**24%**	**15%**

Among the 34 countries with 5G network, the percentage of Europe, North and South America, Middle East and Africa, Asia and Oceania are 50%, 12%, 24% and 15% respectively.

The African 5G Network Index is the ratio of countries with 5G network to all countries in Africa. There are 55 African countries and only 2 have 5G network, thus the African 5G Network Index is 4%. This index indicates how prepared Africa is in these modern times where smart cars are invented, where teleconferencing or other real-time video applications are the order of the day. More smart gadgets that are 5G enabled are produced for use in Europe and other climes but in Africa, many countries are still using the 3G network.

VI. HINDRANCES TO THE 5G NETWORKS IN AFRICA

a. Corruption – The interest of the majority of African leaders are not concerned with how this technology is going to impact the lives of their citizenry, but how they can exploit the system for self-enrichment. This has always been the problem since the introduction of mobile network in Africa and its growth as well as an expansion over the years.

b. Political influence on science across Africa – The political influence on science has always been unhealthy, as the needed human and capital resources are usually embroiled in political patronage, rather than expertise and professionalism. This has hindered Africa from having headways in scientific research and discovery.

c. Inadequate competent scientist in Africa – The compromise of the majority of African learning institutions is continuously eroding the culture of research and discovery. As a result of this, young minds are fast losing interest in becoming a scientist. This has

grievously affected the chances of an African country to compete favourably with other advanced nation in science and technology.

d. The huge cost of 5G infrastructures – As third world countries with weak financial base and poor human capital development, the introduction of 5G network would be a gigantic project for the majority of African countries. The investors are business making minds with market requirements that the majority of African countries cannot provide.
e. Low research institute for the network – African countries have done little in internet application except for South Africa which introduced Digital Satellite Television (DStv) and Mobile Telephone Network (MTN) mobile network before a country like Nigeria followed suit. Generally, Africa has little or no contribution to the early generation network such as 2G. And as we know, it has no input in the case of 3G, 4G and 5G. The competition has been between the Western World and Asia. The lack of interest by various African country governments in research brought us to the point where we are spoon-fed borrowed technologies.
f. Low power supply – The 5G network is a high-powered electronic technology, as it requires a high number of infrastructure in terms of antennas/masts to function properly. Meanwhile, the current set-up of 4G with fewer infrastructures is running virtually on alternative power supply such as generating sets and solar power system. This cut across a majority of African countries, as a result of epileptic power supply.
g. Low literacy level – The heightened level of illiteracy amongst citizens of African countries as a result of decadence in the education system and distortion of facts, has further contributed to the slow progress so far achieved 5G network, especially the misinformation on the implication of 5G on the health condition of network users.
h. Inadequate enlightenment and sensitization of populace – Poor awareness and campaign programme towards the introduction and usage of 5G network in Africa have compounded the smooth sail of the radio communication network.

VII. IMPLICATION OF 5G NETWORK ON SECURITY

a. Unfettered access to 5G applied data/information - All data/information within the 5G network is accessible to the foreign private companies running the network. This makes the country susceptible to any threat that could emanate from the use of obtained data/information.
b. The attraction of foreign meddling/interference – With information power in the hands of these companies, their governments can easily meddle in the political affairs of the country uninvited. This situation gives them the window to decide the government's decisions and policies from the background since they have all information and resources.
c. A gradual loss of sovereignty – Since the absolute mandate given to government has been tainted, it will be difficult for the government to protect the citizens in terms of their privacies and other embedded rights.

VIII. CONCLUSION

The advent of 4G is sure to revolutionize the field of telecommunication domain bringing the wireless experience to a completely new level. It would provide a wealth of features and services making the world a smaller place to live. Thus, 4G seems to

have the capability to realize future scenarios. But 4G should also take a lesson from the 3G's failure to capture the imagination of the end-users. Technology should not be developed for technology's sake rather it should target the end-user. Thus, the user-centric approach towards 4G's development is the key to its success. The common consensus on the standards and the technologies for 4G needs to be reached to fasten 4G's deployment which would be a gradual process. Lot of research work is required to investigate the open issues like the design for SDR, QoS parameters and so forth. The threat analysis model provided by ITU is very apt for the complete analysis and planning for the security of 4G. It can be used as a reference framework for future research. But still, comprehensive research work is required in the field of network security to tackle potential security threats because a ubiquitous "secured" heterogeneous network will appeal more of today's consumers [5]. The purpose of 5G is to provide connectivity everywhere for any kind of device that may benefit from being connected. 5G will support a wide range of new applications which include smart homes, smart television, smart cars, traffic safety, critical infrastructure, industry processes and very-high-speed media delivery. 5G will accelerate the development of the Internet of Things. But with Africa low 5G network index, there is a lot to be done.

REFERENCES

[1] Amit Agarwal (2010). Types of Wireless Networks. ***Digital Inspiration***. Retrieved on November 23, 2020, and available on https://www.labnol.org/tech/types-of-wireless-networks/13667/

[2] Arik Gabbai (2015) Kevin Ashton Describes "the Internet of Things" ***Smithsonian Magazine*** *January 2015. Retrieved on November 18, 2020, from https://www.smithsonianmag.com/innovation/kevin-ashton-describes-the-internet-of-things-180953749/*

[3] Nikhil Bhandari, ShivinderDevra and Karamdeep Singh., (2017). Evolution of Cellular Network: From 1G to 5G.***International Journal of Engineering and Techniques*** - Volume 3 Issue 5, Sep-Oct 2017

[4] AsyaLikhtman (2020). Which countries have 5G? ***The Week***. Available on https://www.theweek.co.uk/106957/which-countries-have-5g. Retrieved November 20, 2020.

[5] Tondare, S. M., Panchal, S. D. and Kushnure, D. T. (2014). Evolutionary steps from 1G to 4.5G. ***International Journal of Advanced Research in Computer and Communication Engineering*** Vol. 3, Issue 4, April 2014. Retrieved 24 November 2020 and available on https://www.ijarcce.com/upload/2014/april/IJARCCE1C%20%20%20a%20%20Sachin%20Panchal%20%20Evolutionary%20steps.pdf

