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5G Network Deployments in Sub-Saharan Africa: A Review

Oluwafemi Alao Jimoh[a], Kingsley Brown Orji[a]
Department of Computer Science,
Ignatius Ajuru University of Education
Port Harcourt, Nigeria

Peter Muwarure Odiboroghene[b]
Department of Chemical Engineering
University of Port Harcourt
Port Harcourt, Nigeria.

ORCID ID: https://orcid.org/0000-0001-9203-3317

Abstract:- The widespread adoption of and transition to the 5G network does not come without its challenges. These challenges are even more prominent in Africa, a continent that houses most of the underdeveloped and poor countries in the world. And even more so in Sub-Saharan Africa-the part of the continent south to the Sahara, despite two of the largest economies in Africa (South Africa and Nigeria) being situated in the location. The aim of this paper is to provide concise and coherent insights into the possible economic, social, and technological developments and advancements that Sub-Saharan Africa would experience with the advent of the 5G network in the region. In this paper, a systematic review was employed to properly analyse the likely impact the 5G network era would have on the digital transformation in Sub-Saharan Africa. This led to a detailed analysis of the key limitations, policy considerations, and the expected social and technological implications in deploying the 5G networkin Sub-Saharan Africa.The data used for the review were gotten from reliable publications on the web and from previous related journal publications. The information retrieved from these materials were compared with other primary sources such as historical data and economic data to validate the information gotten from them. At the end of the review, it was seen that the 5G network has come to stay and is going to be a key tool in the coming industrial revolution, and its widespread acceptance is only a matter of time. Hence, its benefits and downsides must be capitalised on both by individuals, businesses, and governments to see that the networkhas a better performance in the digital transformation of the Sub-Saharan region as compared to its predecessors.

Keywords:- *Sub-Saharan Africa, Digital Transformation, Internet of Things, 5G, Underdeveloped, impact.*

I. INTRODUCTION

A. History of the 5G network

In the last four decades, telecommunications have evolved at such a quick pace that even the sharpest engineers in the 1970s and 1980s couldn't fathom the things we take for granted today. When James Clark Maxwell discovered electromagnetic waves in the 1860s, he speculated that they may move at a speed near to that of light. Heinrich Hertz soon discovered a means to generate and detect electromagnetic waves, which he subsequently dubbed "Radio Waves." Thoughts of exploiting these waves as information carriers began to take shape after they were discovered.

In the late 1940s and early 1950s, Americans and Europeans began using 1G, or First-Generation communications technology, in their communication equipment. Despite the fact that these devices were billed as "mobile phones," their size, security problems, and the blockage in the transmission of signals restricted their usefulness. In 1979, NTT, Nippon Telegraph and Telephone, created the automated cellular network known as the First-Generation Cellular Network, the first true mobile phone. Analog signals were used to transport data in 1G, making it a rudimentary type of wireless communication. However, even though there was a lot of noise involved in the transmission, the clients were presented with an entirely new kind of "mobile" phone.

The second generation of communications technology, known as 2G, was then introduced. In this time, the transmission of signals dramatically altered. In contrast to the preceding generation, this version employed digital signal transmission instead of analog. Radiolinja's introduction in 1991 marked the beginning of a new era for cellular technology. The previous generation's difficulties were solved by this new technology, which sent signals in digital form such that noise was not an issue and digitally encrypted data was only accessible to the intended recipient. 2.5G and 2.75G, which were somewhat improved iterations of the same technology, appeared shortly afterwards. Mobile internet systems such as GSM/EDGE and GPRS had theoretical bandwidths of 50 kbps and 1 megabit per second at the time of their introduction. As an added benefit, this cell phone has Internet connectivity. It turned out, though, that the rest of the globe was just as hungry. A decade after that "radical breakthrough," e-mail and the internet had grown so large that it couldn't keep up with their bandwidth requirements.

That is when 3G, or third generation telecommunications technology, was launched. During the early 2000s, NTT brought 3G technology to Japan for the first time. Data rates were the only area where 3G outperformed 2G, even if phone calls and texting were not much improved. In 2G technology, data speeds were severely constrained. The data rate was increased to 7.2 Megabits per second with the launch of 3G. End-to-end security was also built in to make it more secure. Later, 3.5 and 3.75 G technologies were developed to improve the data rate limits of 3G. Because it had the ability to let its users to

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access the internet from any place, this was previously considered revolutionary.

