African Multidisciplinary Journal of Development (AMJD)

International Research and Development Conference (IRDeC) Special Issue

Pages: 90-100

A REVIEW OF FACTORS AFFECTING MOBILE NETWORKS DEPLOYMENT

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ABSTRACT

Mobile networks have revolutionized communication, enabling individuals and businesses to connect and access information more efficiently. However, the deployment and management of these networks are influenced by a range of factors. Its deployment is challenged due to emerging technologies, security and privacy concerns and other related factors such as poor infrastructure, spectrum availability, power supply, and business factors such as competition, limited access to resources, and regulatory barriers and taxation Investigating these challenges will provide insights into how to address them and improve network quality and coverage. Understanding these factors will also allow identifying strategies to enhance the quality of services provided, provide valuable information for anticipating and preparing for future technology adoption. Hence improve network coverage, reliability, speed, spectrum management. The review will evaluate the effect of Network Infrastructure sharing, effect of backhaul technologies andemerging technologies, effects of security and privacy and effects of spectrum allocation and utilization on mobile network deployment. Literature research has shown that several authors adopted a mixed- methods approach, primarily quantitative, supplemented by qualitative data methods. This approach provided a comprehensive understanding of the technical factors affecting mobile network deployment. Inconclusion there will be a need to design a mobile network framework that will provide solution to the factors affecting mobile networks deployment.

Keywords: **Backhaul, Technologies, Mobile network and Spectrum.**

1.0 Introduction

The topologies of wireless mobile networks are constantly evolving and are mostly made up of wireless links with limited bandwidth. It has wireless transmitters and receivers, and occasionally a platform like

ISSN: 2518-2951 https://doi.org/10.59568/AMJD-2023-12-3-07 African Multidisciplinary Journal of Development (AMJD)

a router. Smart phones and personal digital assistants are examples of mobile gadgets that have advanced in terms of usability, performance, and computational capacity. These gadgets have location technologies and wireless communication capabilities more and more. Operating and managing of mobile networks presents numerous difficulties for mobileoperators in Africa. Regulatory penalties for poor service availability and a decline in QoS have been applied frequently in recent years. This has been attributed by faults in the power supply to the site equipment are to blame for the majority of network outage incidents. Most sites in Africa use diesel generators as a backup power supply, which necessitates frequent maintenance visits.

Poor road systems andchallenging physical geography makes access to the site very difficult to extend the grid infrastructure to the most challenging site locations (Tower Power Africa, 2014) thisresults in too extremely high grid connectionprices. According to Komu (2019), the deployment and management of mobile networks require substantial investments in infrastructure, technology, and human resources. Achieving financial viability and profitability is a critical business factor for operators to sustain network expansion, improve service quality, and meet customer demands.

The regulatory framework governing the telecommunications sectors has a direct impact on the deployment and management of mobile networks. Licensing, spectrum management, taxation, and regulatory compliance significantly influence the business strategies and operational aspects of network operators (Uganda Communications Commission, 2020).Uganda's mobile and wireless market is highly competitive, with multiple operators vying for market share. Intense competition can drive innovation, affordability, and improved services.However, it also poses challenges in terms of pricing pressure, customer retention, and network quality (Komu, 2019).

2.0 Related Literature Review

2.1 Mobile Network Deployment status in thecountry

According to study conducted on network deployment in the country, Uganda's networkinfrastructure poses significant challenges due togeographical factors, including rugged terrains, remote rural areas, and inadequate power supply. These factors make it difficult to establish a robust network infrastructure and extend coverage to underserved regions (Komu, 2019).

