The costs of failing to allocate high demand spectrum on the broadband data market in South Africa

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DECLARATION

I, the undersigned, hereby declare that the work contained in this dissertation is my original work and that I have not previously submitted it to another university in its entirety or part.

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Abstract

Expanding universal access to broadband is the goal of telecommunications ministries and regulators worldwide. The developing world has lagged developed nations in meeting these goals, especially owing to delays in allocating high-demand spectrum. South Africa is one such nation that has been impaired by protracted delays in allocating high-demand spectrum in International Mobile Telecommunications (IMT) bands 700, 800, 2300 and 3500. The study measured the impact that these delays had on the quality of service, competition, price and penetration. A comparative study was conducted among South Africa, Egypt, Nigeria and Germany. Some of the limitations of the study include:

- The lack of consistent data across the countries to make an effective comparison
- Although inferences could be made based on the data, the awarding of spectrum to countries at different times made it challenging to make a like for like comparison

It was found that the delay in allocating high-demand spectrum likely has affected the quality of service because download speeds are lagging the goal articulated in SA Connect. However, linked to this is the importance of operators' capital investments to improve the quality of services and broadband penetration, which spectrum assignment alone cannot achieve. Furthermore, critical to the success of these investments is a deliberate effort by telecommunications authorities, in policy and regulation, to encourage competition by incentivising operators to innovate, thus providing better quality services at the right price.

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CHAPTER 1: INTRODUCTION

Background and overview

We are living in the era of digital transformation and economies across the globe have recognised the importance of ensuring they are equipped to accelerate economic growth. Access to high-quality broadband has been identified as an enabler of economic growth in this increasingly digitised world where communication and access to information are paramount to thriving businesses and a knowledgeable population. According to the International Telecommunication Union (ITU), universal access refers to the availability of communication network facilities and services to everyone. Effective spectrum policy is of supreme importance in promoting universal access. In Africa, mobile technology is the primary means by which consumers access the Internet[1]. As an extension of the National Development Plan, South Africa's Broadband Policy, known as SA Connect, was approved in 2013 as part of the vision to create a seamless information structure by 2030. The policy is geared towards improved broadband access, which has become increasingly important to participate economically. Several goals were geared towards the goal of a '*seamless information infrastructure by 2030 that will underpin a dynamic and connected vibrant information society and a knowledge economy that is more inclusive, equitable and prosperous'*. One of its core goals was to create a universally accessible communication system that enables all the country's citizens, businesses and the public sector to be connected to the rest of the world at a cost and quality that allows them, irrespective of where they are in the country, to stimulate economic participation and consequently economic growth.

Several factors influence the success of increasing broadband access. The availability of infrastructure is a key component to ensure that service providers can meet the growing needs of consumers, be they businesses, public institutions or the public. Radio spectrum, although invisible, is a key infrastructure component in enabling broadband access. Radio spectrum enables the transmission of signals in radio and mobile communications. According to the Spectrum Handbook (2011), radio waves can pass through solid objects and travel long distances, which is

[1] In 2019 the ITU reported that they accounted for 98% of broadband connections

necessary in telecommunications and other wireless applications. In the State of Broadband Report of 2019[2], 5.3 billion consumers were reported to have mobile broadband subscriptions while 1.1 billion were reported to have fixed broadband subscriptions. With this high demand for broadband, it is no surprise that the demand for spectrum has increased. It is a finite resource and each country has its own regulatory body which governs the use of spectrum. In South Africa, it is the Independent Communications Authority of South Africa (ICASA). Established in July 2000 it was a merger between the South African Telecommunications Regulatory Authority (SATRA) and the Independent Broadcasting Authority (IBA) after the Independent Communication Authority Act of South Africa Amendment Act (Act no 13 of 2000) was passed.

The ITU, a specialised United Nations agency for information and communications technologies was founded in 1865 to manage international connectivity, allocate global radio spectrum, develop standards and improve access to underserviced communities across the globe[3]. The ITU divides the world into three regions and the countries within each region align their spectrum allocation in a way that the same frequencies are allocated for the same type of use. Different spectrum bands are allocated for specific use such as maritime, broadcasting and voice calls, etcetera and in each of these regions, the spectrum bands are reserved for particular use meaning, if a frequency band is allocated for broadcasting for example, it cannot suddenly be used for broadband. South Africa is part of ITU region 1 along with the rest of Africa, Europe, the Commonwealth of Independent states, Mongolia and the Middle East and must follow the regulations stipulated therein to make it easier for new technologies to be introduced.

[2] The annual report of the ITU and the UNESCO Broadband Commission for Sustainable Development across the globe
[3] The ITU ‘about’ page

Problem statement

South Africa Connect (SA Connect) highlighted that the challenges in the South African context have always been a lack of high-speed and -quality bandwidth[4]. Table 1 below is a snapshot of the goals extracted from SA Connect:

Table 1: National Broadband Policy Targets

Target	Penetration Measure	Baseline (2013)	By 2016	By 2020	By 2030
Broadband access in Mbps user experience	% of population	33.7% internet access	50% at 5 Mbps	90% at 5Mbps 50% at 100Mbps	100% at 10 Mbps 80% at 100 Mbps
Schools	% schools	25% connected	50% at 10 Mbps	100% at 10Mbps 80% at 100 Mbps	100% at 1Gbps
Health facilities	% of health facilities	13% connected	50% at 10Mbps	100% at 10Mbps 80% at 100Mbps	100% at 1Gbps
Government facilities	% of Government offices		50% at 5Mbps	100% at 10Mbps	100% at 100Mbps

Source: ICASA notice regarding the final IMT roadmap 2019

The targets reflected in Table 1 are central to assessing the goal of expanding universal access. This paper aims to investigate what role the delay in allocating and releasing spectrum has contributed to falling short of these goals. Although the penetration rate of mobile broadband has increased over the last couple of years, studies have revealed that the high cost of communication has inhibited South Africa and its citizens from reaching their full potential when it comes to broadband access. One of the significant contributors to this is the lack of allocation of spectrum, which would enable Mobile Network Operators (MNOs) to enhance universal access and thus

[4] SA Connect, Government Gazette,6 December 2013. Department of Communications

widen the economic growth bottleneck[5]. To illustrate this, there was a delay in the allocation of spectrum in the 700MHz band to mobile services in the ITU's region 1 at the World Radio Conference 2012 because it needed to be migrated from analogue to digital tv for mobile operators (Kedama, 2014: 12). High-demand spectrum is required to increase universal access to broadband and the key issue in South Africa is the delay in the allocation of this spectrum. This spectrum is required to build the next generation mobile network to align with network equipment and end-user devices built on a global scale (Marks, Lewin, Wongsaroj & Chan 2011: 3). Spectrum was last released in 2004/2005, which Mobile Network Operator (MNOs) claim has impaired their ability to meet the growing demand for broadband services. ICASA commenced with the licensing IMT spectrum bands IMT700, IMT800, IMT2600 and IMT3500 in 2005[6]. It was finally awarded in 2022. This was an inordinately long journey.

The demand for spectrum has increased with more businesses and households requiring access to mobile telephone and broadband services. High-demand spectrum is a finite resource, and the allocation thereof is of crucial importance in growing the Information and Communications Technology (ICT) industry and providing users with quality access. The key research problem of the study is to determine how the failure to allocate high-demand spectrum has impacted universal access to broadband in South Africa. While studies have sought to understand the various methods of allocating spectrum and which are the most effective, insufficient studies have looked at the impact of the delay in allocating high-demand spectrum in a world where broadband access has become increasingly critical to the development of economic growth. This paper seeks to contribute to the literature by studying the impact of these delays compared to the goal of increasing universal access within South Africa. The central hypothesis is that the failure to timeously allocate high-demand spectrum has resulted in access to broadband being compromised in terms of price, quality and speed.

[5] Problem statement as documented in the Policy Brief on Spectrum Regulation prepared for the Presidential Economic Advisory Council (PEAC)

[6] ITA for the radio frequency spectrum licences for IMT spectrum, pg 14

CHAPTER 2: LITERATURE REVIEW

Universal access to broadband is one of the goals of numerous governments internationally because it is a catalyst for economic growth. A study by the ITU (April 2012) highlights that broadband technology contributes to economic growth at several levels. These include improved productivity through more efficient processes, innovations which introduce new consumer applications and services, as well as maximising the reach to workforces, raw materials and consumers. Countries worldwide have adopted various policies and interventions aimed at enhancing universal access to broadband and bridging the digital divide. Gelvanovska, Rogy and Rossotto (2014: 4) contend that broadband policy has three core objectives; access, adoption and competition and that objectives differ according to their respective national developmental phase. This can either be emerging, developing or mature, and countries need to employ policies and measures accordingly. Those in the emerging phase are usually characterised by weak competition with one or a few big players dominating the market as a result of low infrastructure development and broadband access which results in poor quality Internet services with high prices.

Governments, regulators and policymakers can intervene with various interventions to increase broadband access. These can be on both the supply and demand sides depending on how well developed their ICT sector is. With access to broadband, governments and institutions can promote social inclusion to all the citizens of a country, enabling them to use it for the advancement of their respective economic goals. In a comparative study undertaken by Zaballos and Foditsch (2014), the benefits to a country's level of social inclusion include education, health, participation in policy making, increased consumption of products and services, connecting family and friends as well as increased innovation. The speed, quality and price of broadband are important considerations. These have become clear over the past few years as the price of data has remained high and access has been skewed to urban areas. This has been dubbed the digital divide. In this paper, there is a greater focus on supply-side interventions in the form of spectrum allocation to increase broadband access.

To better understand the role that spectrum plays in broadband access, examining the technical aspects of both spectrum and broadband may be useful. Since spectrum is a finite resource, regulators need to ensure it is well allocated and used. To meet the goal of expanding broadband access and bridging the digital divide[7], the licensing framework is a vital consideration in ensuring this finite resource is allocated efficiently. Different spectrum bands are available and they range from sub-1GHz to high bands. The sub-1GHz bands (e.g., 700MHz & 800MHz) are more effective at wider coverage while higher bands like 2600MHz are more effective in densely-populated urban areas with their propagation characteristics. The two usage techniques of spectrum in mobile networks are Frequency-division duplexing (FDD) and Time-division duplexing (TDD). FDD allows for the transmission of uplink and downlink at the same time over different frequency bands while TDD allows for the uplink and downlink over different time slots covering the entire frequency spectrum (Wymeersch and Eryilmaz, 2016: 2).

To put it more simply, consumers use broadband to upload messages to the mobile radio network and to download from the mobile radio network. With FDD, uplink messages and downlink messages are sent over varying bands to avoid interference with communication and this has been the most commonly used duplexing technique in mobile communications for 2G, 3G and 4G networks. With TDD, there is only one frequency band where the communication is sent for uplink and download but these occur at different times. With increasing demand for broadband, these technical differences cannot be ignored in the allocation of spectrum owing to their characteristics[8]. When it comes to frequency bands, the ITU gives a framework of what each spectrum range needs to be used for in each region.

There are two types of technologies within broadband; fixed broadband technologies and mobile broadband technologies. Fixed requires the same physical location, while mobile can be accessed on the move. A report conducted in 2011 for the GSMA highlights that investment in fixed networks has historically been low in Sub-Saharan Africa and, as a result, the opportunity to upgrade fixed networks cost effectively would not make sense[9]. At the time of the report, mobile networks had already reached 90% of the population, indicating that mobile broadband use was simpler to upgrade to increase broadband access and use.

[7] Spectrum licencing for Mobile/Broadband systems, March 2021

[8] FDD is considered less efficient from a spectrum use perspective due to the separate bands used for uplink and downlink, but has the benefit of requiring fewer base stations because of wider coverage, Adnan Ghayas (November 2021)

[9] A report compiled for the GSMA on the benefits of releasing spectrum for mobile broadband in Sub-Saharan Africa by Plum Consulting, December 2011

2.1 Spectrum management

From an international perspective, the ITU is responsible for the rational, equitable, efficient and economic use of the radio frequency spectrum while from a national perspective, spectrum management is either controlled by a government through a ministry of communications or an independent regulator. Spectrum licences are usually awarded for a period of 15 to 20 years and confer certain rights on the licensee for the duration (Bakker, 2016). With a longer licence duration, greater certainty is provided to MNOs and encourages them to make long-term investments when rolling out networks and providing new services.

The way spectrum is licensed and awarded is important. The several ways in which it can be awarded come with its pros and cons. In the 1990s, the administrative process and lottery were the most commonly-used methods when countries decided who was awarded spectrum. They were in the form of a "beauty contest" where criteria were imposed and the most suitable recipient was awarded the spectrum. The most common criticism of this method was its transparency. The United States moved away from administrative processes as they were found to be too time-consuming, resulting in a cost to applicants, government and ultimately the public. Lotteries were used where licences were allocated at random to ensure that licences were issued faster. This came at a cost because a large number of applicants applied, including those who lacked the technical expertise, with a high risk of awarding the licences to those who would not make the most efficient use of them (Mc Millian, 1995) In 1990 New Zealand was the first country to make use of auctions to allocate spectrum while EU countries and Canada began reviewing these administrative processes in 1994 and considered the use of auctions. Allocation by means of an auction tends to be favoured by economists as it is deemed to result in allocating spectrum to those who value it more if the allocation process is designed well. McMillian argues that allocation by means of an auction is the most effective method since it also addresses the transparency issue found with other methods such as the administrative method. With an auction, the procedures must be explicitly stated to ensure that all competitors stand a fair chance (Telecommunications Regulation handbook, 2011). However, there is a counter view that spectrum allocation by means of an auction may favour the incumbent who is possibly in a dominant position owing to economies of scale and the risk of preventing new entrants/competitors from entering (Lundborg, Reichl and Ruhle: 2012).

The World Economic Forum also reports that spectrum allocation by means of an auction does not always work as intended[10]. In some cases, the cost of acquiring the additional spectrum is too high owing to the scarcity of spectrum but also because governments can have a short-term goal of raising revenue for other uses. The impact on companies purchasing such expensive spectrum can result in a lack of financial resources to implement the infrastructure required to use additional spectrum. Spectrum can also be allocated in the form of a direct award where frequencies are allocated directly to operators by the regulator, but is often criticised for being inefficient and inflexible, particularly in cases where the regular is not in touch with market needs (Elixirr, 2015). The key thing to note here is that irrespective of the award design, regulators need to ensure that policy objectives, market structure and available spectrum are all taken into consideration (GSMA, 2020).

The allocation of spectrum is not the only key factor to increase broadband access. The efficient use thereof is crucial. Some nations are refarming unused spectrum to counter services providers who do not use all their spectrum. The literature reveals that governments can encourage the efficient use of this spectrum by having claw-back conditions for operators who do not use this spectrum. Some countries make use of spectrum-sharing models to increase efficiency. During Covid-19 and the resulting increased demand for Internet services, ICASA decided to award temporary radio frequency spectrum to operators in the 700MHz, 800MHz, 2300MHz, 2600MHz and 3500MHz bands to meet this demand. The additional allocations can be found in the appendices.

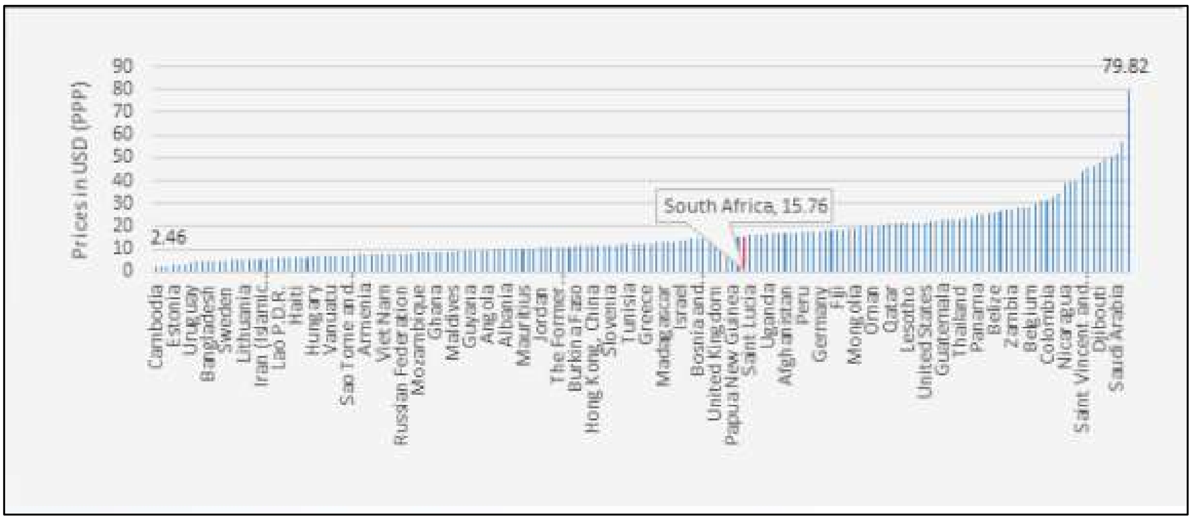
2.2 Cost drivers and data prices

The cost of accessing data is a key issue when attributing broadband access issues in bridging the digital divide. A key barrier highlighted in the (GSMA, 2020)[11] is affordability. The State of ICT in South Africa report (2018) revealed that most South Africans cannot go online owing to the

[10] World Economic Forum Delivering Digital Infrastructure, April 2014
[11] Mobile connectivity in Sub-Saharan Africa: 4G and 3G connections overtake 2G for the first time

high cost of data. In 2017, the South African Competition Commission instituted a data-services market inquiry in response to a public outcry on high data prices and how these were inhibiting their access to the Internet. As summarised in the final report, the inquiry set out to understand what was driving these high costs of data. To better understand these cost drivers, the Competition Commission made a formal call for submissions from major operators and consumer rights organisations. The inquiry found that South African data prices were indeed high when international benchmarking was conducted. Figure 1 below reflects how mobile data prices in South Africa ranked against several countries. 500MB of data cost US$15.76 which is significantly higher than the lowest of US$2.46 in Cambodia.