In Oslo and Stockholm, 4G, the fourth generation of telecommunications technology, was initially made available in 2009. More than 100 megabits per second of download speed and above 50 megabits per second of upload speed were the limits of 4G (also known as LTE commercially). On top of the enhanced security and encryption, the latency in 4G technology has also seen substantial improvements. With a 50-millisecond reaction time, 4G technology was more than enough for any work at the time of its debut.

5G (the fifth-generation mobile wireless standard) is an emerging telecommunications technology. It was first available for public use in 2018 in South Korea and in 2019, cellular phone carriers began deploying the 5G network globally[1]. According to the GSM Association, 5G networks would have more than 1.7 billion members worldwide by 2025 [2]. Every new generation of wireless technologies, abbreviated as "G," has brought astounding improvements in data-carrying capacity and latency, and 5G will be no different. 5G is predicted to be at least three times quicker than current 4G standards, despite the fact that actual 5G standards have yet to be established. In 2008, NASA aided in the formation of the Machine-to-Machine Intelligence (M2Mi) Corp, which is tasked with developing IoT and M2M technology, as well as the 5G infrastructure required to support it. South Korea established a 5G R&D program in the same year, and New York University established the 5G-focused NYU WIRELESS in 2012. 5G's better connection was expected to revolutionize everything from finance to healthcare. 5G opens the door to life-saving breakthroughs like remote surgery, telemedicine, and even remote vital sign monitoring. 5G networks, like its predecessors, are cellular networks with service areas separated into small geographic units called cells. Radio waves connect all 5G wireless devices in a cell to the Internet and telephone network via a local antenna in the cell. The key benefit of the new networks is that they will have more bandwidth, allowing for faster download speeds of up to 10 gigabits per second (Gbit/s) in the future [3].

II. METHODOLOGY

The research used secondary data from the internet, journals, papers, blogs, and books. The study used a case study methodology because it allows the researcher (s) to perform an in-depth examination of complex phenomena within a given setting. A case study approach is often recognized as the most effective and widely utilized method in academia for qualitative researchers. Through full observation, reconstruction, and analysis of the case under examination, case studies aid in conveying all the processes and results of a phenomena. case study method entails the examination of data within a specific circumstance. In most cases, a case study method chooses a small geographical region or a small number of individuals as the subjects of study. The data collected cover countries in the Sub-Saharan African.

III. 5G IN SUB-SAHARAN AFRICA

Geographically, Sub-Saharan Africa is the part of the African continent south of the Sahara. It includes all African countries and territories that are wholly or partially south of the Sahara [4]. This region has experienced massive growth in its mobile communications sector. Although nearly half a billion individuals in Sub-Saharan Africa have access to mobile services, the region still has a 45 percent penetration rate. According to the GSMA's 2021 Mobile Economy Sub-Saharan Africa study, 477 million individuals in Sub-Saharan Africa subscribed to mobile services by the end of 2019. However, the region is expected to increase at a compound annual growth rate of 4.3 percent until 2025, according to the report [5].Activities over the last few years show that there is a growing demand mobile operations across a broad range of industries in this geographical location. For example, Microsoft opened its first Africa Development Centre (ADC) in Nairobi, Kenya, and Lagos, Nigeria, in March 2019, to drive AI, machine learning, and mixed reality innovation in the region and Google unveiled its first AI Lab in Africa in Accra, Ghana, in April 2019 to work on a solution that might assist farmers diagnose plant diseases and increase production.

This comes as no surprise because with a population of approximately 1.14 billion people, Sub-Saharan Africa presents an alluring opportunity for technological investments, and as digital trends in Sub-Saharan Africa point to increased demand for enhanced connectivity, understanding the role of 5G in the future connectivity landscape is critical. 5G wireless technology is expected to provide multi-gigabit per second peak data speeds, ultra-low latency, better stability, huge network capacity, increased availability, and a more consistent user experience to a larger number of users. With its higher performance and efficiency allowing new user experiences and industry connections.

A. Expected impacts of the 5G network in the digital transformation of Sub-Saharan Africa

Establishing the 5G network was mainly to the end that there is increased connectivity between for internet activities. In the African continent as a whole, the 5G network presents an opportunity for massive digital transformation. The need for digital connectivity among individuals and businesses, and for many ordinary activities, including work and study has increased. Especially since the Covid-19 pandemic most of these everyday activities have shifted online. And given the limited access to fixed broadband connectivity in the region, the present opportunity for the 5G network is to employ Fixed Wireless access (FWA) to improve the communication in enhanced broadband access for homesand businesses of all sizes.