The American Tower Company operates 3,517 mobile towers across the nation, according to the 2020 Tower change report. With an industry-low average tenancy ratio of just 1.14 BTS per tower, these cater to about 4,000 Base Transceiver Stations (BTS). Only 1,600 of the current BTS are 3G capable, and at least 3,500 more towers are needed to support full connectivity. According to the report, the increase in the

ISSN: 2518-2951 https://doi.org/10.59568/AMJD-2023-12-3-07 African Multidisciplinary Journal of Development (AMJD)

number of handheld computing devices, such smartphones, in use has led to the growth of the data infrastructure and advancements in mobile infrastructure. Additionally, it demonstrated that mobile devices which accounted for 99.86% of subscriptions in June 2020 as opposed to just 27,351 in June 2020 remain the predominant method of internet access. Numerous rural areas in Uganda continue to have spotty coverage, and telecommunications companies do not view these areas as having a profitable business rationale. Due to the recent rise in teledensity in urban regions which is powered by mobile technology the digital divide between rural and urban areas has widened. By linking remote locations to the broadband core networks, it is necessary to provide rural residents with mobile phone service and wireless broadband access. (Report on Telcom-ICT, 2017).

2.2 Mobile deployment Issues

When it comes to data infrastructure, the private sector is over-relied upon. The effective installation of fiber optic infrastructure in the nation is hampered by a lack of funding to bridge the gap between private investment and telecommunication needs. Furthermore, the absence of fiber optic-specific regulations, unlike in industrialized nations, may encourage unfair competition.

One of the biggest obstacles to sustainable development on the continent is generally acknowledged to be the absence of shared infrastructure found in the majority of South Sahara Africa (Commonwealth Business Council, 2013). As a result, ICT operators need to invest heavily in their owninfrastructure even where there was availability of resources from other operators this has increase the rate of digital gaps between ruraland urban areas. The availability and quality of physical infrastructure, including power supply, fiber optic networks, and transmission towers, are crucial for the deployment and management of networks. Insufficient infrastructure can hinder network expansion, impact service reliability, and increase operational costs (WorldBank, 2018).

According to Kurtis and Eric A Brewer (2013), Traditional network operators find it economically undesirable to build mobile infrastructure in rural and underdeveloped areas because of the low number of users that would be serviced, making it difficult to recover the expensive infrastructure costs (for access and backhaul) and ongoing operating expenses. Using licensed spectrum for deployment could be too costly for non-traditional operators. As previous research has shown, the cost of powering base stations is another problem in underdeveloped countries.

According to Benjamin and Adebayo (2017) fiber optic deployment are faced by a number of technical and management challenges in

developing countries for example in Ghana, theirstudy revealed that the deployment of it in Ghana came

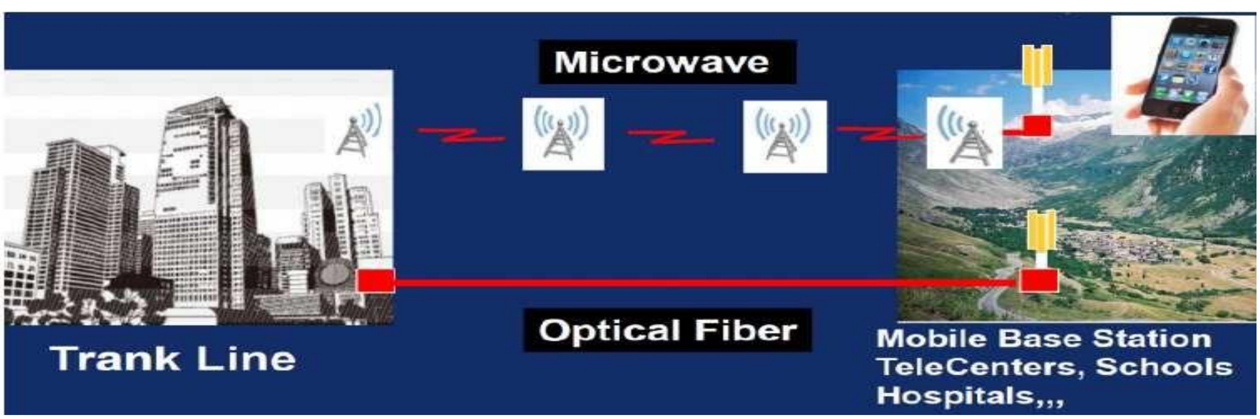
ISSN: 2518-2951 https://doi.org/10.59568/AMJD-2023-12-3-07 African Multidisciplinary Journal of Development (AMJD)

with many technical challenges. During fiber optic deployment, Subterranean fiber optic cable is typically installed beside city roads and highways in areas where buildings are constructed without permission, making it challenging to plan fiber routes and follow them. It gets harder to design and install fiber as intended. (Farmer J, Lane B, Bourg K, Wang W., 2017).