Figure 1: Mobile prepaid data prices in USD (PPP, 500MB (2017)



Source: Retrieved from the Data Market Service Inquiry Final report which was adapted from ITU 2018 Measuring the Information Society

At a granular level, a comparison between two major MNOs in South Africa, who have a presence in other African countries, also reveals that South Africa ranked high in 2019 compared to these regional counterparts. In 2019, Vodacom's price of 1GB of data in South Africa was US$7.83 which was the second highest compared to a basket of eight countries, with the DRC being the highest. MTN in South Africa ranked the highest at US$10.08 for 1 GB of data while costing only US$2.71 in Uganda. Both MNOs have argued that, among other things, this comparison does not consider the cost differences across countries of quality and spectrum allocations, which may account for the pricing differences. However, the inquiry does reveal that the operators have not satisfactorily shown that the cost and quality factors do indeed account for the price differentials.

Operators have cited that the delay of allocating high-demand spectrum has contributed significantly to the high cost of providing data services. The final findings of the data services market enquiry[12] that indeed the delay in allocating high-demand spectrum has left MNOs with insufficient low-frequency spectrum which has left them with little choice but to compensate for the shortage by increasing the volume of base stations, causing higher operational costs. The report, however, noted that the release of high-demand spectrum will not necessarily result in price decreases unless mobile operators are put under competitive pressure to do so. To successfully do so, the Commission further highlights that ICASA needs to be mindful of how the spectrum is assigned for the benefit to be realised in the form of lower prices. This is particularly important in ensuring that the spectrum is not allocated in such a way that the already-marginalised members of society fail to benefit from the cost savings associated with the awarding of spectrum.

The cost of obtaining spectrum is a key factor to consider when it comes to pricing. This refers to the price MNOs pay to acquire additional spectrum. Pricing of spectrum is set with the objective of allocating this scarce resource to those who will use it efficiently to meet the needs of the end consumer. Some economists have argued that the costs associated with acquiring additional access is a sunk cost and therefore should not be used by operators in pricing strategies. Economists who are oppose this view highlight that if these sunk costs were not taken into consideration when pricing, operators would not be able to see the return on investment of acquiring the additional spectrum (GSMA, 2019). The debate is two-sided in that there are substantial arguments for and against but insufficient studies have been conducted to establish a causal link between spectrum prices and the prices end consumers pay. There are up to three components when it comes to spectrum prices: Upfront reserve prices, competitive premium prices (if it's an auction) and annual fees, all of which toned to be considered for MNOs wishing to acquire additional spectrum to provide broadband access (GSMA 2017).

[12] Final report, Data Market Enquiry

The studies conducted have focused more on identifying correlation rather than a causal link, which would be able to separate the impact on the end consumer of spectrum prices from other factors. One such study was conducted by Cambini and Garelli (2017) who found that there was a positive correlation between spectrum prices and revenue but their chosen model could not establish a statistically significant result. In another study by Kuroda and Baquero (2017), it was found that high spectrum prices that were a result of auctions resulted in lower 3G take up. Song, Rey- Moreno and Jensen (2019) reveal that sometimes, auctions don't work as intended because they do not attract sufficient participants owing to high reserve prices. A study by the GSMA in 2019 reveals that there is some evidence to prove that in developing nations, the prices that consumers pay have been driven up by higher spectrum costs although they have stated that further research is required for this to be conclusive. By charging for spectrum, governments increase revenue and it has been found that the more ones in Africa tend to have higher spectrum prices. A plausible explanation is that through spectrum fees, governments aim to maximise revenues collected from spectrum[13]. Where high spectrum prices exist, recent research has revealed that there is a causal relationship between high spectrum prices and reduced coverage, and the quality of mobile services[14]. With higher spectrum prices, the average cost of mobile services increases, therefore reducing operators' returns, and reducing their incentive to expand and upgrade the networks needed to improve coverage and speed of broadband. An empirical study conducted by Nera Economic Consulting (2017) confirms academic literature where it was found that higher spectrum prices have resulted in lower investment in 4G and increased data prices for consumers.

2.3 Competition

The level of competition is an important element to explore because it pertains to spectrum and broadband access. Competition in the market is necessary for consumers to obtain quality products and services at reasonable prices. Perfect competition is ideal but rarely occurs in reality, which necessitates competition policy and regulation that address market failures such as natural monopoly and features of the market, which may reduce competition such as network effects.

[13] GSMA 2020, Effective pricing in Africa: How successful awards can help drive mobile connectivity
[14] The impact of spectrum prices on consumers, GSMA, 2019

While competition policy is concerned with tools to promote competition and ensure that the market is conducive for such competition to be sustained, regulation is necessary where the market itself results in undesirable outcomes or to drive the market towards desired outcomes (Telecommunications Regulation Handbook, 2011). There are two types of regulation, Ex Ante regulation which is involved with market structure, and Ex Post regulation which addresses anticompetitive behaviour or market abuse and is concerned with market conduct. As stated earlier, spectrum is a limited resource and the allocation and management thereof needs to be considered carefully by governments and regulators. Accordingly, spectrum management forms part of the ex-ante regulation of telecommunications markets and is instrumental in telecommunications policy and regulation (Telecommunications Regulation Handbook, 2011: 95).

It would be naïve to believe that markets with high entry barriers such as telecommunications can simply self-regulate. Therefore, it is important to have a competition policy aimed at encouraging and protecting entrants and ensuring that incumbents compete fairly in the market. This requires a regulatory authority that sets clear rules for fair competition and ensures that laws are adhered to in the use of spectrum. When governments and regulators allocate spectrum, it is important to consider how this affects competition in the mobile broadband market because this ultimately impacts the consumer. Factors to consider include market concentration, the method of spectrum allocation, and the price. Market share can tell us who the dominant companies are in the marketplace, but this may be insufficient in revealing if there is anticompetitive behaviour in the market. In telecommunications, there are barriers to entry such as infrastructure and network access. Spectrum is usually allocated to MNOs who then provide Mobile Virtual Network Operators (MVNOs), such as Rain in South Africa, with access to the provision of services to the end consumer. Therefore, important to consider, over and above market shares, if there is any anticompetitive behaviour exhibited by the incumbents. Although there are numerous participants in the South African mobile market, some of which are exclusively Internet Service Providers (ISPs), the Herfindahl-Hirschman Index of 3 495, which is higher than the rule-of-thumb yardstick of 2 500, illustrates high concentration (Gillwald, Mothobi and Rademan, 2018).

Assignment options, beauty contests and auctions pose possible competition problems because it is assumed that the operator with the most efficient use of spectrum is likely to be able to pay higher prices in the auction, thus favouring incumbents who are already in a dominant position (Lundborg, Reichl and Ruhle, 2012: 667). Therefore, it is important for countries using this method to consider such factors in the design of their spectrum auction. The spectrum allocated to operators is an important factor because the various bands of spectrum have different propagation characteristics and thus operators build base stations to fully optimise the spectrum allocation. Costs for operators to rollout the network are an important consideration owing to the differences in these propagation characteristics. During the 1990s in Europe, market entry in second-generation mobile communications took place and usually the first two operators in most nations received an allocation of spectrum in the 900MHZ band while those who entered the market later were granted spectrum mainly in the 1800MHZ band (Lundborg, et al., 2012).

When additional spectrum is later allocated, these operators need to adjust accordingly and potentially augment their infrastructure. The econometric model conducted within the study by Lundborg, et al. (2012) indicates that a network based on 1800MHz needs up to 3.4 times as many base stations compared to a network built for 900MHz. The study further mentions that spectrum above 1GHz has a higher propagation loss path compared to spectrum lower than 1GHz, meaning that the latter covers a wider area of the population than the former, with the same number of base stations. To understand this, operators who have been allocated spectrum below 1GHz would find it less costly to reach more consumers from a base-station perspective because there would be fewer required. At face value, this may appear as if the operators that get allocated spectrum above 1GHz would be in a less favourable position, but it is pertinent to consider other factors such as the cost of acquiring this spectrum.

The cost of additional spectrum is worth considering because it pertains to competition as well for MNOs. In Canada, the three national carriers (Bell, Rogers and Telus) incurred an additional cost when the federal government auctioned spectrum, which resulted in higher consumer prices for consumers of mobile services (Crandall, 2021). At this auction, a set amount of spectrum was set aside for smaller regional carriers to encourage participation and thus promote competition in the mobile data market. This resulted in the three national carriers having less spectrum available at the auction and ended up paying 3½ times more than the smaller players, who were subsidised. The costs of additional spectrum for the three main carriers resulted in operators having to increase their prices to consumers for mobile data and didn't increase competition on a national level as the federal government had expected by setting aside spectrum for smaller operators to increase their chances of participating and competing on a national level. Pricing through an auction process is intended to enable efficient operators to acquire spectrum but it has been argued that this can distort competition since dominant operators may have first-mover advantages (Lundborg, et al, 2012: 667).

In South Africa, Vodacom and MTN are the bigger operators and dominate the market compared to the smaller players such as Rain and Cell C. Vodacom and MTN were both granted licences in 1993 for mobile telecommunications after Telkom had been the sole player in the market and thus had dominance. Cell C was granted a licence in 2001 to increase competition. In 2010, Telkom introduced their own Mobile Network called 8ta which was later rebranded to Telkom Mobile and in 2006, the first (MVNO was launched by Virgin Mobile who operated on Cell C's network. An MVNO is a reseller of wireless communication services who leases wireless capacity from a third party (MNO) at wholesale prices and resells it to consumers at reduced retail prices (McKenzie, 2014). MVNOs can charge less as they don't have to pay for spectrum licences and have no complex infrastructure to build and maintain. However, their ability to offer lower prices depends on the price they are charged by the MNO for access. Thus, there must be sufficient competition to allow MVNOs to have a choice of operators so that the MNOs have to compete to provide the best offering to the MVNO. This is known as facilities leasing. MNOs provide an essential facility to other firms who don't have direct access to them.

According to economic theory, an essential facility is a physical infrastructure to which an entity requires access to conduct business within that industry (McNutt, 2005). Examples of this include telecommunications, rail infrastructure, ports, airports, fixed-line local loops, etc. The doctrine of an essential facility is also applicable to more than a physical facility such as intellectual property (Cotter, 2010). According to policy roundtables held by the OECD (1996), an essential facilities doctrine requires that there are two markets involved: one upstream and another downstream. In determining whether a facility is essential or not, it is important to consider the following:

- What competitive advantage it confers on the downstream market
- How duplicable is the infrastructure

- Whether the provision of the essential service increases the owners' costs
- Would the provision of access to the infrastructure discourage future investment

In this instance, spectrum is the essential facility. An empirical study conducted by Bouckaert and Verboven (2010) highlights three types of competition between ISPs: Firstly, inter-platform is not dependent on access regulation but rather on the competition between the different infrastructure types i.e., DSL and cable networks; Secondly, facilities-based relies on access leasing unbundled loop elements and investing in their facilities and equipment. Lastly, service-based intra-platform competition depends on mandatory access where new entrants do not invest much but resell the incumbents' broadband services. Gruber & Koutroumpis (2012: 172) highlight the two ways in which competition can be achieved in broadband: through facility-based competition with alternative technology platforms, and service-based competition where open access provisions are made at varying levels of network infrastructure. Spectrum assignment is key for facilities competition because operators can provide broadband access to their clients by expanding into areas where they would otherwise have no reach such as in rural areas where a specific spectrum type is required owing to its propagation characteristics. To clarify, if more operators are awarded 700MHz spectrum, this encourages competition and is more likely to improve the quality and price of broadband in rural areas, compared to allocating it to only operators. MVNOs are involved in service-based intra-platform and are dependent on competition at a facilities level. In the interests of consumers, service providers must also have an incentive to provide services, so regulators have a task to ensure that the interests of new entrants, who help drive down prices, and incumbents, who provide long-term infrastructure investments, are considered.

Telecommunications services have been on a trajectory of liberalisation since the 1980s and one of the debates is whether incumbent operators need to provide access to new entrants by providing connection to an essential facility that they control. Owing to the duration of licences, it is not easy to enter the broadband data market as a new entrant and it may be useful to partner with an incumbent and obtain any unused spectrum. Those in support have stated that by having new entrants, the competition will drive down prices for consumers and enhance the quality and access to broadband. Through infrastructure sharing, it is argued that the cost savings on capital and operating expenditure can enable more MNOs to expand their footprint into previously underserviced areas and thus bridging the digital divide, resulting in greater broadband access. In the case of MVNOs, the cost saving of not paying for spectrum licences can benefit the consumer because they would be able to charge lower prices (Strusani & Houngbonon, 2020: 3). Naturally, access to broadband should increase as it becomes cheaper. The findings of the final report on data prices by the South African Competition Commission reveal that the lack of competition in the mobile market has ramifications for consumer prices.

Basic economic theory holds that the more competition in a market, the less the end consumer will pay. In the South African market, although there are four operators which is similar to countries with competitive markets, MTN and Vodacom have an entrenched duopoly where they have dominated market share for years. This has left little for operators such as Cell C, Telkom and Rain to make inroads which can be attributed to a lack of pro-competitive regulation. In more competitive markets, authorities tend to have more pro-competitive regulations, such as facilities leasing on fair terms, to encourage smaller operators. With such a market structure, the less dominant players find it difficult to make inroads in a way that encourages competition. Strusani and Houngbonon (2020: 2) argue that in developed markets where there is sufficient funding and purchasing power, it may make better sense to have each market participant invest in their own infrastructure whereas in developing/emerging nations, it makes less sense owing to higher costs and risks.

Proponents also argue that without infrastructure sharing, new entrants have the burden of first investing in infrastructure which could take years, whereas the additional spectrum could just be allocated to established players who already have the infrastructure allowing them to quickly deploy new technologies and new generation networks. A key issue is that broadband access tends to be skewed towards urban areas while rural areas are underserviced. In some countries, small operators are usually oriented towards low-income segments and spectrum tends to be a cost barrier to entry, and even in cases where the larger operators are given nationwide licences, MNOs tend to focus on urban areas. This is due to the value of spectrum being higher in urban areas where the greater population concentration causes higher usage. Muente-Kunigami and Navas-Sabater (2010) suggest the flexible use of spectrum when it comes to frequency allocation in rural areas by allowing operators providing broadband services there, to use available spectrum in commercial frequencies for better and profitable coverage. One of the resolutions that has been tabled is to use the digital dividend spectrum, which ranges between 200 MHz and 1 GHz in rural areas, owing to its strong propagation characteristics and thus be able to cover a wider area, lowering the costs for MNOs in rural areas. In South Africa, the switching of television from analogue to digital will allow IMT700 to be released to support goals related to broadband access (ICASA, 2020).

2.4 Broadband penetration

To assess how many people have access to the Internet within a country, the broadband penetration rate is a variable that is often used. The definition thereof varies from country to country but the OECD (2017) definition is “the number of subscriptions to fixed and mobile broadband services with advertised speeds of 256 kbps or more, divided by the number of citizens in that country. This measure aids governments and regulators to track the progress of their efforts in increasing broadband access. As stipulated earlier, fixed-line services on the African continent are limited. Mobile broadband has been the fastest-growing means of accessing the Internet for most consumers. Mobile is reported to have grown faster in developing countries for a number of reasons which include a regulatory environment that allows for more competition and investment in the private sector as well as the ease with which wireless networks can be installed compared to wired infrastructure (Minges, 2016). It was reported that in 2014 mobile broadband penetration was four times higher than fixed broadband penetration in developing countries. Mobile broadband subscriptions grew from 2.3 in 2007 to 27.9 in 2014 (ITU data). Fixed broadband has remained low in Africa with 1 subscription per 100 inhabitants, as shown in figure 2 below while mobile broadband subscriptions as reflected in figure 3 have continued to grow, and was at 41 active subscriptions per 100 inhabitants in 2021. The focus of the study is on mobile broadband because this is the primary means for citizens in Africa to access broadband.