The Fourth Industrial Revolution (4IR) is also projected to be facilitated by 5G. Some African governments have declared their intention to implement the 4IR concept. A concept characterized by the merging of the digital, biological, and physical worlds, as well as the increasing use of new technologies such as artificial intelligence, cloud computing, robotics, 3D printing, the

Internet of Things, and advanced wireless technologies, in a bid to see that Africa is not left behind in the coming revolution[5]. Although, the region still lags behind in digital technology industry, introducing the 5G network could act as a catalyst to help Africa, and Sub-Saharan Africa in particular meet up. The pandemic has made such plans even more important, as 4IR solutions could be critical to improving economic productivity and efficiency, as well as strengthening economic resilience in the future. Intelligent connection – the combination of high-speed networks, artificial intelligence (AI), and the internet of things (IoT) – will be enabled by 5G, supporting new and existing technologies to alter industrial processes and produce major social and economic advantages. Manufacturing, agriculture, financial services, and extractive industries are among the key sectors in the region that could profit.

Sub-Saharan Africa has some of the most commercial cities on the African continent. Including Lagos, Johannesburg, Nairobi amongst others. These cities also have some of the highest network congestion in Africa. As the issue of high traffic density becomes more pronounced in the region, 5G will have an integral part in alleviating network congestion in city centres, as an essential component of the infrastructure alternatives to sustain high traffic density to include the optimal functioning of major industries. Because of the 5G network, new consumer services will be possible. With 5G, existing consumer services like video streaming will be improved, while new use cases like augmented reality (AR) and virtual reality (VR) will become the new normal. It will be easier for industries and individuals to interact on a digital scale as 5G supports new consumer services.

The 5G era will provide social, cultural, and economic benefits to the region. More than $155 billion of economic value was added by mobile technologies and services in Sub-Saharan Africa. Which represents about 9% of the GDP of the region. In comparison to earlier generations, the technology will have a greater use in enterprise use cases. On a social and cultural scale, beyond what has been observed with present technologies, 5G will be the trigger for significant long-term changes in the way people live, work, and play. The 5G era will provide social, cultural, and economic benefits to the region.

GSMA in their report identified five mobile industry goals for the 5G era in Sub-Saharan Africa [6]. According to them, the 5G network will aim to achieve;

- Boundless connectivity for all by interacting with 4G networks and other telecommunication technologies to provide a high-speed, dependable, and secure internet experience to a wide range of users.
- Deliver sustainable network economics and innovation by utilizing a combination of known and novel technology, as well as licensed and unlicensed spectrum across several frequency bands, to offer higher-quality networks at a lower cost, either individually or through sharing/partnerships.
- Transform the mobile broadband experience through giving better broadband experience with up to 1 Gbps speeds and less than 4 millisecond latency, as well as a platform for cloud and AI-based applications.
- Drive growth in new use cases for massive and critical IoT by facilitating the mass deployment of intelligent IoT connections for a variety of situations and providing an upgraded platform to support the widespread use of vital communication services.
- Accelerate the digital transformation of industry verticalsestablishing networks and platforms to expedite the digitization and automation of industrial practices and processes (including assistance for Fourth Industrial Revolution aims).

B. Benefits and impact of 5G networks on social life

The utilization of more advanced satellite integration with terrestrial networks, particularly 5G networks, would undoubtedly address some of the world's most pressing concerns, particularly for regions like Sub-Saharan Africa, which is adversely affected by extremely high levels of poverty, extreme hunger, poor education, and healthcare. Such hybrid technology can help offer positive social effect in accordance with most of the 17 Sustainable Development Goals stated by the United Nations (SDGs) [7]. For example, as a result of the Covid-19 pandemic, digital connectivity and a good network system are now the backbone of sustaining societies, as residents must increasingly rely on fast, reliable, and trust-worthy connections for day-to-day activities.

As a result, a hybrid network would be able to bridge the digital divide in Sub-Saharan Africa by extending coverage to underserved and unserved communities, allowing them to access better livelihoods through better healthcare, reduced inequality, and financial inclusion, as the UN Sustainable Development Goals (SDGs) intend [7]. A more advanced network system, such as 5G, would considerably increase mobile broadband capabilities to stimulate digital governance, strengthen enterprises, open up new prospects, and allow for extremely effective partnerships at regional and global dimensions.