According to the study reports, one of the challenges faced by investors during the deployment of satellite infrastructure is the insufficient financial investment in Very Small Aparture Terminal (VSAT) connectivity. The industry's lack of technical expertise and this have both hindered the expansion of the satellite communication sector. Many consumers are unable to access the internet because multiple operators have duplicated their optical fiber routes, raising both the cost of infrastructure maintenance and internet rates. To stop infrastructure duplication, the government should put its policy on infrastructure sharing among operators into practice. The government should also undertake the NBI optic fiber expansion. Data infrastructure will become more affordable and accessible as a result.

2.3 Backhaul & Emerging Technologies

A variety of backhaul options are available to mobile operators; these should be chosen based on various factors, such as cost-effectiveness for a given deployment scenario. Backhaul traffic is largely handled by microwave technology, but mobile providers are increasingly adopting fiber-optic, especially in city centers. Copper line is still a possibility, mostly as a bonded Digital Subscriber Line (DSL) solution. A limited portion of backhaul links for the network periphery, where pre-existing infrastructure is present, use satellite backhaul is not accessible, or for recent installations in which the operator has not been successful in acquiring long-term Point-to-Point (PTP) or PMP electromagnetic link permits.



Source: Report on Telcom-ICT, (2017)

The most popular backhaul networks are optical fiber ones because of their enormous bandwidth, better bit error rate performance, and higher data rates, capacity, and coverage. Additionally, it enables the

ISSN: 2518-2951 https://doi.org/10.59568/AMJD-2023-12-3-07 African Multidisciplinary Journal of Development (AMJD)

furthest reach before a resend signal is required. The deployment of fiber connections is time-consuming, and it is not feasible to install fibers beneath buildings, at highways, mountains, or rivers. Another element that negatively impacts its applications is the initial deployment cost, which includes trenching, splicing, and cable costs. An further determining factor is the cost of optical fiber aggregation and transit.

Copper-based backhaul. Copper-based backhaul was the main backhaul technology used with 2G and even some 3G networks. Copper-based backhaul has become an uncommon choice due to the volume of traffic generated by LTE customers. One additional difficulty associated with copper-based backhaul solutions is the inverse relationship between available DSL bandwidth and distance. Specifically, the longer a DSL connection is between a cell site and an aggregation point or digital subscriber line access multiplexer, the lower the bandwidth of the connection is likely to be.

Wireless backhaul. According to the majority of studies, wireless backhaul is extensively utilized globally since it is practical and affordable. Similar to optical fibers, their deployment is determined by a number of factors, including site locations, cost factor, traffic volume, propagation conditions, and interference levels. As a wireless backhaul medium, microwave and millimeter wave give the operator end-to-end network control. These comprise TVWS backhaul networks for rural areas, satellite, microwave, millimeter, and free space optics (FSO) backhaul networks.

The GSMA (2018) states that mobile carriers face difficulties while trying to backhaul voice and data traffic from a range of locations, including offices, private dwellings, skyscrapers, public buildings, tunnels, and urban and suburban areas.

It's emerging more and more obvious that heterogeneous networks (HetNets) have mega and small cells that can rely on 3G, 4G, and 5G. The 60 GHz V-band and the 70/80 GHz E-band microwave and millimeter bands are ideal for HetNet backhaul because they enable traffic aggregation from multiple base stations for outdoor cell sites and access networks. This traffic can then be routed to mobile switching centers and ultimately the core network.

Most backhaul networks constructed nowadays use microwave lines, which are frequently owned by operators, and fibre/copper based links (often leased) with different proportions per operator and country (J. Allen and F. Chevalier, 2014).