Figure 2: Fixed-broadband subscriptions per 100 inhabitants by region, 2021

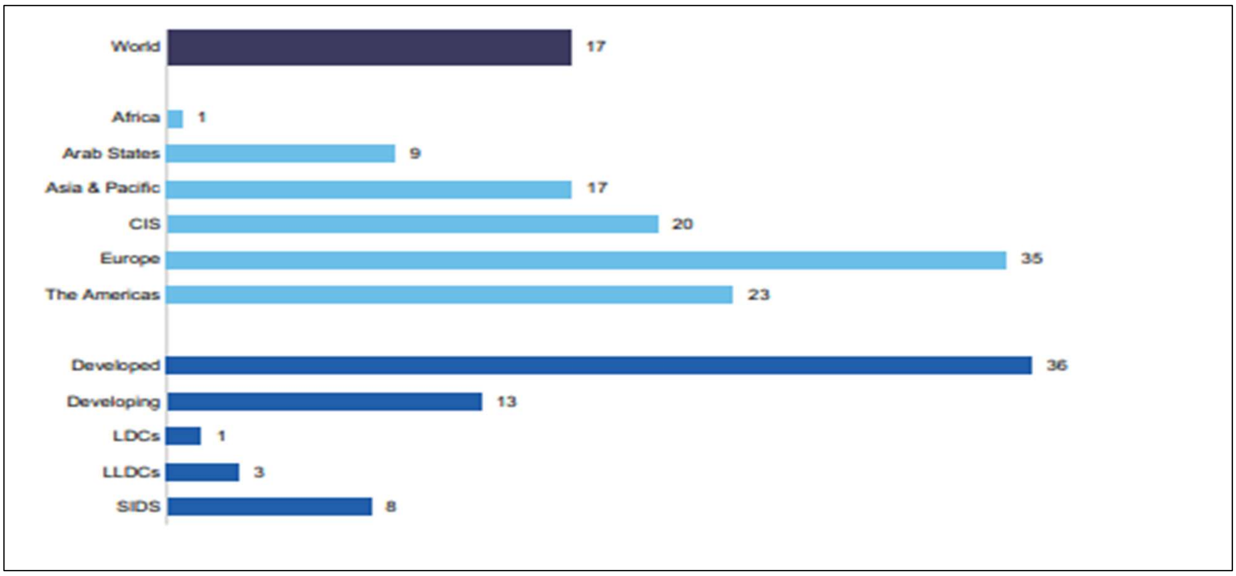
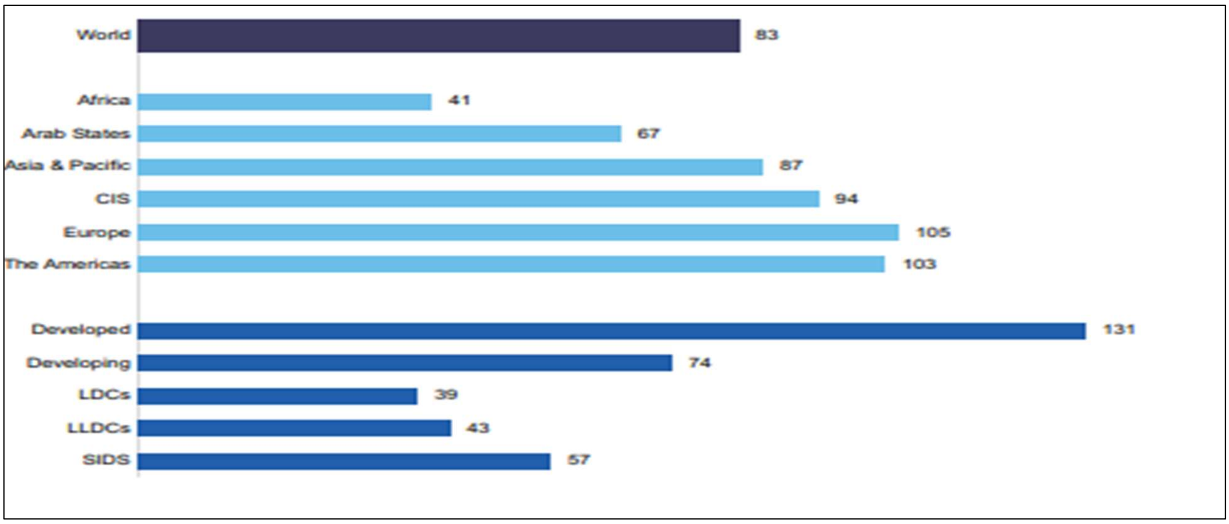


Figure 3: Active mobile-broadband subscriptions per 100 inhabitants, by region, 2021

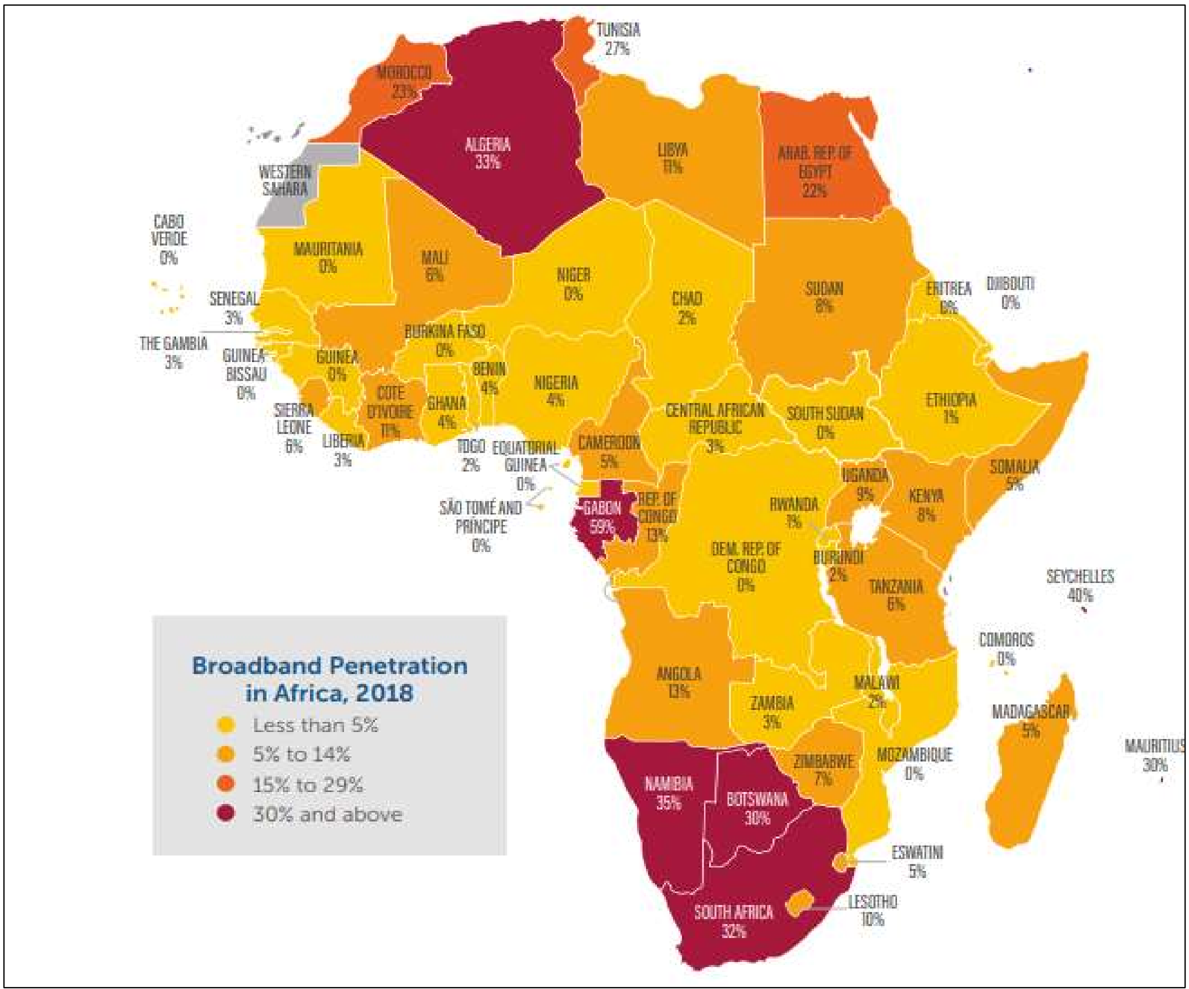


Source: Measuring digital development- Facts and Figures 2021, ITU

Policy interventions in a country can be employed to improve broadband goals. Falch (2007: 247) distinguishes between three different types of policies: direct intervention, regulation and facilitation. Firstly, direct intervention refers to governments actively providing services instead of providing just market information or regulating the market. Secondly, regulation is characterised by direct market interference through the law, with binding consequences, and includes both infrastructure and content. Lastly, facilitation is a form of market interference albeit milder than regulation since it refers only to instances where regulators and the government act as observers and do not enforce regulations on market participants. The type of policy applied will vary from country to country and many have redesigned their regulatory policies to improve competition in the telecommunications sector to benefit the consumer. Spectrum policy is a regulatory tool aimed at increasing broadband access for citizens. Allocation and licensing of spectrum has been highlighted as a key component in ensuring that mobile broadband penetration rates grow in sub-Saharan Africa. With accelerated demand, network providers would face capacity constraints without the additional spectrum, in turn affecting mobile penetration rates.

It is important to factor in the evolution of mobile technologies when assessing broadband penetration. Analogue generation started in the 1980s which enabled access to mobile telephony for some citizens and it was 2G GSM in the 1990s that resulted in access to telephony for the masses. It was not until the 2000s that mobile access to the Internet was introduced through 3G which was later followed by LTE and LTE-A (4G) which significantly enhanced the performance of broadband. 5G was first launched in 2019 and most countries are still making plans for the allocation and licensing of spectrum geared towards it. As a result, this study focuses on 4G broadband penetration. Figure 4 below shows the 4G penetration rate per country in Africa in 2018. Very few countries at that stage had achieved 4G penetration above 30%, with most being below 5%. These figures are concerning given the goals of enhancing broadband access by various nations, to accelerate economic growth and enhance the lives of citizens.

Figure 4: 4G Mobile broadband penetration in Africa, 2018



Source: Extract from Connecting Africa Through Broadband, 2019

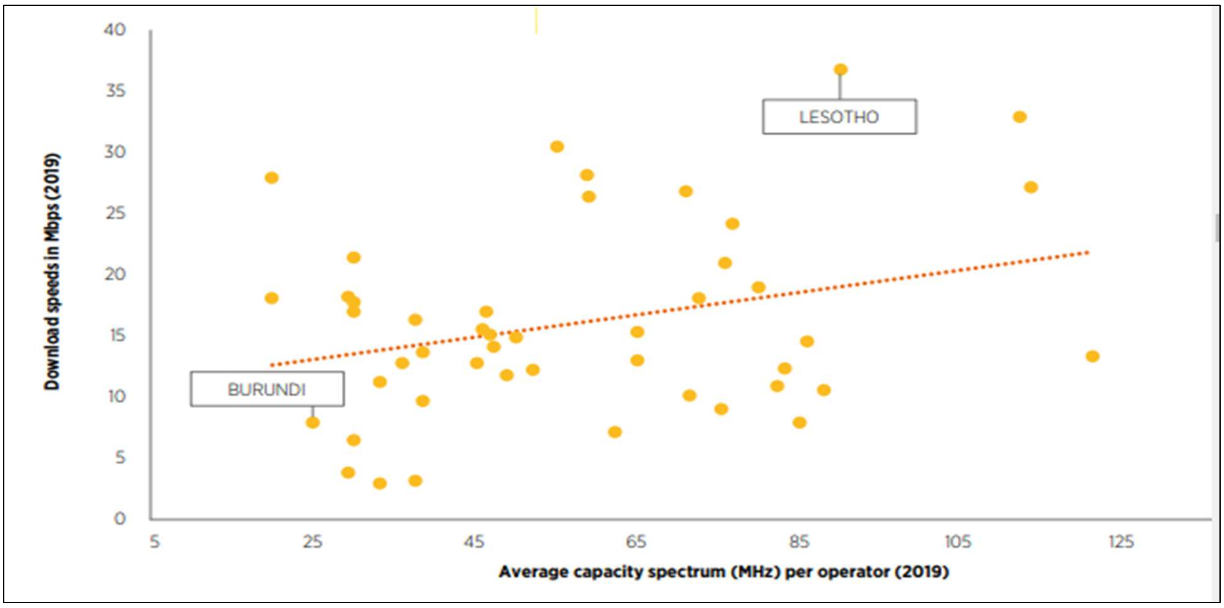
2.5 Quality of broadband

While broadband penetration has increased in South Africa, it is also important to consider broadband access in terms of the adequacy of the available broadband service. Although there is no universally agreed measure of the quality of the Internet, broadband speed is the most commonly-used measure to test the quality of broadband (Bauer, Clark, Lehr: 2010). Both upload speeds and download speeds are used although there is more reliance on download speeds, also known as downstream throughput. These download speeds refer to the speed at which a user receives data from a local or international server (Chetty, Sundaresan, Muckaden, Feamster and Calandro: 2013). Various organisations that conduct speed tests but variability does exist owing to methodological differences in assessing these speeds. In the study conducted by Bauer, et al (2010), the Ookla Speedtest approach was highlighted as the best among the available sources owing to their use of multiple Transmission Control Protocol (TCP) connections which eliminate the issue of measuring from a common desktop computer. Chetty, et al. (2013) also highlight that the performance of broadband can be affected by several things such as the time of day, the distance to the nearest measurement server, equipment used by users and shared connections

SA Connect stipulated a goal of 100 Mbps download speed by 2030 while periodic targets were set to ensure that continuous review can take place. Several studies have measured the quality and adequacy of broadband access and services. Chetty, et al (2013)[15] highlight that consumers in South Africa are not getting the advertised speeds for either fixed or mobile. Although mobile has a higher throughput, interconnection between ISPs also tends to be an issue. One of the reasons often assumed to affect the advertised speed versus the actual speed is that broadband access providers rely on multiple users sharing the network capacity that is available and that during peak times, there will be more users accessing the service which affects the speed and end-user experiences. The demand for data has also increased as a result of those already connected to the Internet requiring increased data for gaming. Users further report that high latencies between destinations cause performance failures, and therefore recommend improving this interconnection and ensuring content is closer to users. This finding is from 8 years ago, and because broadband penetration has increased over time, it is worthwhile to test whether the quality of broadband has improved. A GSMA study reveals that where governments have licensed more capacity spectrum (more than 1GHz), operators also have higher average download speeds. The figures below obtained from this report illustrate that where Lesotho was found to be the country with the highest capacity of spectrum per operator and faster network speeds while Burundi was found to have the lowest capacity of spectrum and the slowest speeds.

[15] Measuring broadband performance in South Africa ACM DEV-4 '13: Proceedings of the 4th Annual Symposium on Computing for Development

Figure 5: Download speed (Mbps) relative to average capacity spectrum(MHz) per operator, 2019



Source: GSMA Effective Spectrum Pricing in Africa, November 2020

According to Statista (Sep 2022), the mean download speed in South Africa was 28.62 Mbps in 2022 which is far lower than the goal highlighted in SA Connect of having 50% of the population at 100 Mbps by 2020. This is explored further later in the paper when analysing broadband speeds.

CHAPTER 3: METHODOLOGY

3.1 Introduction

Spectrum allocation and licensing are imperative in accelerating broadband access, as highlighted in the previous section, and analysis of this is a challenging task for the policymakers. Countries at varying stages of infrastructural development have different levels of capability when it comes to technological resources. The efforts of the different ministries of communication and the strength of the telecommunications regulator are crucial in ensuring that the digital divide and the goals to increase broadband access are obtained. In the South African case, the release of spectrum, (i.e., high-demand spectrum) has been, as already highlighted, a contentious issue for some time, and the goal of this paper has been to measure to what extent the delay has resulted in the constraint of universal access. A comparative analysis between a few countries was selected as the best approach to make meaningful inferences in light of the complexity associated with spectrum allocation and assignment. The countries that have been selected for this comparative study are Egypt, Kenya, Nigeria and Germany. The decision to focus on these countries was based on them falling within the same region where the ITU has prescribed the frequency ranges and its uses, to simplify spectrum harmonisation which in turn, among other factors, enables global roaming and ease of compatibility of manufactured products across these nations. Although countries are still at liberty to decide when, how and which bands of frequency will be released, analysing countries within the same region makes for better comparison because their spectrum bands are used for the same purposes.

According to Statista[16], Nigeria has the highest number of Internet users in Africa at 109.2 million followed by Egypt at 75.66 million and South Africa at 41.19 million. Considering just the number of users to represent how advanced a country is regarding broadband access would be an oversimplification since there are other factors to consider. An additional source was considered in the selection of these countries. The African e-Connectivity Index 2021 ranked South Africa as the highest in terms of the quality of its Internet connectivity with a score of 100 points while

[16] These statistics are as at January 2022 as seen on the Statista website

Egypt ranked third at 95.42, Kenya fourth at 89.60 and Nigeria tenth at 71.29[17]. 28 indicators were selected to rank countries on this index which includes the number of mobile networks per country and the percentage of the population covered by 4G. These countries also represent each of the four regions of Africa. Given that African countries have lagged in terms of the allocation and licensing of spectrum compared to the rest of the world, a decision was made to also look at developed nations who have made headway with allocation of spectrum required for next-generation networks, specifically 5G, the latest advancement to meet the increased demand for broadband. Germany, among the first countries to embrace 5G, was selected to compare to the African countries. The central hypothesis of this study is that the failure to allocate high-demand spectrum has impacted the goal of increasing universal broadband access and each of these countries was explored where the research questions are concerned.

The research questions that were addressed in the study are as follows:

3.1.1 Have mobile data prices remained high owing to the failure to allocate high-demand spectrum?

3.1.2 Has the failure to release spectrum resulted in less competition in the mobile broadband data market?

3.1.3 Do mobile broadband penetration rates increase with the release of spectrum?

3.1.4 Does the release of high-demand spectrum result in improved download speeds?

The methodological approach is discussed to better understand the rationale for the study. This is followed by discussion on the data collection methods and, lastly, the limitations of the study are addressed.

3.2 Methodological approach

Countries across Africa have the common goal of increasing broadband access to their citizens because the economic benefits, as have been highlighted, are enormous. A report conducted by the GSMA (2020) highlights that governments in Africa are generally lagging the developed world

[17] Investment Monitors e-Connectivity Index is aimed at highlighting how many opportunities ae available for Investors on the African continent

and have only assigned half the spectrum compared to the global average. Although the countries selected for this study all fall within ITU region 1, they are at different points on their respective journeys towards increasing this access, based on the availability of infrastructure and the release of spectrum. Their progress in technological advancement differs and as a result, the allocation and release of spectrum naturally differs. Some countries are also further along because of policymaking and the implementation thereof, and have thus been able to make advancements in terms of next generation networks while others lag. Consequently, a decision was made to conduct a comparative analysis across these countries over a period. Background on each country's telecommunications industry and, more specifically, the broadband policy and goals is provided in the section that follows. This helps to understand the goals of each country and their respective efforts towards accelerating broadband access. To address the research questions a combination of reviewing literature and reports, as well as collecting data from various secondary sources was done to conduct a quantitative analysis on the selected variables.