Furthermore, satellite 5G networks using small 5G cells in conjunction with HTS or a constellation of LEO satellites could help the Sub-Saharan Africa sub-region achieve SDG 7 and SDG 13 by facilitating better use of clean and affordable energy [7].In the last two decades, ICT has become an integral part of daily life. The capacity to access and utilize the internet successfully today has substantial economic, social, cultural, and political ramifications for people. Because mobile technology is increasingly used to access the internet, how individuals' access and utilize 5G will impact their life chances. People are increasingly utilizing the internet for everyday tasks including shopping, social networking, job and business searches, and leisure. This tendency will only grow with 5G.

Those who have unfettered access to 5G and the capacity and abilities to properly use it have a substantial edge over those who do not. Commonly used to describe uneven access to digital networks like the internet, the world's de facto digital communication medium. On the other hand, Hargittai claims that the phrase "digital divide" has been used to distinguish between those who have access to and those who do not [8]. She believes this is no longer suitable since the bulk of society is now online, and they utilize the internet in various ways. She coined the phrase "digital inequality" to describe the varying levels of access to and usage of digital media. Aiming to deliver universal mobile internet access, the term "digital inequality" seems more accurate of how society will interact with 5G than "digital divide," which implies a binary gap in access. Researchers believe the digital gap and digital inequality stem from social inequality [9]. When the internet initially appeared in the 1990s, many people assumed it would assist to increase access to information. Contrary to popular opinion, certain socioeconomic groups, particularly those with high education and money, were more likely than others to use the internet [8]. This demonstrated that rather than equating access to knowledge, the internet was highlighting social inequities [8]. Since 5G promises to provide equitable access to information and social networks, it is important to examine how social disparities lead to inequality and how this might be reduced.

Digital inequality has four aspects, according to Van Dijk and Hacker [9]. Not having access to access technologies such as computers and network connections, lacking digital skills, and not having large use possibilities are all factors. When mobile technology and the internet were launched in the early 1990s, inexperience with new technologies and lack of access devices were key factors. Those most impacted were the elderly, those with little education, low money, and those living in rural regions.

Once a person had easy access to the internet, they quickly learned the skills required to use it. Those who could afford and use the internet had an advantage over those who could not. It is clear that one's capacity to acquire and master new technologies influences one's lack of or presence of digital abilities.

In general, the young and educated are better equipped to adapt and experiment with new technology. Elderly and uneducated people are less likely to accept new technology. For example, in industrialized countries, the elderly are less likely to utilize the internet, despite the fact that it may provide a greater income due to their limited mobility. If the elderly can access and utilize the Internet, they can take charge of their life by doing everyday things like banking, shopping, and even seeking medical advice. More and more activities will be available over the internet as internet and networking technologies progress, making 5G a requirement for contemporary living. 5G will link a broad range of sensors to houses and people, allowing physicians to monitor the health of the elderly in real time. Thus, if the elderly are sufficiently 5G guarantees universal access regardless of location. Rural residents may expect the same amount of access as urban residents. Rural regions are less inhabited and so more costly to link than metropolitan areas. Rural interconnection cannot be left to private network operators due to high costs. Government may help by developing suitable rules, rewarding network providers, and actively investing in network infrastructure. Just as governments are responsible for providing transportation networks, they should likewise guarantee that everyone has access to 5G regardless of geography.

5G also promises to make the underlying technologies visible to consumers. In reality, inaccessible technologies typically lead to access issues [10]. This shows that 5G consumers will not notice a big change in user interface design. Multimodal user interfaces enable users to engage with networks using all five senses, including voice, hand movements, and facial gazes [11]. So multimodal user interfaces make complicated networks more tractable by reducing the need to memorize complex commands.

Intelligent personal assistants for mobile and desktop devices are also emerging. These personal assistants simplify man-machine interactions by anticipating user demands and requesting tasks from the underlying technology. Apple's Siri [12] and Google Now [13]. Intelligent personal assistants may become commonplace by the time 5G is widely deployed. This will assist achieve another 5G goal, namely tailored services for end users.

Indeed, 5G is being developed to serve as a communication method for IoT. (IoT).Using conventional communication protocols, Atzori et al. [14] describe the IoT as a global network of networked items. They think the IoT will enable new applications in transportation and logistics, healthcare, smart environments, personal and social domains. These apps have the ability to enhance our quality of life by managing our daily business and social lives. As IoT technologies become more extensively used, the requirement for sophisticated digital skills may diminish.

From Van Dijk and Hacker's digital inequality dimensions, it seems that 5G will address the three aspects immediately related to physical access and network usage. Lack of expertise with new digital technology, lack of access technologies like computers and network connections, and digital abilities. Concerning the absence of large utilization potential, additional research is required.