2.4 Mobile Network Security and Privacy According to Akin, Reilly & Associates (2002),security on the mobile networks is now at theforefront of computer system associated questions.The Internet's development and networking's progress have made network dangers more prevalent. Many of these

ISSN: 2518-2951 https://doi.org/10.59568/AMJD-2023-12-3-07 African Multidisciplinary Journal of Development (AMJD)

dangers have evolved into deftly executed attacks that steal or cause harm. Mechanisms for detection, prevention, and response in real-world security are veryvital to secure mobile network (Salah A., 2009). According to Jo S.,(2005), In order to ensure that the network is appropriately equipped, the first approach of cell phone network protection involves addressing the physical layer of the network and adhere to mobilenetwork administrative guidelines.

According to the GSMA (2022) report, the physical infrastructure which consists of core network assets, backhaul network transfer, and cell sites is where mobile network security starts. One essential network function that needs to be secured is the list of authorized users. This is because it is a single point of vulnerability that can be attacked maliciously or malfunction. Mobile network operators and equipment vendors are coming up with new ways to strengthen these, even if they have been largely successful thus far.

The report advised the mobile network industry to collaborate and coordinate with global law enforcement organizations and national security authorities in order to respond to harmful assaults on mobile devices and networks and to identify the offenders. This can be done by making use of security incident response groups that are currently in place and, if needed, creating new ones to cover any gaps. As per the report, mobile phone network operators must ensure the privacy, security, and accessibility of communications across the network by safeguarding critical resources (equipment, software, and data) and preventing unauthorized access or intrusion to any component nodes or links. It is critical to protect the integrity of mobile devices since, from the user's point of view, the end-user mobile device is the main point of entry into the network. A wide range of users must be able to access mobile networks using a variety of devices and networking protocols. To provide the anytime, anywhere functionality of contemporary networks. they must also interact with a multitude of other communications networks worldwide (fixed, mobile, ISP, and enterprise). Hence, safeguarding devices and networks is highly complex in practice (GSMA report, 2022).
The report also pointed out that, when compared to legacy generations, improving subscriber identity protection and introducing new authentication capabilities are having a major positive impact on security. But for a while, it's likely that 5G capabilities will coexist alongside earlier iterations of mobile infrastructure; in that scenario, it will be necessary to safeguard both the new and old infrastructure (GSMA study, 2022).

A defense-in-depth security principle employs layered security tactics as countermeasures to safeguard a network infrastructure, according to Jander et al. (2018). A network's security can be increased by using

ISSN: 2518-2951 https://doi.org/10.59568/AMJD-2023-12-3-07 African Multidisciplinary Journal of Development (AMJD)

a multi-layered strategy with intentional redundancy, which will handle the several attack routes that hackers may employ. Additionally, reducing the likelihood that a network attack would be successful could be achieved by implementing a multi-layered security solution. The GSMA's Fraud and Security Group has worked hard to deliver system operatives with guidance on mitigating the security concerns related to signaling. Numerous known threats have been lessened by the security improvements developed in 4G and 5G. Exploits of 4G network weaknesses can be minimized by ensuring that the security features included in the standards are deployed and configured correctly. But since 4G and 3G/2G are backwards compatible, they won't disappear until backwards compatibility or old technology becomes obsolete (GSMA report, 2022).

According to the report, 5G technology has more security features than older 4G/3G/2G networks, which can counter many of the threats. These controls include additional security safeguards, improved subscriber identity protection and additional mutual authentication features. To protect the larger communications ecosystem, network owners and users must implement the necessary security measures, such as virtual private networks, or VPNs.

The GSM Association (2021) suggests the Mobile Networking Privacy and Security Architecture to protect users, guarantee the secure use of mobile services, and secure the processing and storage of personal data. Along with ensuring the accuracy and safety of the infrastructure for mobile phones and the gadgets used to access those networks, it also describes the role and obligations of mobile operators in supporting government agencies in their efforts to protect the public.

2.5 Spectrum allocation and utilization

The allocation and availability of spectrum influences mobile network performance. Dan, Micheal, and Basit (2013) state that spectrum is a scarce resource and that in order to maximize the value of existing spectrum and maximize network performance, advancements in network technologies and design are encouraged. Pricing services, configuring devices, managing the network, and even educating customers are some ways to reduce the demand for spectrum.

The study also recommended that mobile network operators consider sharing newly acquired or refarmed spectrum1 effectively as they rethink methods for sharing spectrum with other operators, as this can be done similarly to tower sharing to provide customers with better services. This is another strategy for reducing congestion on mobile networks and improving quality of service.