Best practice is to award licences for 20 years to MNOs (GSMA, 2022). A comparative analysis was conducted in the study with data collected on a number of variables across different countries and observations between 2010 and 2020 to find if there was any impact on broadband access as a result of changes that have taken place to spectrum allocation and licensing. Although licences are usually awarded over 20 years, the period selected for this study is only 10 years because, in 2010, African governments assigned spectrum in line with the developed world but generally these governments assigned less additional spectrum than the rest of the world. In addition, 4G LTE services were first launched in South Africa in 2012 and 4G has been selected in terms of broadband penetration. Where possible, data was collected on an annual basis for the variables measured. The prospect was to identify whether changes to the variables of interest which influence broadband access are the result of the delay in spectrum allocation or due to other factors. Where the data was available, up to date data beyond 2020 was used.

3.3 Methods of data collection

There are different ways of collecting data for a study, all with varying benefits and limitations. Some studies choose to use primary data collection where the researcher collects data directly from a sample of the population to test the hypotheses and if there is enough evidence to conclude their validity. This method of data collection may be in the form of surveys or questionnaires and often the responses are grouped and a statistical model designed to test for any correlations between the independent variables and the extent to which these variables account for any changes in the dependent variable. Other studies opt to make use of secondary data that has been collected by someone else owing to the complexities associated with collecting such data from primary sources. For this study, secondary sources of data were used to conduct a comparative analysis between the selected countries. It would be challenging to collect primary data across the different countries as it relates to spectrum allocation owing to the differences already highlighted in each country's respective journey. It would also be onerous to collect data for all the participants, such as MNOs and MVNOs, who play a role in each country and having to synthesise those to represent the country.

There are various organisations that have, over time, collected data directly, through surveys or measuring variables of interest, by observing changes through data revealed in industry associations. To determine broadband speeds, some companies such as Ookla conduct a Speedtest to measure the performance of an Internet connection in a location which may vary from day to day[18]. As mentioned above, each country is responsible for managing its spectrum through their its own regulatory authority and ministry of communications. To attempt to answer the research questions and to test the hypothesis on universal broadband access, various sources were used. There was a selection of information available on the variables of interest and data, and literature was collected from the following sources, in no order of importance:

3.3.1 GSMA: A global organisation aimed at bringing together the mobile ecosystem from three pillars: Industry services and solutions, Connectivity and Outreach.

3.3.2 Information Telecommunications Union (ITU): With the world dived into 3 regions from a spectrum perspective, there is useful data here.

3.3.3 Regulatory authorities: These provided information regarding the regulatory measures that are intended to guide telecommunications in the various countries.

3.3.4 Government/Ministerial websites: These sites provided insight into the goals of the different communications ministries.

[18] Users of Ookla can determine their own connection speeds and Ookla also provides analysis on industry trends

3.3.5 Competition authorities: As the enforcers of competition laws, there were useful insights into enquiries and the outcomes thereof in the journey towards increasing broadband access.

3.4 Methods of data analysis

This study focused on quantitative analysis of the variables shown below, between 2010 and 2020, where the data is available, otherwise any restraints on data availability are mentioned in the limitations section of the study. A trend analysis was conducted across countries to compare and contrast the effects of allocating spectrum to better understand what the impact of delaying the release of high-demand spectrum has had on broadband access in South Africa. The section below breaks down each of the variables that were measured in the study, to answer the research questions and explains how they were measured at source.

Price of 1GB of data

Quantitative data on the price of 1GB of data was collected over the period to analyse the delay in allocating high-demand spectrum has had on data prices. This was in two parts:

- To compare the African countries in the study, the cheapest 1GB data was collected from Regulatory Impact Analysis's Research ICT Africa Mobile Pricing Index (RAMP), which focuses on the lowest data collected quarterly for each mobile operator. This data was available from 2014 Quarter 2 to 2021 Quarter 3 and is based on advertised prices collected by Research Africa from MNO websites.
- To include Germany, the average price of data was collected over three years from 2019 to 2022. The prices were based on sim-only mobile plans which sometimes included calls and texts. Pure data plans for laptops and tablets were also included to provide a balanced view. The averages were collected as the median of all recorded package prices within each country.

Quality of mobile broadband

Although the quality of mobile broadband does not have a standard definition, the speed of download is often used to measure it. The mean speed of downloading was used to represent the quality of broadband in the various countries, to take account of the different ISPs. The data was sourced from www.cable.co.uk who collaborated with M-Lab who collect speed data in 220 countries. A single speed test was used, which did not reflect the maximum speed available to a router in a household but rather the speed available to a device via the router. Different service providers have different means of doing these speed tests and the data collected by M-Lab is comparative in nature and should not be viewed in absolute terms for the speed in each country

In addition, 4G coverage experience was used to highlight consumer experience of the MNO at a point. This measures, on a scale of 0 to 10, the locations where users of a specific mobile operator received a 4G signal in relation to users of another mobile operator. This was retrieved from Opensignal who collect data from billions of individual measurements from smartphones internationally.

Market share

Data on market share was collected for the main MNOs in each country. The aim of this was to measure the impact of spectrum allocation on the competitiveness in the market and to identify whether spectrum allocation had influenced this. The data collected for the African countries in the study was on the top 3-5 operators by revenue and subscriber base, and was retrieved by Asoko Insight from the ITU. The market share data collected was based on the total number of subscribers that each operator has and was retrieved from company annual reports. It is important to note here that the market share data does not isolate the number of broadband subscribers but is the total subscriber base of the mobile operator.

Broadband penetration rates

Quantitative data was collected on the number of active mobile subscriptions per 100 people in each country over 10 years. The ITU collected this data and defines active mobile subscriptions as "the sum of standard mobile broadband and dedicated mobile broadband subscriptions to the public Internet"

Spectrum

Information was collected from different regulators' websites, telecommunications and various publications including newspaper reports on spectrum plans, allocations and licensing. A brief histogram on the journey of spectrum in each country was provided to better analyse how this has contributed to the progress or impediment of broadband access. The total spectrum holdings of each operator are shown in the appendices.

Service revenue and capital expenditure

Data was collected over five years for Vodacom and Safaricom as the leading operators in South Africa and Kenya respectively. Specifically, it was service revenue data and capital expenditure extracted from the respective financial reports of the operators to make a comparison at operator level, to better understand the impact of having spectrum allocated. Service revenue encompasses revenue collected from data and mobile services while capital expenditure refers to capital investments including natural capital which spectrum is classified as. …..?

3.5 Limitations

It is important to note that there were several limitations noted during this study which must be addressed to avoid misrepresenting the analysis.

3.5.1 Universal access is concerned with ensuring that all citizens have access to broadband whether they are in government institutions, clinics, libraries and schools. This data was not all readily available which resulted in reliance on broadband penetration overall at a country level. The impact is that the analysis may not adequately reveal how the delay in releasing high-demand spectrum has impacted consumers in rural versus urban areas.

3.5.2 There are different methods of awarding and licensing spectrum which could have varying ramifications, as indicated in the literature. Some countries award licences through administrative processes while others do so through auctions. The benefits and critiques of these various methods have already been mentioned in the literature review section but it is important to highlight that the differences in methods between the countries make it challenging to make a like-for-like comparison when it comes to the allocation and licensing of spectrum. The impact on the choice of method to allocate has on broadband access has not been explored and leaves scope for future studies.

3.5.3 Although the countries within the study all fall within the same region, meaning they use spectrum for the same purposes, the release of spectrum has happened at different times. This made it difficult to make a fair comparison of how the release of spectrum has impacted price, quality, competition and penetration rates, especially because each country adopted fourth-generation networks at different times.

3.5.4 There are differences in measuring the quality of broadband. Countries find themselves at differing stages of development which makes it difficult to come up with a universally-agreed measure of the quality of the Internet. Some countries have been able to move rapidly to next-generation networks compared to others which limits the ability to fairly compare the quality of the Internet in the nations of interest. While there is no universally agreed measure, there has been more leaning on 10 Mbps download speed and caution should be exercised when making these comparisons. This is also since in each country, there are urban areas as well as rural areas which themselves present challenges when it comes to measuring the quality of service. It should thus be noted that the findings make no distinction between rural and urban. The mean average of speed data was used in this study and the data was sourced from www.cable.co who, in turn, sourced it from mLab whose platform was upgraded in 2020, which accounts for the sharp increase in Year-on-Year speeds during that period, so caution must be exercised when analysing that data. The data also includes all the ISPs in the country and is not limited only to mobile broadband, so when interpreting the data, note this is not purely representative of mobile broadband access.

3.5.5 The price of data is measured per 1GB of data and quoted in dollars for comparability across countries. Countries have different MNOs and the price of data used to compare countries is based on the average price of the operators and does not make a distinction between prepaid and post-paid data which have different prices. It also does not consider differences between data specials and normal pricing. This approach does not consider the fluctuations in currency and nor does it consider the variances in price across the operators based on their market share and other factors such as their operating costs. In some instances, the price data was not updated at source (e.g., MNO websites) and research collection companies had to rely on old data.

3.5.6 The availability of consistent data was a limitation which made it difficult to compare over the same time frame. In some instances, there was only a shorter period available, like when considering market shares.

3.5.7 Market share data for mobile operators were used to assess competition and did not separate between mobile and data services.

CHAPTER 4: DATA ANALYSES AND FINDINGS

In this section, the findings of the study are revealed. A brief introduction is provided for each of the countries and their telecommunications sector with a specific focus on spectrum, broadband access and the various telecommunications authorities. In the next section, the findings on each of the variables (price, quality, broadband penetration and competition) is provided followed finally by an analysis of the respective variables.

South Africa

South Africa's telecommunications sector is regulated by ICASA and the broadband policy called SA Connect was introduced in 2000. Since then, there has been a protracted process to release high-demand spectrum largely owing to changes in the ministry of communications and litigation that has taken place from some of the MNOs objecting to the proposed release of spectrum. The delays have impacted the goals that have been stipulated in SA Connect and have been reported to impact the ability of MNOs to provide broadband access at the required quality and price. There Vodacom, MTN and Cell C are the main operators providing broadband access followed by Telkom and Rain.

Nigeria

The Nigerian Communications Act 2003 (NCA 2003) governs the telecommunications centre, and the independent regulatory authority is the Nigerian Communications Commission (National ICT Policy, 2012). The first broadband plan in Nigeria was formulated in 2013 for 5 years, to increase broadband access with minimum download speeds of 1.5 Mbps at a minimum coverage rate of 30% and ensure that it reached at least 80% of the population. A new broadband policy was formulated after President Muhammadu Buhari pledged in his Independence Day speech in July 2019 to lift 100 million Nigerians out of poverty in 10 years. He highlighted the extension of the ministry's duty to develop the digital economy.

The four major MNOs in the country are MTN, Globacom, Airtel Nigeria and 9Mobile (formerly Etisalat). Although the number of Nigerians getting access to mobile broadband had increased, a penetration rate of only 49% reflects that there may be some inefficiencies with the use of spectrum.

Egypt

The telecommunications sector in Egypt is overseen by the Ministry of Communications and Information Technology, which was formed in 1999 and has the key responsibility of formulating policies for the industry (Oxford Business Group). The National Telecommunications Regulatory Authority (NTRA) has the responsibility of managing, supplying and regulating radio spectrum in Egypt, in line with the Telecommunications Regulation Act No. 10 of 2003. The first broadband plan was launched by the Egyptian government in 2004 which saw the acceleration of Internet connections in Egypt. As part of the efforts to increase access to citizens, the NTRA formulated the Universal Service Fund in 2005 whose aim was to compensate telecom service providers and operators for costs incurred in providing access to unprofitable and underserved areas. The aim was to ensure all citizens have access to telecommunications at a reasonable cost with affordable rates. As part of this initiative, the broadband project was formulated to increase the "deployment of high-speed Internet in Egypt". The National Broadband Plan, eMisr, was announced in 2011 and had the important goal of ensuring access to fast broadband to all Egyptians by 2021, as well as ensuring that broader social objectives, such as improving education, health and living standards, are achieved.. A 2014 report revealed that the lack of certainty on spectrum release made mobile operators sceptical about infrastructure investment to meet future demand (Miller, Wongsaroj & Hogg: 2014).

Kenya

The Communication Authority of Kenya (CA) is responsible for developing and implementing policies within telecommunications that propel economic growth. This includes issuing licences and ensuring that telecommunications operators are meeting their obligations according to the licences, and adhering to the obligations stipulated in the Kenya Information and Communications Act, 1998 and the Kenya Communications Regulations, 2001 (Communications Authority of Kenya website). The National Broadband Strategy (NBS) in Kenya defined broadband between 2012 and 2017 as '*connectivity that is always on and that delivers a minimum of 5 Mbps to* *individuals, homes and businesses for high speed across to voice, data, video and applications for development'*. Spectrum was identified as one of the main reform areas to provide adequate spectrum for mobile broadband services, as reflected in Table 3 in the annexure. The Communications Commission of Kenya (CCK), along with the Ministry of Information, Communications and Technology (MoICT) together developed the Broadband strategy. Spectrum in Kenya is allocated by using an administrative approach rather than relying on the market. There are three major MNOs in Kenya: Safaricom Kenya Limited, Airtel Networks and Telkom Kenya Limited who respectively have approximately 64%, 27% and 6% of the mobile market, and most of the spectrum assignments are held by these operators. There is one MVNO, Finserve Africa Limited (Equitel).

Germany

Germany is one of the countries that have a developed broadband market. There are three main MNOs in Germany: Telekom, Vodafone and Telefonica. Four main authorities in Germany are responsible for the national broadband strategy and policy:

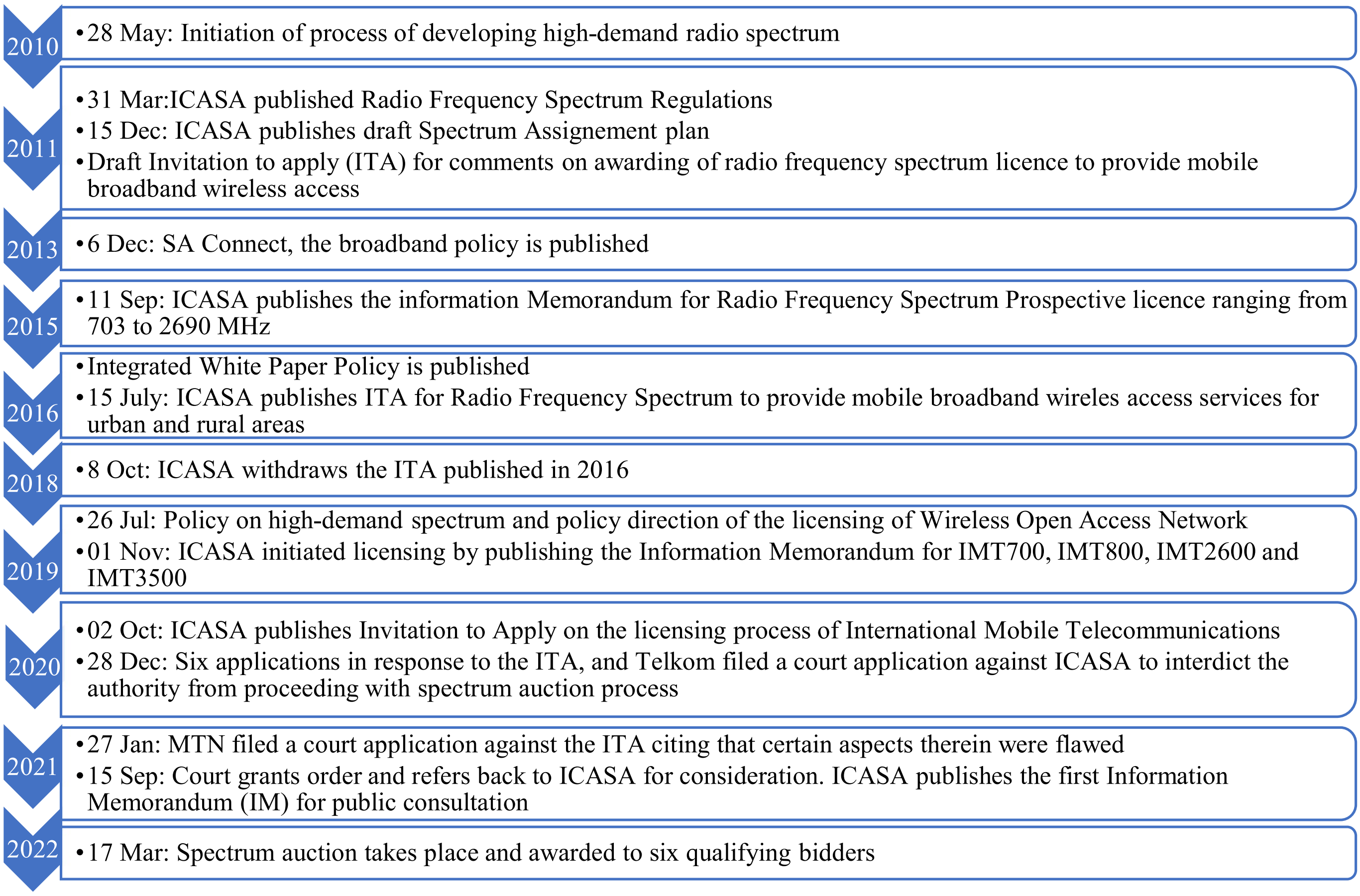
- The Federal Ministry for Digital and Transport (Bundesministerium für Digitales und Verkehr, BMDV) who are responsible for the development of broadband and implementing the federal government's broadband strategy
- The Federal Ministry of Economic Affairs and Climate Action (Bundeministerium für Wirtschaft and Klimaschutz) is responsible for promoting digital and transport infrastructure
- The Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (Bundesnetzagentur) is responsible for the implementation of the regulatory framework laid down in EU and national law.
- The Federal Gigabit Bureau (Gigabitbüro des Bundes) is responsible for maintaining contact with the broadband competence centres of the federal states.