IV. 5G DEVELOPMENTS IN AFRICA

At the end of September 2020, there were 103 active 5G networks in 45 nations and territories throughout the globe, which represents the beginning of the 5G transition. There will be over 2 million 5G connections this year, according to GSMA Intelligence, which represents just over 2 percent of all mobile connections worldwide. A majority of 5G connections are being made in Asia today, including four out of every five in China alone, and almost a fifth in South Korea.

Vodacom and MTN, two of Africa's largest mobile service providers, will debut commercial 5G mobile and fixed wireless access (FWA) services in South Africa in 2020, thus kicking off Africa's 5G era. After the Covid-19 epidemic, the South African government issued emergency 3.5 GHz spectrum. This led to the transfer much sooner than intended.African countries like as Telma Madagascar, Cable & Wireless Seychelles, and the Indian Ocean Island of

Réunion all expect to introduce commercial 5G services within the next few months.

Commercial 5G services are expected to be accessible in several of the continent's largest markets by 2025, whereas the 2020s are expected to witness more widespread 5G operations. 3.3 percent of all mobile connections in Africa will have 5G by then, with less than 45 million 5G mobile connections throughout the continent. The GSMA believes that widespread market adoption of 5G is still some time away, pointing out that the worldwide average is 21%.

A combination of business and regulatory factors supports this position. It is difficult to justify the cost of mass-market 5G rollout in Africa based on the existing level of demand for better connectivity and use cases across the continent. " Leapfrogging is problematic from a regulatory standpoint since legacy phone services must be supported for the foreseeable future. VoLTE over 4G networks will be challenging to implement in areas where voice traffic is still heavily reliant on 2G networks and devices are still in 2G mode.So, governments and the telecom sector in the area will concentrate on increasing 4G penetration in the near to medium term. In order to stimulate demand for faster connection, this will need measures to lower the cost of 4G devices and the distribution of relevant digital content. Increased 4G penetration will be critical in preparing customers for 5G and bolstering the commercial case for 5G rollout for mobile industry operators.

Despite this, 5G is inevitable and will flourish in Africa as a logical evolution from earlier generations. It's safe to say that 5G will play a significant role in the future of connection, especially in light of the current outbreak of the Covid-19 virus [15].

A. Egypt

ExxonMobil and Nokia are working together with Egypt to improve the cloud core network. The Information and Decision Support Centre (IDSC) of Egypt's cabinet said on Saturday that the country is making progress toward the deployment of 5G networks and artificial intelligence applications.IDSC has published a paper on Egypt's efforts to jumpstart the fourth industrial revolution and the notable worldwide experiences Egypt may draw from.

According to the National Telecommunications Regulatory Authority (NTRA), which has been working on broadband optical fibers that are essential for the fourth industrial revolution, 5,300 government buildings have been equipped with fibre optics.Egypt's National Transportation Authority (NTRA) plans to spend EGP 6 billion on this project, the IDSC said [16].In addition to launching the Egyptian satellite Tiba 1, Egypt is working with ExxonMobil and Nokia to modernize its cloud core network and deliver 5G networks, according to the center.

B. Kenya

Safaricom, Kenya's mobile network provider, has announced the deployment of a 5G network. According to the Global System for Mobile Communications (GSMA), a group that represents mobile network operators throughout the globe, this makes it the second nation in Africa to provide the technology to users. The business is now testing the technology in four cities, with plans to extend it to nine cities over the course of the next year.

Safaricom CEO Peter Ndegwa praised the company's inauguration last week as "a watershed moment in the country's history." The telecommunications business is executing the initiative with the help of technologies from the Finnish company Nokia and the Chinese firm Huawei.

By "commercial 5G network," the Global System for Mobile Communications (GSMA) refers to a network where customers may buy a 5G subscription. MTN and Vodacom were the first to provide 5G service in South Africa last year. Telecommunications firms in a number of additional African nations are undertaking 5G testing, but these trials are not yet generally accessible for public usage, and as a result, they are not included in the GSMA's total [17].

C. 5G Network: Healthcare and Education

Advanced diagnostic tools and smart health-care equipment allow for better patient care by delivering real-time vital signs, both of which are enabled by smart health-care. Smart health care aims to make patients' lives easier by providing them with knowledge about medical problems and how to solve them. Patients may take appropriate action in the event of a crisis with the help of smart health care [18]. Health care providers are able to expand their services outside geographical boundaries thanks to this service, which reduces the cost of treatment. As the number of smart cities grows, so does the need for a reliable smart health-care system that can meet the needs of its residents. An important contributor apart from health is the Things (IoT) industry, which is expected to be worth $158.1 billion by 2022 [19].