A 2020 GSMA research states that increased spectrum allocation enables network operators to host more traffic and capacity with their existing infrastructure, deploy as many sites as necessary to achieve a certain level of coverage, and save deployment costs. Spectrum over 1 GHz is typically utilized to obtain

ISSN: 2518-2951 https://doi.org/10.59568/AMJD-2023-12-3-07 African Multidisciplinary Journal of Development (AMJD)

more data traffic capacity and faster speeds, consequently greater quality of service (QoS), whereas spectrum below 1 GHz is typically preferable for expanding coverage in areas with low population density. A mobile network's capacity and bandwidth are determined by the spectrum it has been allotted. More spectrums enable higher data rates and allows for accommodating more simultaneous users and devices (GSMA report, 2020).

According to NTIA (2020), it is very difficult to provide coverage in rural or remote areas due to the sparse population and difficult terrain, and expanding network coverage to such areas often requires additional infrastructure investment and deployment strategies. Densely populated areas, like urban areas, require more spectrums to serve a higher number of users and their data demands; hence, heavy cell deployments are needed to ensure coverage and capacity.

A 2019 study by the Third Generation Partnership Project found that appropriate allocation and efficient spectrum use result in Quality of Service (QoS). Operators are able to prioritize and maintain QoS factors including packet loss, jitter, and latency when they effectively utilize network resources. For applications like online gaming, real-time chat, and video streaming, efficient resource management guarantees seamless user experiences. Additionally, this affects network load balancing. In order to guarantee the best possible use of network capacity, intelligent load balancing techniques assist in distributing network traffic among the resources that are available. Algorithms for load balancing dynamically control traffic, reducing congestion and enhancing network efficiency.

3.0 Methodology

Most studies used descriptive research designand cross-sectional survey desig**n to gather quantitative data.** They used a hybrid research methodology, with the qualitative information methods serving as a supplement to the main quantitative data methods. This method gave rise to a thorough comprehension of the technological aspects influencing the installation of mobile networks, while the qualitative approach provided insights into the experiences and perspectives of key stakeholders involved in network optimization.

The studies consisted of three main phases that is; data collection, data analysis, and framework design. Using a qualitative research approach, major players in the telecom sector, such as mobile network operators, government agencies, and industry experts, were interviewed and held focus groups.

4.0 Recommendations

- Policy makers need should positively implement some infrastructure sharing frameworks already

ISSN: 2518-2951 https://doi.org/10.59568/AMJD-2023-12-3-07 African Multidisciplinary Journal of Development (AMJD)

on to a paper work in order to easy new networks technology deployment in the country. This will helpto create an enabling environment that fosters competition, innovation, andinvestment in the telecommunicationssector, ultimately benefiting consumers andthe overall economy at large.

- As new advance network technologies gets adopted, the stakeholders especially at core network and regulatory bodies should take serious consideration of such factors that affects mobile network deployment to anticipate and make proper planning and preparation for future technology adoption and expected network infrastructure to support these advancements effectively
- Mobile networks play a vital part in closing the digital gap by facilitating access to services, communication, and information. The governments should takeserious considerations of such factors that affect deployment mobile deployment to make wide network connectivity and reduce the size of digital divide among rural and urban areas.

5.0 Conclusion

These papers provide an overview of factors affecting mobile network deployment. It is economically unattractive for traditional network operatives to install mobile organization in rural and developing areas. Conferring to the majority of research, mobile operators face difficulties while trying to backhaul mobile voice and data traffic from a variety of settings, including offices, private houses, skyscrapers, public buildings, rural and suburban areas, and tunnels.

As per an investigation, operators of mobile networks must ensure the privacy, reliability, and accessibility of communications across the network by safeguarding essential resources (hardware, programs, and data) and preventing unlawful access or infiltration to any of the element nodes or links.

The majority of research has demonstrated that appropriate allocation and efficient spectrum use result in Quality of Service (QoS). Additionally, studies have demonstrated that a variety of technical and difficulties with management in developing nations.

Due to these deployment variables, a suitable mobile network framework design is required.

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