4.1 Spectrum allocations per country

In this section, a timeline is provided for each country and its journey to spectrum allocation and licensing. Only significant milestones, that were deemed to be relevant for this analysis, were considered. It is only in the next section that an analysis is made of the variables selected to address the research questions compared to spectrum.

South Africa

Figure 6: Timeline of South Africa's broadband journey



The journey of allocating spectrum in South Africa has been protracted as can be seen in the timeline above. This was predominantly due to delays by the ministry of communications and litigation. The information memorandum for high-demand spectrum was published in 2015 and for spectrum to be allocated only in 2022 is drawn out, so it is not surprising that the goals of the national broadband policy have not been reached. These will be discussed in the respective sections below. Spectrum holdings are reflected in Annexure A for all the MNOs. Only the spectrum holdings before the auction of spectrum in 2022 are reflected, given that the auction occurred only recently and the impact thereof will take time to contemplate. The main players, Vodacom and

MTN have equal holdings in the 900MHz spectrum bands while all main operators (Vodacom, MTN, Cell C, Telkom) have equal holdings in the 1800MHz band with Rain holding slightly higher spectrum in that band. All operators hold equal amounts of spectrum in the 2100MHz spectrum band. In response to increased demand during the Covid-19 pandemic from businesses and the public, ICASA allocated temporary spectrum in various bands as shown in the table below.

Mobile Network Operator	**Temporary spectrum allocation**			
	700/800MHz	2300MHz	2600MHz	3500MHz
Cell C	N/A	N/A	N/A	N/A
Vodacom	40MHz	20MHz	50MHz	50Mhz
MTN	40MHz	N/A	50MHz	50MHz
Telkom	40MHz	20MHz	40MHz	12MHz

Source: ICASA website

Egypt

Figure 7: Timeline of Egypt's broadband journey

2015

- March: the NTRA signed a memorandum of understanding with the GMSA to reflect efforts and commitment towards a supportive regulatory environment aimed at addressing both demand and supply side factors such as spectrum licensing and infrastructure sharing

2016

The NTRA announced that 40MHz was available at a price of 50 million USD per MHz which was met with resistance from operators citing the high price as an issue coupled with the fact that 50% of this allocation had to be paid for in US Dollars. Licences for 4G started being issued by the NRTA in 2016 with TE being the first to acquire one followed by the rest of the operators in October and in 2017, Egypt launched 4G services. Initially only Telecom Egypt (TE) agreed to the terms and paid 797 million USD for 5MHz in 900MHz and 2x5MHz in 1800 MHz . Before the companies refused to bid for licensing in September, Orange and Vodafone were meant to obtain 7.5MHz each while Etisalat was to obtain 10MHz. The NTRA had to renegotiate and Orange and Etisalat ended up with 10MHz each while Vodafone ended up with 5 MHz

2017

June: Spectrum allocated to all four operators
December: MNOs requested new frequencies to keep up with demand

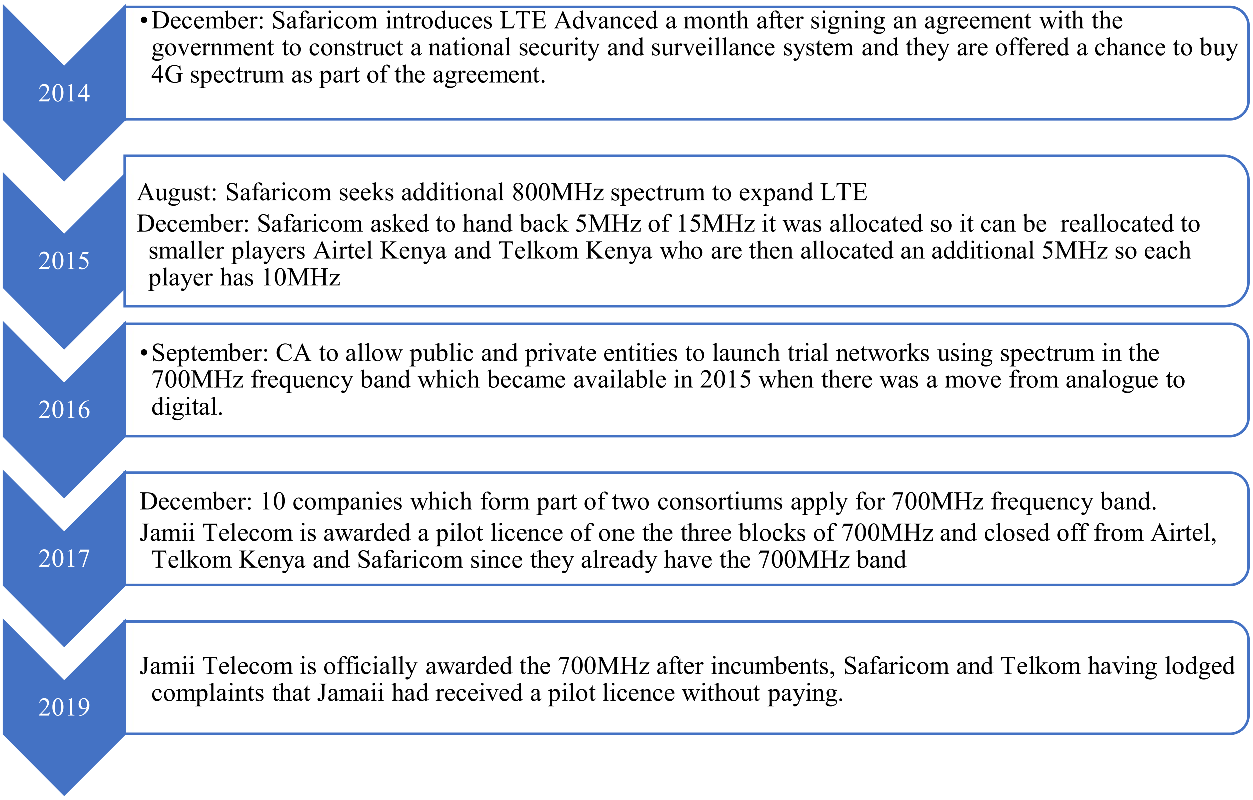
2020

September: Telecom Egypt apply for mobile spectrum in the 2600MHz TDD frequency Range
November: Vodafone Egypt awarded 40MHz of 2600MHz frequency band for 10 years
Telecom Egypt offer approved for 20MHz
Etisalat Misr outbids Orange fo 20MHz in the 2600MHz TDD frequency range

Egypt has been one of the faster-moving countries in Africa when it comes to spectrum licensing. The timeline shows a commitment towards this because a year after the NTRA signed a memorandum of agreement with the GSMA, they announced the availability of 4G spectrum which was allocated to operators in 2017. Telecom Egypt (TE) acquired the licence first in August 2016 because they were first to accept the terms while the rest of the players were contesting the terms and only agreed in October. Orange which is the country's second largest was the first of the other mobile companies to acquire the licence and Vodafone and Etisalat followed suit. The spectrum was allocated to all the operators in June 2017 when Orange and Etisalat ended up with 10MHz each while Vodafone ended up with 5MHz. In 2020, Vodafone was awarded 40MHz for the 2600MHz frequency range while TE obtained 20MHZ and Etisalat Misr outbid Orange for 20MHz. Orange obtained the spectrum in this frequency range only in 2022. Of the four operators, Orange and Vodafone have the highest spectrum holding at 42.5MHz each across the different frequency bands. Etisalat follows closely at 40MHz while Telecom Egypt holds 15MHz (NTRA, Spectrum Map). The method used for spectrum allocation in Egypt has predominantly historically been by using an administrative process

Kenya

Figure 8: Timeline of Kenya's broadband journey



In 2014 Kenya was one of the first African countries to assign 4G spectrum and has three main operators, Safaricom, Airtel Kenya and Telkom Kenya with Jamii Telecom being the latest entrant in the mobile market. The operators have been granted spectrum in the IMT800, IMT900, IMT1800 and IMT2100 frequency ranges. Safaricom holds the largest amount of spectrum in IMT900 and IMT1800 while in the other frequency ranges they have an equal allocation with the other operators. As the largest spectrum holder, this may give Safaricom a competitive edge over other smaller players as they can reach more users.

Nigeria

Figure 9: Timeline of Nigeria's broadband journey

2009
- February: The NCC announces that broadband will be rolled out nationally
- May: A directive is issued for the cancellation of the licensing round and asks for the players to be reimbursed which the operators aren't happy about how it was handled

2013
- NCC announces auction of 30MHz of 2.3GHz spectrum which attracts only 2 bidders and is won by a new entrant Bitflux

2014

April: The NCC plans the regional licence auction
August: Stakeholders are invited by the NCC to discuss the 2.6GHz auction for
October: An Information Memorandum is published for the planned auction of 10 year licences for spectrum in the 2.6GHZ frequency band

2015
- March: The planned auction of 2.6GHz band is suspended

2016

March: The postponed 2.6GHz auction is restarted
April: Interested parties are invited for applications in the 3.5GHz band
May: Only one qualified bidder, MTN applies and qualifies for the 2.6GHz auction
June: MTN Nigeria announced as the only approved bidder for 2 X 30 MHz slots

2019

April: NCC approves the transfer of Visafone's 800MHz licence to MTN Nigeria which was initially annouced by MTN in April 2015 when MTN announced that they were acquiring Visafone. The acquisition in December of 2015. In September 206 the NCC questioned the acquisition as it would increase market share for MTN
June: MTN Nigeria launches LTE-A following the 800 MHz approval.

The journey for spectrum licensing in Nigeria is one of the most protracted ones in comparison to the countries in the study. The initial announcement was made in 2009 about broadband being rolled out nationally and the spectrum auction to take place in only 2014 shows a regulatory environment marred by inefficiencies. Across the main operators, MTN holds the largest share in the 800MHz and 2600MHz frequency ranges and has an equal proportion in the 1800MHz and 2100MHz ranges as the other players. Spectrum is allocated through an auction in Nigeria.

Germany

Figure 10: Timeline of Germany's broadband journey

2010

- January: FNA receives applications from six operators to partake in the digital frequency auction in the 800MHz, 1.7GHz,1.8GHz, 2GHz and 2.6GHz ranges
- March: Four applicants are admitted into auction
- April: Auction takes place
- September: FNA allocates frequency blocks in 800MHz and 2.6GHz bands. Telephónica O2 Germany receives the first two blocks of 5MHz, middle two go to Vodafone Germany, upper blocks to Deutsche Telekom. Allocated through a lottery process
- December: FNA grants permission for E-Plus to use 900MHz band it acquired for voice services for mobile data transmission services

2012

January: FNA announces that the three MNOs have met their coverage obligations for the 800MHz in seven of the 13 required states and are now able to use their assigned frequencies in the federal state

June: FNA approves for E-Plus to use 1800MHz for the provision of mobile broadband services which was historically for GSM services only

November: Coverage obligations for 800MHz fulfilled in all 13 states that were historically underserved meaning they can make unrestricted use of it

2013

- June: FNA announces plans to auction 900MHz and 1800MHz frequencies from 2014 and give mobile operators until October to respond with opinions

2015

May: Germany becomes the first country in Europe to sell spectrum in the 700MHz frequency band for mobile broadband services in the multi-band frequency auction

June: Spectrum auction is concluded where Vodafone Germany acquired 2x10MHz in the 700MHz range, 2x10MHz in the 900MHz range, 2x25MHz in the 1800MHz range and 20MHz for the 1500MHz range. Telekom Deutschland acquired 700MHz (2x10MHZ), 900MHz (2x15MHz), 1800MHz (2x15MHz) and 1500MHz (20MHz). Telefonica Deutchland was awarded 700MHz (2x10MHz), 900MHz (2x10MHz) and 1800MHz (2x10MHz)

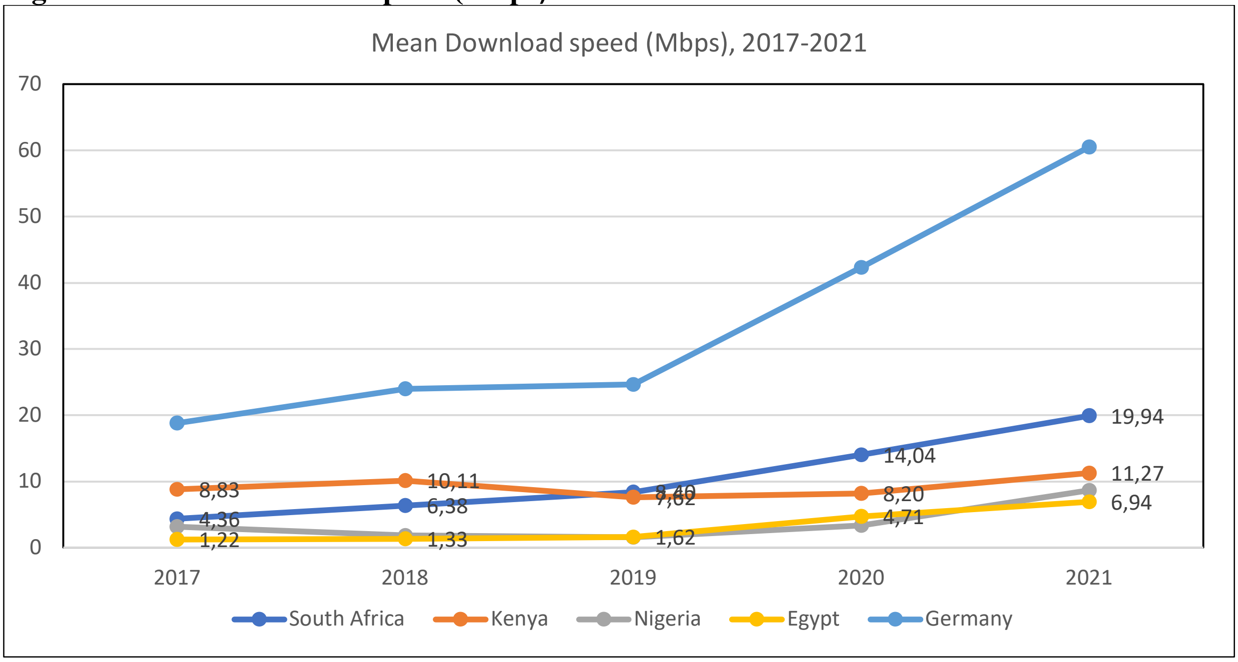
2018

- September: Draft terms published for planned auction of 5G mobile frequencies

4.2 Quality of service

Governments, regulators and policymakers are also interested in knowing that consumers are getting what has been promised by service providers. To assess if broadband access is at the required level for citizens, measuring download speeds is a measure used frequently. The mean download speed was used to measure the quality of service for this study and is reflected in Figure 11 below.

Figure 11: Mean download speed (Mbps)



Source: Cable.co.uk

This is the mean of all speed tests from unique Internet providers in the country from 2017 to 2021. Germany is leading the African countries throughout the period while their growth has been slow as expected. In line with the findings on the mean download speeds, Germany had the fastest mean download speed over the period. This is no surprise as developing countries have been reported, through multiple studies, to be lagging their more developed counterparts in allocating spectrum, and it can thus be expected that the quality of broadband would be impacted by this. It must also be noted that speed-test data tend to have a negativity bias in that users are inclined to conduct speed tests when they have issues with their connection, which explains why speed-test averages tend to be lower than expected. In 2019, African countries had allocated less than half the spectrum allocation compared to the global average (Pedros, et al 2020). Of the African countries, Nigeria has experienced the slowest broadband speed while South Africa leads. The Nigerian National Broadband Plan 2020 – 2025 aimed to deliver download speeds of 25 Mbps in urban areas and 10 Mbps in rural areas with coverage to at least 90% of the population. Nigeria had the lowest mean download speeds of the countries which is not surprising given that the journey of spectrum allocation in the 2.6GHz frequency band has been delayed so many times. In 2020, the mean download speed jumped from 1.62 to 4.71. The launching of LTE-A by MTN Nigeria after the

800MHz approval in 2019 could have to do with this significant improvement in download speeds, especially because MTN Nigeria is the market leader.

Kenya started off leading the pack with a faster download speed and was one of the first countries to make the switch in 2015 from analogue to digital, which resulted in the 700MHz frequency band being available for testing in 2016 by private and public entities to boost Internet speeds (The community society of Kenya, September 2016). Download speeds began to decline in 2019 at which point it was surpassed by South Africa. With Kenya one of the first countries to offer 4G, it is surprising that broadband penetration rates have remained stagnant and even been superseded by South Africa which launched 4G only later. To further investigate this, two of the main players in South Africa and Kenya were compared to better understand plausible reasons for this. Vodacom and Safaricom were selected as the players to drill down into plausible explanations why the broadband speed in Kenya has stagnated. A snapshot of the service revenue and capital expenditure for the two operators from 2018 to 2021 is shown in Figures 12 and 13.