Asset management in hospitals, behavioral change monitoring, remote monitoring, treatment compliance monitoring, assisted living, smarter medication, and telemedicine may all benefit from IoT in smart-health care. It is expected that these applications will have a significant impact on health care in the near term. There are a slew of potential uses for mobile technology, e-health, and/or web services integration. In [20], a smart health application for assessing and inspecting diets is being developed. The author of [21] proposes a new approach to developing mobile health apps.

Smart antennas play a critical role in 5G network communication [22,23]. Smart Antennas make use of a wide range of cutting-edge technologies to expand 5G's reach and capacity. This includes beamforming (vertical and horizontal), in which RF energy may be targeted to specific locations instead of being dispersed across an area of a large region. As the higher frequency mmWave RF fades due to identification loss and distance from things striking (e.g., automobiles, buildings, etc.), beamforming is very useful for 5GNR. A higher chance of optimal transmission capacity and signal quality may be ensured with a better-coordinated RF beam. Beamforming sites of interest are diminished with attenuation;however, it is critical to remember that line of locate is still a concern.

Machine-to-machine connectivity and the Internet of Things (IoT) are projected to be the foundations of smart healthcare in 5G networks. If implemented, the proposed methods would confront two major hurdles.

To begin with, the sheer volume of terminals has resulted in very dense networks (e.g., 106 connections per square kilometer). Ultra-densification, scalability issues in IoT and M2M applications need solutions. IoT-based applications that rely on wireless sensor networks (e.g., the minimum necessary battery life is 10 years for specified conditions) use a lot of energy owing to their nature. It is projected that the research on the 5G network's deployment and commercialization would be finished by 2020. More data is predicted from 5G networks in addition to network densification and support for a large number of IoT devices. For IoT-based smart health-care applications, 5G networks are being designed to be flexible and versatile in order to support new applications that not only require high data rates but also other requirements, such as massive connectivity, dense deployment, reliability, low latency, high energy efficiency, and long-range communication.

D. Potential Limitations and Policy Considerations

➢ Technical Limitations

The deployment of 5G in Sub-Saharan Africa will be hampered by a variety of factors, including technical, economic, and regulatory constraints. The following are some of the challenges:

- Infrastructure
- Traffic Routing
- Protocol Convergence Integration Issues and Synchronization
- Spectrum Sharing, Resource Management, and Interference Mitigation
- Mobility Management and Handover
- Energy Needs of Satellite-Powered Machine to Machine (M2M) and Internet of Things (IoT)
- Signaling and Backhaul Constraints

➢ *Infrastructure*

Sub-Saharan Africa has some of the world's poorest fiber connectivity, which is a fundamental requirement for backhaul and fronthaul in 5G networks. Epileptic and severely inadequate power supply, as well as outdated road transport networks, are all significant impediments to the growth of mobile services to new areas of Sub-Saharan Africa, complicating operations and increasing costs with poor service quality. Furthermore, 5G necessitates the construction of ultra-dense base stations, which include both macro and tiny cells [24]. MNOs will also need to upgrade its baseband and remote terminals to multi-standard 5G. Cloud-based RAN, network virtualization, and software defined networks will all be key components of 5G architectures, allowing for coexistence with existing 2G, 3G, and 4G networks that would otherwise be difficult and expensive to manage and operate.

➢ *Traffic routing*

Here, the satellite payload system determines if the traffic routing will be simple and easy but extremely slower (transparent payload) or faster but complex (regenerative payload).

➢ *Protocol convergence integration issues and synchronization*

Protocol convergence, latency imbalance, the need for Software Defined Network and Network Virtualization features for satellites, Sa integrating multicast features across the two networks, and link aggregation schemes for small cell connectivity, among other things, make integrating satellite networks with legacy systems and 5G networks a major challenge. TCP's performance over satellite networks, for example, needs to be improved to avoid packet loss owing to delays and endless retransmissions or negative acknowledgments (NACK). Furthermore, due to propagation effects and satellite link delays that have not been fully explored, the 5G New Radio waveforms may encounter unanticipated distortion.

➢ *Spectrum Sharing, Resource Management and Interference Mitigation*

The pattern of spectrum resource distribution across terrestrial and satellite systems, and hence how resources are divided among users, is an essential problem that should be investigated. This will, of course, affect spectrum usage, efficiency, and interference.

➢ *Mobility management and Hand-over*

To provide ubiquitous coverage and connectivity, a hybrid system like 5G would undoubtedly necessitate vertical hand-overs and more complex mobility management methods across terrestrial and satellite networks [25].

➢ *Signaling and Backhaul Constraints*

Because careful provisioning with respect to use cases supported, signaling demands, and other factors is necessary, the necessity for experts to be involved in the backhaul for ultra-dense 5G small cells employing satellite could represent a substantial issue.

➢ *Energy needs of satellite powered Machine to Machine (M2M) and Internet of Things (IoT)*

Linking with satellites must not impose unrealistic energy requirements with millions of IoT and M2M devices in the 5G ecosystem.

- Regulatory, Policy and Economic Factors
- Spectrum
- Inflexible ICT regulations
- Low Average Revenues Per User

➢ *Spectrum*

One of the most significant obstacles for National Regulatory Authorities (NRAs) in successfully deploying 5G networks is this. Spectrum scarcity must be avoided at all costs, and technologies that promote efficient and effective spectrum sharing should be prioritized and implemented first. As a result, NRAs should use a technology-neutral licensing approach in their decision-making process.

➢ *Inflexible ICT Regulations*

Policies governing satellite terrestrial integration by NRAs in the region is not clear thereby causing difficulty in obtaining Right of Way (ROW) permits, permits for macro base stations/small cells, permits and licenses for ground stations, multiple taxation, environmental and EMF radiation permits, taxes for ICT equipment, stringent rules and very alarming fee rates are all very common in Sub-Saharan Africa creating an adverse effect QoS, coverage and cost of mobile services.

➢ *Low Average Revenues per User*

In Sub-Saharan Africa (SSA), the average revenue per user is extremely low. According to studies based on the GSMA 5G Market Readiness Index tool, 22 of the 37 countries in SSA spend more than 3% of their monthly income on mobile services, compared to less than 1% in developed countries' markets. The affordability of smart devices and high-speed services is a major challenge [26]. Low Digital Literacy, a lack of relevant local content, and other factors all make effective use of high-speed networks more difficult, even when they are available.

E. Dealing With 5g Network Issues In Africa

In order to address the majority of the challenges associated with 5G deployment, multi-stakeholder collaboration and innovation are critical. This will help to reduce the tensioning pressure in the technical, economic, and regulatory aspects, making satellite 5G networks commercially available to all in the Sub-Saharan Africa region. As a result of research and some proven experiments, some tried and trusted techniques for the industry to mitigate technical challenges are highlighted below. [26, 27, 28].

➢ *Industry Solution*

From an infrastructure standpoint, the use of renewable energy sources for the deployment of small cells relying on would result in a massive reduction in capital and money required to run this distribution, while HTS's and LEO constellations could help reduce costs per bit for satellite links [26, 28]. On many fronts, infrastructure sharing and spectrum sharing can drive innovation and save money, while techniques like Advanced Coding and Modulation (ACM), use of advanced codes, byte caching, use of advanced phased array antennas, predictive and in networking caching, satellite network virtualization, and others can make it easier to integrate satellite and terrestrial systems with higher capacity. Increased buffer size for Hybrid Automatic Repeat Request (HARQ) or increased number of HARQ processes can improve Satellite link TCP performance to a very high standard, but at the cost of increased complexity [29]. Network coding for multipath is an efficient strategy for harnessing multi-path diversity and protecting against packet losses. When crossing satellite links, especially GEO links, 5G NR waveforms can be rectified with non-linear compensation algorithms to eliminate any distortions that cause delays or other problems [30].

From an economic standpoint, the government should consider structuring and developing financing models to assist in bridging the significant costs required to deploy 5G and satellite infrastructure in the region, such as lease-to-own models, which provide vendors with the capacity to fund network construction and then enter into a revenue-share agreement with the operator until the equipment vendor recovers the investment cost, with ownership then transferring to the operator.

Finally, governments and other stakeholders should collaborate to launch customised digital skills training across the region to overcome the vast usage gap that limits effective use of high-speed networks even where coverage is available.

➢ *Key Policy Considerations for Satellite 5G*

In order to bring satellite 5G to completion, the regulatory priority should be on the following four important areas: network deployment, network flexibility, spectrum access, and regulatory costs.