Figure 12

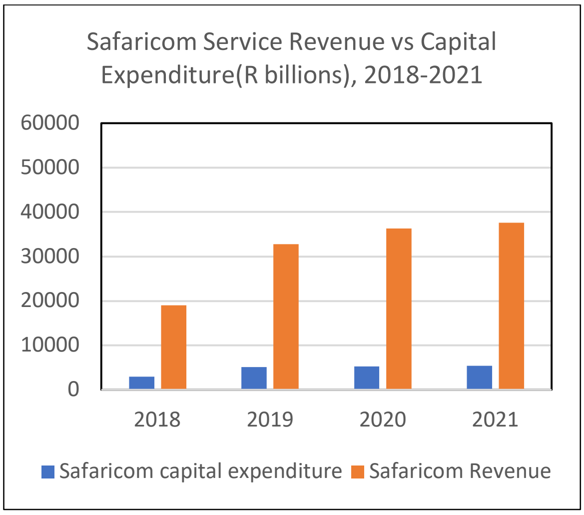
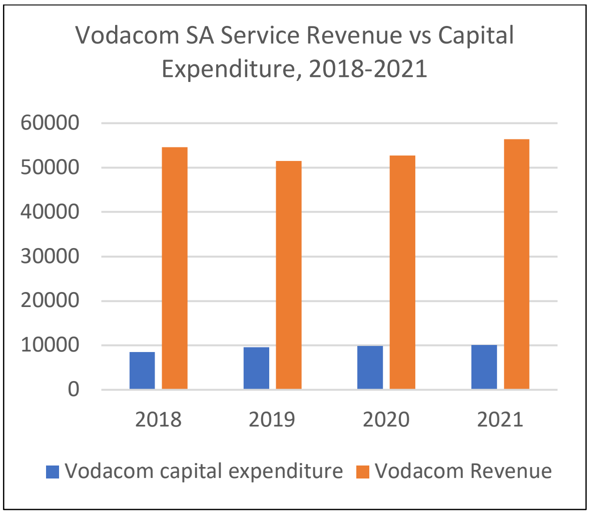


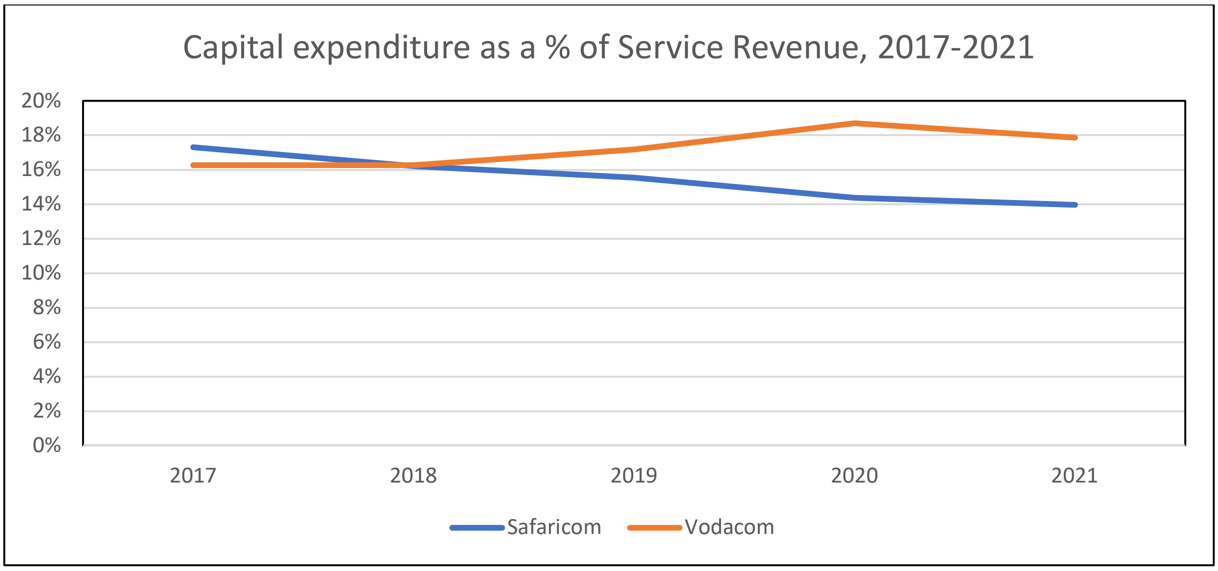
Figure 13



Source: Vodacom Company financial reports

The graph indicates that Safaricom continued to grow its service revenue over the period with the biggest jump from 2018 to 2019 which was driven by an increase in customers and the growth of M-Pesa (Vodacom preliminary results, 2019). Capital expenditure for Safaricom remained relatively low. Vodacom SA invested in network infrastructure and implemented several initiatives geared towards the increasing demand in response to Covid-19 when capital expenditure increased by 2.2% in 2021. Service revenue increased by 7% in 2021 owing to increased demand for connectivity. These graphs show only a snapshot of the market even though these are the largest operators in the respective markets. The aim here was to identify how much capital investment has been made by the operators to improve their network capacity and infrastructure. Given that the two markets are different as well as the size of both operators, the graphs are insufficient when comparing the two. Figure 14 below compares the two operators more accurately by representing capital expenditure as a percentage of service revenue. In 2017, Safaricom, which had a greater proportion of capital being invested, began to decline and was surpassed by Vodacom in 2018. Capital expenditure as a percentage of service revenue continued to decline while that of Vodacom increased showing their commitment to expanding infrastructure, which, as highlighted previously, could be due to the lack of spectrum release or to the increased competition that Vodacom faces compared to Safaricom.

Figure 14: Capital expenditure as a percentage of service revenue

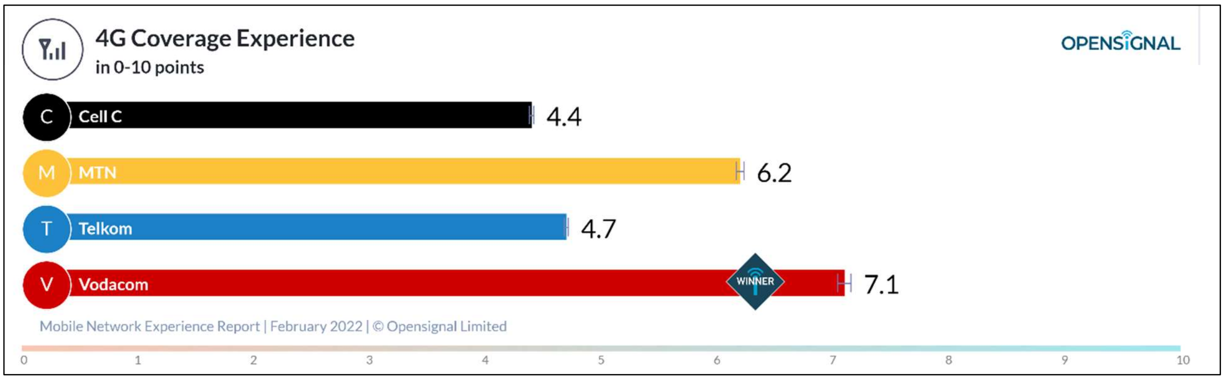


Source: Company financial reports for Vodacom and Safaricom

It is clear in the Kenyan case (represented by Safaricom) that the growth in capital expenditure has been marginal and thus possibly explains why broadband quality has not improved significantly. Vodacom has made a greater investment and thus possibly explains the higher speeds in South Africa compared to Kenya who had licenced spectrum earlier. Vodacom likely had a greater incentive to invest because it faces greater competition while Safaricom had less of an incentive owing to market dominance. It is also possible that Vodacom had a greater incentive to invest in infrastructure due to the delay in high-demand spectrum release.

The latest Mobile Network Experience Report released in February 2022 on South Africa (Opensignal.com), which is aimed at reflecting the consumer mobile experience reveals a little more on what consumers experienced. Figure 15 below illustrates how consumers experience 4G coverage on an operator's network.

Figure 15: 4G Coverage Experience



Source: Opensignal.com

Regarding coverage experience, Vodacom leads the pack with a 7.1 score out of 10 while MTN follows with 6.2 points, Telkom at 4.7 and Cell C at 4.4. The spectrum holdings of MTN and Vodacom are the same so it is unlikely that these differences are attributable to the spectrum holdings of the operators. Seeing that 4G coverage experience analyses the locations where consumers obtained 4G signal relative to other operators, this may be explained by Vodacom's greater share of the market. Indeed, more spectrum would enable MNOs to reach a greater number of consumers as they expand into rural South Africa as part of the goal to bridge the digital divide.

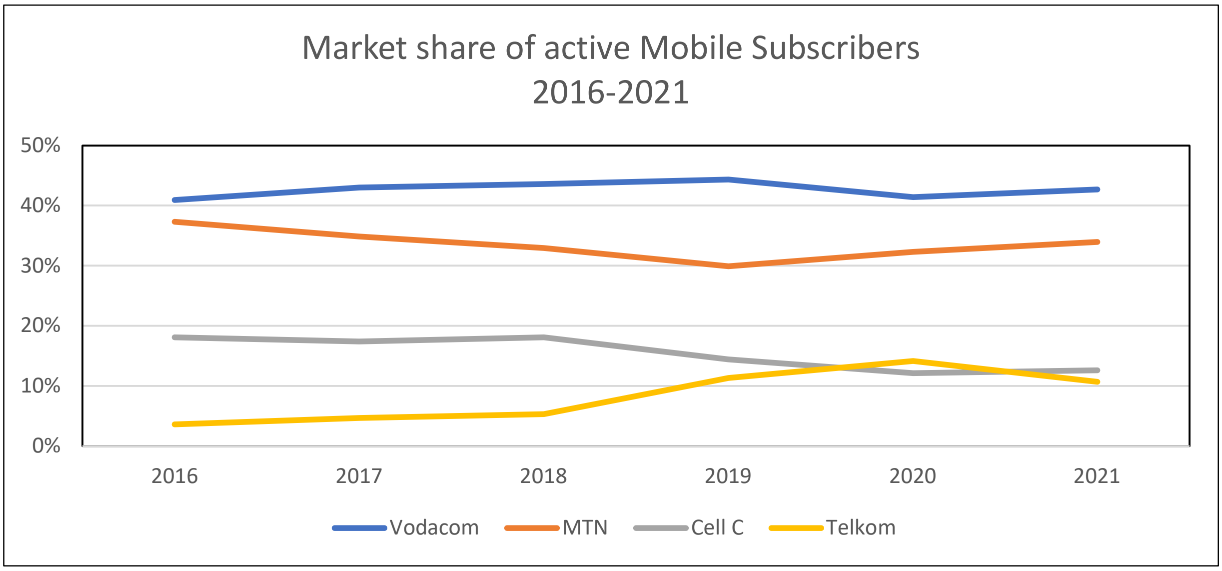
The above shows that the spectrum allocation journey is certainly one that African governments and regulators need to be more deliberate about to increase the quality of broadband since this affects the user experience. They need to insist that spectrum holders are committed to ensuring that the allocated spectrum is being fully used and the necessary capital outlays are made for network infrastructure to emphasise that the spectrum made available to operators is used efficiently and effectively. While they cannot and should not dictate to operators what capital expenditure is made, conditions set for the use of spectrum may be a useful way to encourage operators to improve their network infrastructure to make use of this spectrum. It is important to avoid cases such as Nigeria where spectrum was awarded in the 2.3GHz spectrum band in 2013 but by 2017 there was minimal evidence of the rollout of LTE services (Song, 2017). It is also evident, given the Safaricom and Vodacom comparison above, that where operators dominate, there may be less incentive to improve infrastructure, and thus interventions by competition authorities to promote competition may also have a positive impact on the levels of investment and quality.

In Egypt, the mean download speed remained relatively flat between the years 2017 and 2019, but only in 2020 was there a notable increase. This coincides with the award of licences of 40MHz of spectrum in 2020 although it cannot be concluded that it was a result of this spectrum allocation since it usually takes time to see the results of the awarded spectrum because operators have to make the necessary infrastructural adjustments.

4.3 Mobile Network Operator market shares (MNO)

Economic theory asserts that competition helps to regulate the market and improve the level of products and services consumers get from service providers. The more competitive a market is, the more service providers improve their product or service offerings to capture a greater share of the market. The market share of mobile subscribers for the respective MNOs was considered when assessing the level of competition and the impact of the delay in releasing spectrum possibly had on broadband access. It must be noted that the market share data is for mobile subscribers in their entirety for each operator and not specifically for their share of the market in broadband services. Each country's market shares are illustrated in Figure 16 below for the main mobile market operators and, owing to data limitations, only Germany, Kenya and South Africa had data provided from 2016 until 2021 while for Kenya and Nigeria it was until 2018.

Figure 16: South Africa Mobile Subscriptions Market Share



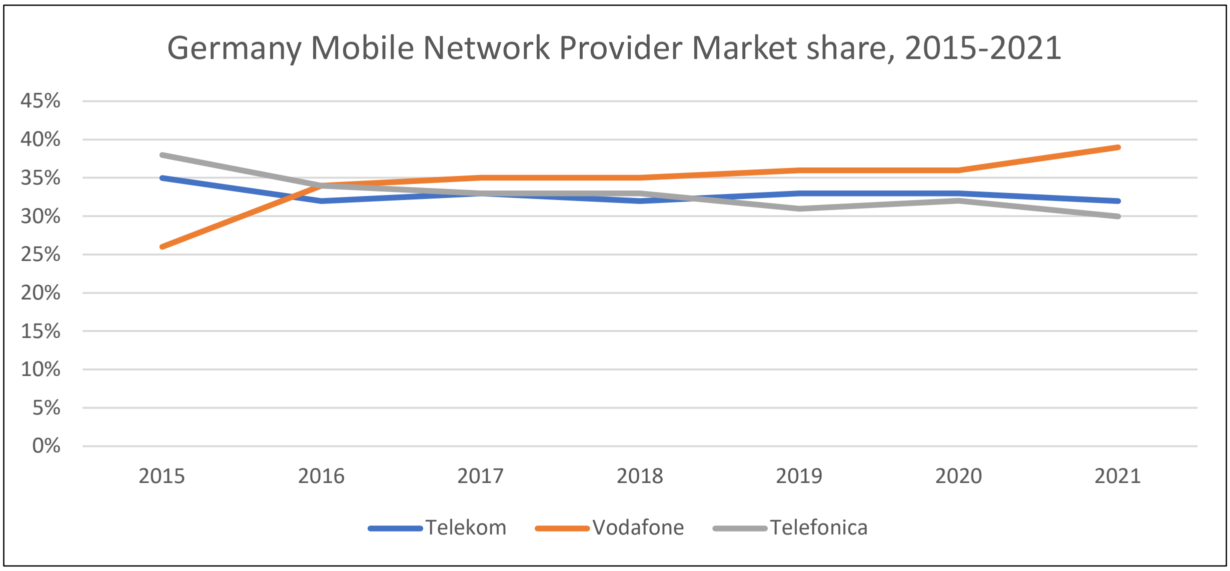
Source: Company financial reports

Vodacom SA is the market leader in South Africa with a market share of 43,79%, nearly half of the market. This is followed by MTN at 31.79%. They have dominated the market for several years and Cell C is the third largest operator. Market shares for Vodacom dropped from 2019 and 2020 at which point it started to pick up again. Owing to the delays in releasing high-demand spectrum, not much can be said on the impact of spectrum release on competition. However, in April 2020 ICASA released temporary spectrum to meet the increased demand with employees and students having to work and learn from home. The MNOs that were given this temporary spectrum were Vodacom, MTN and Telkom. In all the spectrum bands, except the 2300MHz band, MNOs were given an equal allocation of spectrum. MTN was the only operator not to have been awarded the temporary spectrum licence in the 2300 MHz frequency band.

The spectrum was made available to the operators in April 2020 but there was a time lag in the operators using it, and as reported by Broadband (2020), MNOs still needed to buy and install new radios and equipment to use this temporary spectrum. The objective of allocating this spectrum was to ensure that consumers get good quality connectivity and to alleviate congestion. One of the conditions that MNOs were given was to ensure that they support and create virtual teaching and classrooms during the National Disaster period and zero rate all Covid-19 sites. Therefore, the marginal increase in active mobile subscriptions and thus market share, cannot conclusively be attributed to the increase in this temporary spectrum, which operators had to return to the authority.

In addition, given that this data does not separate broadband subscriptions from voice subscriptions, it is hard to judge just how much impact the awarding of this temporary spectrum had on competition in the broadband data market. It is noteworthy that Telkom and Cell C have struggled to grow their market share, when Telkom experienced a decline from 2020 and Cell C plateaued after a decline. This raises the question whether the smaller players in SA can compete effectively with the incumbents who have dominance and perhaps highlights the need for more deliberate pro-competition policy and regulation.