F. Policy Considerations for Satellite 5G Deployment

➢ *Network Deployment and Flexibility*

Governments and NRAs, in particular, must create clear, flexible, and streamlined regulatory and administrative circumstances that make the deployment of such networks easier. For the development of the satellite 5G mobile ecosystem, the industry may need to establish new models for network management and network ownership, as well as examine market structures that will foster a pro-investment and pro-innovation environment.

➢ *Spectrum*

Develop unambiguous spectrum roadmaps for 5G that encompass both terrestrial and satellite spectrum for transparency and clarity. MNOs can also re-farm part of their existing spectrum to help with 5G adoption, and spectrum sharing, including with satellites where possible, could be beneficial. Harmonized spectrum distribution has a number of benefits, including reducing radio interference along borders, facilitating international roaming, and lowering equipment costs. Exclusive-licensed bands will have the greatest influence on ensuring QoS and SLAs, but spectrum sharing will also be critical to satisfy 5G's large-scale consumption scenarios. However, caution is required, particularly in bands where satellite-terrestrial sharing has been shown to be infeasible based on ITU research and Radio Regulations.

➢ *Regulatory Costs*

Regulators should work hard to reduce or eliminate tax burdens on fiber deployments (ROW), remove ICT sector specific taxes, address the issue of multiple taxation, encourage reasonable, fair, and non-discriminatory fees for small cell/base station deployments, and make ground station permits, environmental, and EMF radiation permits easier. To cover the high expenses of deploying 5G and satellite infrastructure in the region, creative funding approaches are required. To promote viable models for large-scale network development, public-private partnerships are required.

V. CONCLUSION AND ROAD AHEAD

The importance of 5G in digital economies, improving economic growth, improving citizens' lives, and creating new business prospects cannot be overstated, as most sectors directly tied to its operation will see rapid exponential growth. Although it is on the verge of taking over the global area, it is expected to take only a few more years, perhaps 2023-2025, for it to become extremely prominent in Sub-Saharan Africa.

As governments and businesses take advantage of the Industrial Revolution, excellent connection will always be at the heart and essential to a world of new, sophisticated, and smarter ecosystems, addressing the majority of the largest concerns confronting individuals and businesses. 5G will be a critical enabler, enabling new and existing technologies like AI and IoT to change industrial processes, resulting in huge societal and economic advantages.

Governments must take a critical step in the implementation of 5G by beginning to develop clear roadmaps and modern, investment and innovation-friendly legislative and policy frameworks that will aid the 5G mobile ecosystem, with satellites playing a major role for the area. Importantly, affordable access for all should not be overlooked as a key consideration, as this will help bridge the digital divide by allowing everyone to benefit rather than only serving developed, urban markets, which would be a barrier for why the developmental goal of launching 5G was set in place. The project aims to carry everyone along benefiting from these high-speed networks, which necessitates multi-stakeholder collaboration by all relevant parties such as satellite operators, regulators and policymakers, service organizations, vendors, and industry associations such as the GSMA, among others. To ensure that the benefits of 4G and 5G are actually realized, all government programs must include digital skills training as a basic component.

Also, governments in Sub Saharan Africa must apply caution in establishing the commercial case and determining priority use cases worthy of investment that can bring in the tremendous impact to a region struggling to close the gap between demand and supply of 4G mobile services. It would be helpful and quite thoughtful to prioritize expansion of existing 4G networks in the immediate short-term, as this can in turn become a major backbone to a more cost-effective Non-Stand-Alone deployment of 5G. Spectrum bands below 1GHz will be critical to reaching rural areas; while Ka bands will help both high capacity mobile and HTS satellite systems as well. Any 5G investment decision must be backed by a sound investment case, and deliberate policies to achieve set targets in line with National Broadband Plans and E-Government Policies.

Early deployments of 5G in Sub Saharan Africa could focus on Fixed Wireless Access (FWA) and enhanced Mobile Broadband (eMBB), as this as the most immediate impact in boosting broadband and opening up realistic use cases in the region. Key areas are Digital Government, Education, Healthcare, Agriculture, Smart Cities and Industrial IoT. One of the most important uses of the 5G era will be the productivity and efficiency gains by enterprises from Satellite 5G enabled services and applications, having a lot of positive impact on economic and environmental sustainability. For example, 5G-enabled sensors in factories, cities, farms and homes will provide the foundational elements to innovate, improve productivity and manage resources efficiently. This will be of extreme use in Sub-Saharan Africa where there is a very high need to increase efforts to achieve key SDG targets related to sustainability.

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