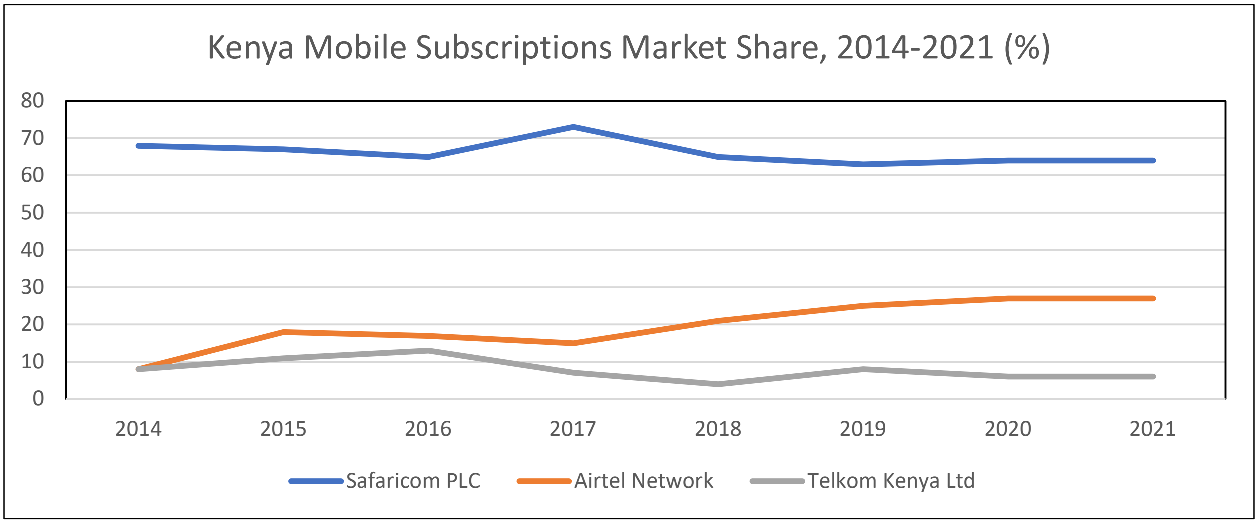
Figure 17: Germany Mobile Network Provider Market Share



Source: Statista 2022

The three dominant players in Germany have had relatively stable market shares over the period. Vodafone has the largest share at 38.7% in 2021. The graph reflects a market structure that at first glance seems to be more competitive. However, caution should be exercised in concluding that this means the market is competitive because the stable market shares could in themselves be an indicator of a market that is not very competitive. This is in contrast to South Africa who have one more operator but less competition. The operators in Germany appear to be competing for market share since they have a similar share of the market and there have been some fluctuations. This market structure leads to fewer concerns with using an auction as the chosen method of spectrum allocation. Concerns of the largest operator being able to acquire the available spectrum owing to its dominance reduces. However, this may deter new entrants where market shares are relatively stable, which presents a challenge for them because the capital outlay required to compete effectively is intensive. The market share of the main operators in Germany has remained fairly consistent even after awarding them spectrum in 2015. Looking closely at the spectrum award of 2017, Vodafone Germany had a greater allocation at 110MHz across the different frequency bands, followed closely by Telekom Deutschland at 85MHz and Telefonica at 60MHZ. When assessing Figure 17 above, Telefonica has dropped its market share after starting in a position with a higher market share than the other two players in 2015. Vodafone Germany has surpassed the other two players. This could be illustrative of the fact that the higher spectrum allocation to Vodafone has resulted in them gaining a higher share of the market. It will be useful for future studies to assess the impact of the 5G frequencies on competition.

Figure 18: Kenya Mobile Subscriptions Market Share

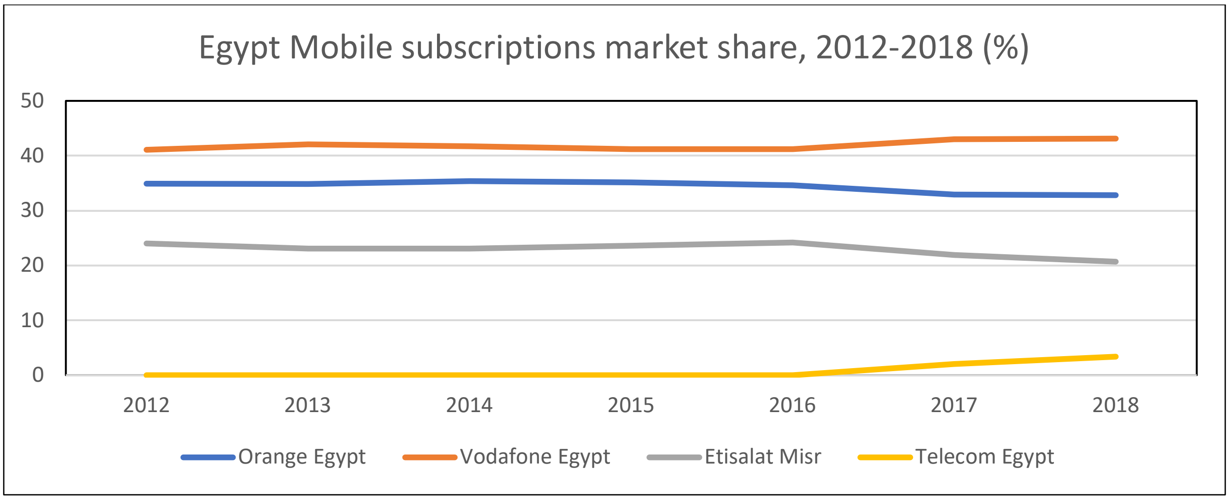


Source: Communications Authority of Kenya Annual reports

Safaricom consistently held the greatest market share in Kenya, at nearly two-thirds of the market, over the period reflected in the graph above. It has consistently dominated the market and peaked at a market share of 71.9% in 2017 but started to drop while Airtel Kenya experienced the sharpest growth of the network operators moving from a market share of 14.9% in 2017 to 21.4% in 2018. The partial retraction of spectrum in 2015 that was initially awarded to Safaricom to allocate it to Airtel Kenya and Telkom Kenya in the 800MHz band was a good move by regulators to enable all players to have a fair chance at improving broadband access for their users. It does seem, however, that Airtel Kenya obtained the greatest benefit of this move over the other smaller operators such as Telkom Kenya. The move to award smaller players with the spectrum must be done with careful consideration without giving one smaller player an unfair advantage over the others, in an attempt to make the market more competitive.

Safaricom holds dominance in Kenyan with two-thirds of the market, which is much more than in any of the countries in the study. It was beneficial in a market like this that the regulator requested Safaricom to hand back part of its spectrum to allocate to smaller players and give them a chance to provide quality broadband to their users, which may not have been achieved if an auction system was used. In 2017, the market share of Safaricom began to decline while that of Airtel Kenya increased, which is a likely indicator that the move by CCK to request Safaricom to hand back some spectrum in the 800MHz band was a wise decision in allowing smaller players to improve services for their subscribers and compete more effectively. The administrative manner in which spectrum is allocated, licensed and managed makes sense because if it was auctioned, the smaller players may not have otherwise stood a chance to gain market share. Nonetheless, caution should be exercised with administratively allocating spectrum to smaller players in a market such as this one, to encourage competition from other up-and-coming operators rather than skewing it towards one. A strict spectrum cap could work if an auction is the chosen method since Safaricom would be limited in terms of how much they could acquire, leaving the rest of the players with a fair chance to acquire spectrum. Special attention should also be given to the price at which incumbents and new entrants are sold spectrum because this may deter new entrants and inhibit competition, and cause even more dominance.

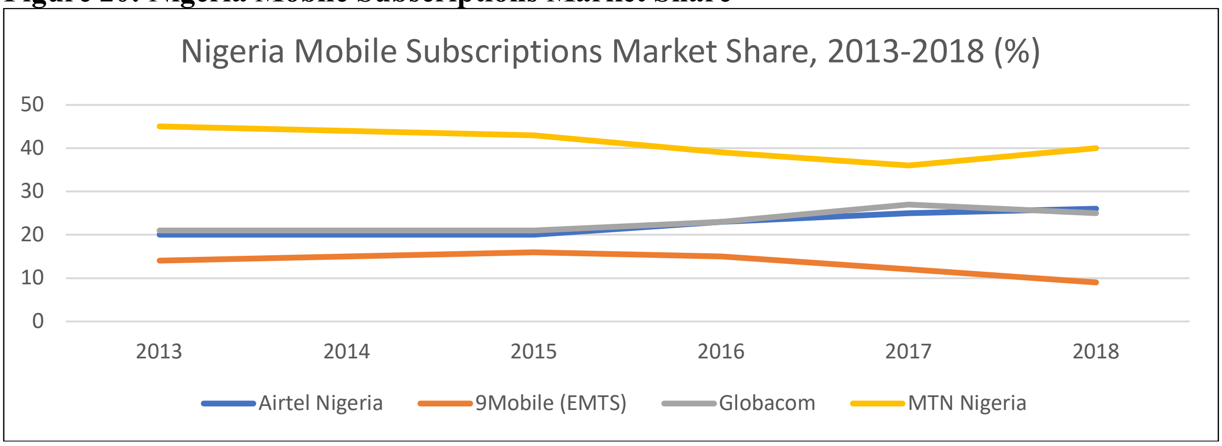
Figure 19: Egypt Mobile Subscriptions Market Share



Source: Asoko Insight

The dominant player in the Egyptian market has consistently been Vodafone Egypt with the highest market share of 43% in 2018 followed by Orange Egypt at 32%. The market shares of the three main MNOs remained relatively stable until 2017 when Orange Egypt's declined by 2% while Etisalat Misr saw its sharpest decrease of 3%. The decline in market share for these players coincides with the entry of WE, the mobile network formed by Telecom Egypt in 2017. Vodafone Egypt saw an increase of 2% in market share. All the operators were allocated spectrum in 2017. Vodafone and Orange both hold total spectrum of 42.5 MHz as reflected in the Spectrum table in the Appendices. They are followed by Etisalat at 40MHz and WE at 15MHz.

Figure 20: Nigeria Mobile Subscriptions Market Share



Source: Asoka Insight

The Nigerian market is dominated by four main players: Airtel Nigeria, Globacom, MTN Nigeria and EMTS. MTN Nigeria is the market leader and has experienced a steady decline in market share in mobile subscriptions from 2013 when it was at 45% to 40% in 2018. Airtel Nigeria experienced growth from 2015 and has continued to rise. As the market share of Airtel Nigeria continued to rise, the market share for MTN Nigeria declined which could be illustrative of consumers switching from one MNO to another. A study conducted by Nkordeh, Stanley, Olu, Popoola, Bob-Manuel and Aderemi (2018) reveals that the markets share of MTN began to decline significantly in 2013 after the introduction of mobile network portability in Nigeria. The reasons they cite for subscribers changing from one network to another is owing to poor quality service, high tariff rates on data bundles and inefficient customer care agents.

One of the other leading causes in the significant decline of market share of some of the operators was that authorities in Nigeria had to force MNOs, through issuing fines, to deregister improperly registered lines after it was found that this aided terrorist group Boko Haram to organise attacks. Etisalat had the largest number of consumers and had to deregister 19.46 million, followed by MTN at 18.6, Airtel Nigeria at 7.2 and Globacom at 2.33m (Africa Research Bulletin, October 2015).

Spectrum in the 2.6GHz band was awarded only to MTN Nigeria, for 10 years, in 2016 because they were the only operator to meet the requirements. MTN Nigeria's market share began to increase in 2017 after having declined from 2014. In 2017 this market share increased from 36% to 40% while all the other operators declined except Airtel Nigeria which increased only marginally, by 1%. This reflects that the awarding of spectrum has potentially had an impact on increasing market share, since MTN Nigeria was the only operator awarded spectrum.

Some industries have higher barriers to entry than others, which then results in fewer participants in the market. This proves to be no different in the broadband data market because there are capital outlays to be made for infrastructure and obtaining spectrum licences. Owing to the licensing requirements the countries in this study have few MNOs who dominate the market with not many instances where new entrants have been able to enter the mobile market and provide mobile broadband services. Many of the new entrants are MVNOs who have to rely on the licences that the MNOs possess. It appears from the countries reflected above that in more competitive markets there is no dominant player, so allocating spectrum using an auction affords the participants a fair chance in obtaining additional spectrum to enhance universal access. In South Africa, Vodacom and MTN have continued to dominate the market despite the entrance of Rain in the MVNO space. An important factor to consider is the fact that Rain is not a typical MVNO since they can acquire their own spectrum and traded some of it for access to Vodacom's network towers.

Owing to spectrum in South Africa being released only in 2022, it was difficult to assess what impact this has had specifically on competition in broadband services. It emerges that how spectrum is allocated also has implications on competition. Smaller entrants are wary of allocation by using an auction because they argue that the bigger players are better positioned to get access since the cost of acquiring spectrum is often priced too high, which results in the smaller players or new entrants being deterred. MTN Nigeria was the only bidder to qualify for the 2.6GHz spectrum auction and was subsequently awarded a 10-year licence in 2016. It appears, based on the crude market share metric, that this may have harmed competition.

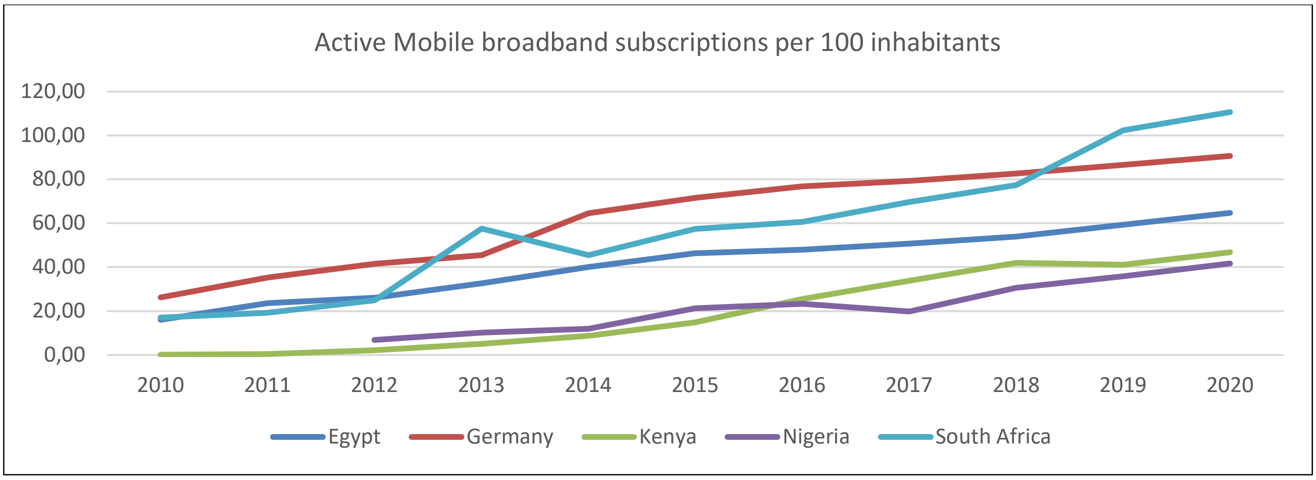
In Kenya, the smaller players, Airtel Kenya and Telekom Kenya, were awarded additional spectrum in the 800MHz band bringing each player to a total of 10MHz in that band in 2015. This spectrum was awarded at the request of the Kenyan government to Safaricom who had initially been allocated this and about which the smaller players complained. The market share of Airtel Kenya leapt from 16.5% in 2014 to 21.4% by 2018. There was however a decline between the years of 2016 and 2017 which could be attributed to a review of a tariff that led to a reduced number of new acquisitions for the operator (Communications Authority[19]). One of the concerns often cited in allocating spectrum using an auction where there are a few large operators, is that they are more likely to obtain the additional spectrum where new entrants are excluded, and thus could result in even greater dominance which might ultimately affect the consumer in the form of higher prices, less quality and less coverage. Safaricom and other operators classified as "other" were the only operators who saw an increase in market share between 2015 and 2016. In such a market, it may be worthwhile to give new entrants an opportunity as the Kenyan authorities did by awarding spectrum administratively. The price of data is explored later in the paper.

[19]Communications Authority of Kenya, third quarter sector statistics report for the financial year 2016/2017

4.4 Broadband penetration rates

Broadband penetration rates can give policymakers and regulators an indication of the impact of the various interventions they have targeted to increase universal access. According to a GSMA report, operators who have had more access to spectrum have had higher broadband coverage. As highlighted above, South Africa has a goal to increase broadband access to a wider audience to improve the livelihood of its citizens and increase economic growth. Nigeria has been highlighted as the largest mobile telecommunications market in Africa but lags when it comes to 4G coverage with only 37% of the population covered, and download speeds lagging that of countries in similar income brackets (Nigerian National Broadband Plan 2020-2025). When compared to its peers, Nigeria is reported to lag South Africa, Egypt and Kenya who have penetration rates of 113%, 74% and 48% respectively (Business Day, 25 March 2022). Figure 21 below further explores this by relating that to the population size in each country.

Figure 21: The number of mobile subscribers per 100 inhabitants



Source: ITU data on active mobile broadband subscriptions

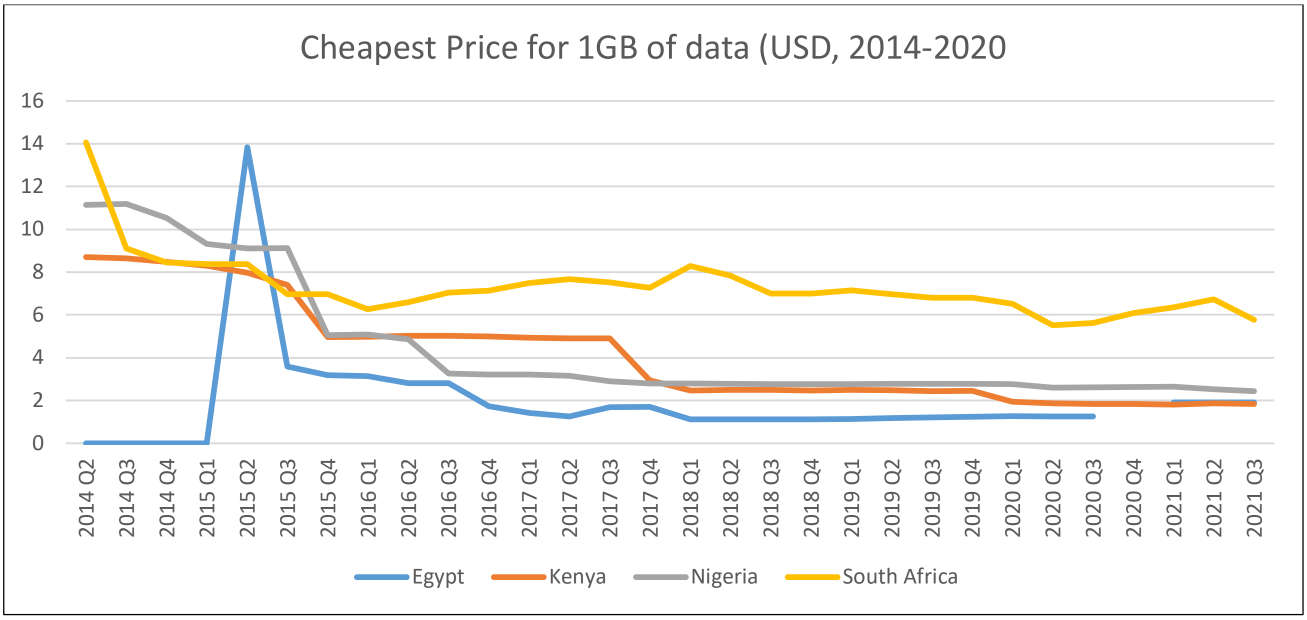
This is the number of active mobile broadband subscriptions in relation to the population of the country. South Africa has the highest penetration rate among the five countries at 110% in 2020 followed by Germany at 90%. South Africa has the highest active mobile subscriptions per 100 inhabitants, and it crossed the 100% mark in 2019. During that period, no new spectrum was allocated so this increase in mobile broadband penetration cannot be attributed to that. Having had a penetration rate less than 20% in 2010, South Africa's penetration rate has grown remarkably and overtook Germany in 2018 to have the highest mobile penetration rate of the five countries. This is in line with the growth seen in mobile broadband in developing nations compared to developed nations, who rely predominantly on fixed broadband. This growth has taken place despite the delay in allocating high-demand spectrum. It is evident from the analysis that thus far spectrum assignment is important but it is not the only factor in influencing broadband penetration rates positively. There are clearly factors outside of spectrum release that enhance broadband penetration and, essentially, competition policies and regulatory measures geared at improving broadband access must consider that because spectrum assignment is critical, it cannot be removed from these other factors. Kenya experienced the steepest growth of broadband penetration rates among African countries between 2015 and 2018. They are the only country to have been awarded 800MHz spectrum in 2015. The 700MHz spectrum was awarded as a pilot in 2017 and only officially awarded to a new operator in 2019 after litigation was resolved. After 2018, broadband growth began to stagnate.

Germany had the highest jump in penetration rates between 2013 and 2014 moving from 45% to 64%. Spectrum in the 800MHz frequency band was awarded in 2012 and by November of the same year, all thirteen states had met their coverage obligations to rural areas. The significant spike in broadband penetration over such a short period may be attributed to the release and awarding of this spectrum band. Nigeria has had the slowest growing broadband penetration rates even though it has one of the largest populations in the world. It is also considered one of the largest telecommunications markets in Africa and one would expect to see better penetration rates. There have been many issues in Nigeria which have inhibited the progress that one would expect to see in such a large market. Their journey of spectrum allocation has been marred by the postponement of the awarding of spectrum in the 2600MHz frequency band, as evidenced in the last section on spectrum resulting in MNOs having less faith in the system. The terms of the award were also onerous resulting in only one applicant applying when the invitation to bid was issued. When this happens, operators tend to invest less on infrastructure aimed at expanding services to meet the demand of citizens.

4.4 Prices of 1GB of data

The price of data is one of the measures in assessing broadband accessibility. If the price is too high it affects the accessibility consumers have to broadband especially in poorer or developing nations where the income per capita is low. Data prices have been a bone of contention in South African as evidenced by the market enquiry conducted by the South African Competition Commission. The public outcry prompted this enquiry into mobile broadband data prices. MNOs have cited in their various submissions that the impact of not releasing high-demand spectrum has meant that they have had to spend more to ensure that their customers have access and coverage from quality broadband services, in the face of a lack of high-demand spectrum. This means that they have had to spend more to ensure that they can meet consumer demands in both urban and rural areas where 700GHz spectrum is required owing to its higher propagation characteristics. To further investigate this, the price of 1GB of data in USD for the four African countries was considered. Figure 22 below shows the lowest price of data across Egypt, Nigeria and Kenya. The price of data was measured quarterly over a period running from 2014 to 2021. The price of 1GB of data has been on a downward trajectory across all countries. In South Africa, the price peaked in Q1 of 2018 and it started dropping again, but remained significantly higher than the other countries at nearly three times more. Prices in Egypt have been the lowest and have remained steady from 2018 Q1 right through to 2020 Q2. Nigeria experienced a sharp decline between 2015 Q3 and 2015 Q4 and continued to fall until steadying from 2016 Q3. Kenya was on a downward path and plateaued in 2015 Q4 until a further decrease in Q4 of 2017.

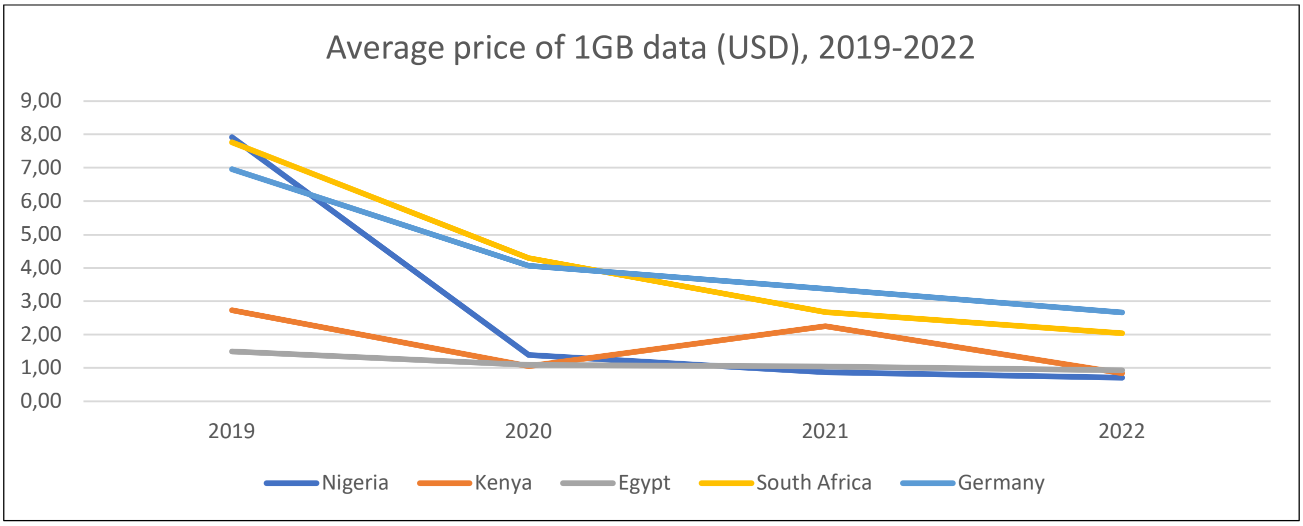
Figure 22: Cheapest price for 1GB of data



Source: Research ICT Africa Mobile Pricing (RAMP)

From Figure 22, it can be seen that the price of data has remained relatively flat with little change over the period when considering the cheapest 1GB of data. South Africa has been more developed when it comes to mobile broadband, as seen in previous sections, when it comes to quality and penetration, however the prices remain higher than its African counterparts, which may indicate that the delay in allocating high-demand spectrum has to an extent affected the price of data. The extent of which remains to be seen now that this high-demand spectrum has recently been awarded to winning bidders in 2022. However, it is not necessarily the price of spectrum that will lower the price of data, as per the findings of the data market inquiry by the Competition Commission of South Africa. The inquiry has certainly confirmed that the costs operators face due to a lack of spectrum are significant but have reported that the release of high-demand spectrum will not necessarily translate to lower data prices without increased competition (Data Services market enquiry, P172). To further investigate, the average price of 1GB of data was looked at for all the countries forming part of the study including Germany, as Figure 15 above only considered African countries in the study. The average price of 1GB of data from 2019 to 2022 featured a sharp drop in 2020 owing to methodological changes at mLab where the data was sourced. Kenya is the only country that experienced an increase in average prices of 1 GB of data from 2020 to 2021. Egyptian average prices have remained relatively flat over the period. Germany has had a consistent decline in the average price of 1GB of data but remains higher priced than all the other countries in USD terms.

Figure 23: Average price of 1GB data



Source: Cable.co.uk

At face value, based on these results and comparing them with when spectrum was released, one would conclude that lower data prices are not dependent on the release of spectrum, given that all the countries were on a downward path for the price of data, even without any allocations as in the case of South Arica. However, the comparison in price across the countries does not consider other important differences. A study by Grechyn & McShane (2016) found that the difference between income levels and GDP per capita are among factors affecting the price levels. Investments at operator level have also not been considered to factor into capital expenditure incurred when upgrading to next-generation networks, which one would expect to result in data prices remaining the same, even with additional spectrum as operators try and recoup the capital outlay.

CHAPTER 5: CONCLUSION

Each authority and government need to fast-track their release and licensing of spectrum to meet their respective goals of increasing broadband access for the betterment of the citizens of the country. In a world where digital transformation has accelerated the way business is done and provided consumers with more access, enabling them to better their lives through access to the Internet, authorities need to ensure that both supply-side and demand-side policies support these goals timeously. Although the study had various complexities making it difficult to make like-for-like comparisons across the countries as they pertain to the variables measured, a few interesting observations were made and their potential linkages to high-demand spectrum. Overall, the study has revealed that delaying the release of high-demand spectrum, a supply side factor, has indeed negatively impacted broadband access in South Africa.

Notably, the quality of broadband (measured by download speed) has not grown to meet the goal which was set through SA Connect of having at least 50% of the population at 100 Mbps. Although it was mean download speeds that were used to represent their levels, its peaking at 19.91 Mbps in 2021 is indicative that the delay in allocating high-demand spectrum has constrained universal access for South African consumers when it comes to quality. Comparatively speaking, there is a vast difference between the mean download speed in Germany and that of the three African countries which, at face value, shows that the delays in releasing high-demand spectrum have negatively affected the goals set by the African countries in their respective goals for broadband quality. While this may in part indicate that the lack of allocating high-demand spectrum has inhibited MNOs from offering better-quality services to their customers, the analysis shows that there are more complexities to consider when doing a comparison across countries.

There are other factors to consider when seeking to understand or solve for the impact that the lack of spectrum assignment has had on broadband access. It is clear that even when the additional spectrum has been assigned, such as in the Kenyan case, there are factors that need to be considered, including the level of capital investment operators make towards improving the quality of services like increasing base stations. that need to be considered. The impact of not making the required investments is that consumers are faced with poorer quality hindering productivity, a lack of broadband access in rural areas and thus potentially inhibiting economic growth that would have otherwise been obtained through better-quality broadband services. The Kenyan case showed that even when spectrum is made available, this will not necessarily lead to higher download speeds if MNOs do not spend the necessary capital to effectively make use of the available spectrum. A holistic approach is necessary when designing policies and regulations because operators who are issued the spectrum may not innovate or invest in the necessary infrastructure to ensure improved quality of services. Authorities should endeavour to increase competition in the mobile broadband data market to improve the quality of services rather than just expecting that spectrum assignment on its own will resolve this. Germany illustrated this well when their authorities mandated that those operators who have been allocated spectrum must roll out services in all 13 states before any additional spectrum is released. Therefore, it is important that spectrum licensing be accompanied by requirements by regulators for operators to make use of the spectrum to encourage this investment which should, in turn, result in better-quality broadband. Additionally, by encouraging competition, operators will have a greater incentive to make the necessary capital expenditure to protect and grow their market share.

From a price perspective, it wasn't clear whether greater spectrum availability holdings result in lower prices being charged to the consumer for data. This was particularly evident in the case of Germany where the price of 1GB of data was the highest of the countries in USD terms. However, it is noted that this is comparative pricing and does not consider factors such as the cost of living in each of the countries and also does not account for the better quality that is found in Germany. A quality-adjusted price may give a better reflection for future studies. The data market inquiry in South Africa also revealed that high data prices are not always due to the lack of spectrum. While there is merit to the high costs that operators face due to having to spend more on infrastructure with limited spectrum and ensure consumers have quality broadband, it cannot be assumed that the allocation and release of high-demand spectrum will automatically lead to lower data prices. Promoting competition by encouraging more new capable entrants to participate is necessary to also encourage lower prices. The presence of Rain as an MVNO has likely also aided to drive down prices. The high reserve prices at auctions of acquiring spectrum may in itself initially result in increased data prices while operators try to recoup their investment. Caution must be exercised too when setting reserve prices for acquiring high-demand spectrum so there is not too much focus on raising revenue for the government through these, which can deter new entrants or fail to attract participants in spectrum auctions.

Studying the level of competition through market share provided an aid to better understanding how spectrum allocation affects competition and how inversely, competition is impacted by spectrum allocation especially where spectrum is allocated only to the dominant player on the market (e.g., MTN Nigeria in 2016). In South Africa, the spectrum holdings of each of the main MNOs (MTN, Vodacom and Cell C) are not far apart. In such a market, allocation via an auction is not a bad idea where operators have a relative ability to acquire spectrum. The method of allocating spectrum matters and is also important depending on how competitive the market is. It is important to carefully select the method in which spectrum is allocated depending on the structure of the market and how concentrated or competitive the market is. An auction may be a good approach in a market where the MNOs have a reasonably equitable share of the market while in less competitive markets, an administrative approach like in the Kenyan case, where smaller players are allowed to acquire spectrum, may be best to encourage participation. This should be met with obligations to ensure that operators make use of the spectrum within a certain time.

Recommendations

The impact of this delay on universal access was not easy to measure given the differences between the countries in terms of the variance in spectrum allocation. The delays that have marred the developing African countries need to be addressed to ensure that looking forward, the goals that each nation has set for broadband access are met, especially given the increasingly digitally transformed world we live in. This study was limited to measuring this impact through price, quality, penetration and competition before 2021. As more countries internationally are fast-tracking their journey with the allocation and licensing of spectrum, especially with the advent of fifth-generation networks and the advent of Covid-19 which revealed the importance of having universal access. it is recommended that South African authorities continue to design policies to ensure there are effective regulations in place to hold incumbent MNOs accountable, to promote fair competition and to encourage entry from new participants. For future studies, it will be worthwhile to study the extent to which the licensing of high-demand spectrum in 2022 has had on these variables in this study, as well as the impact on economic growth.

APPENDICES

A: Egypt Broadband policy

Targets		Short Term (2015)	Long Term (2021)
Availability Targets	Fixed	75% of households have access to Broadband (2 Mbps)	90% of households have access to Broadband (25 Mbps)
	Mobile	98% of population with 3G coverage	90% of population with 4G/LTE coverage
Penetration Targets	Fixed	4.5 million (~22%) households subscribed to broadband services	9 million (~40%) households subscribed to broadband services
	Mobile	8 million (~10%) citizens subscribed to mobile broadband services	14 million (~15%) citizens subscribed to mobile broadband services
National/Social Targets		• 50% of Egyptian communities connected to 25 Mbps • 50% of 3rd level Egyptian administrative localities (Sheyakha and Village) served with at least one Public Access Point with 25 Mbps	• 100% of Egyptian communities connected to 25 Mbps • Each 3rd level Egyptian administrative locality (Sheyakha and Village) served with at least one Public Access Point with 25 Mbps

B: Kenya National Broadband Strategy

Minimum broadband speeds

	2013-2017	2018-2022	2023-2027	2028-2030
URBAN	40 Mbps	300 Mbps	1024 Mbps	2048 Mbps
RURAL	5 Mbps	50 Mbps	100 Mbps	500 Mbps

Broadband penetration targets

	Baseline	Target by 2017
% of penetration by households	6.3%	35%
% of penetration by schools	43.4%	100%
% of penetration by health facilities	n/a	100%

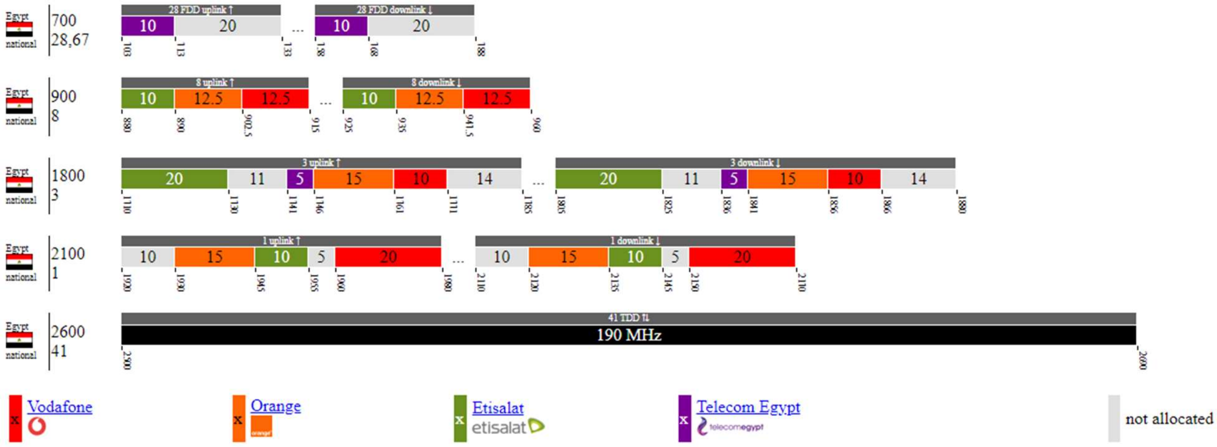
C: Nigeria Broadband policy

No	Pillar	Initiative
1	Infrastructure	Critical National Infrastructure (CNI) – Issuance of Executive Order to Declare Telecoms infrastructure as CNI and full implementation of Plan
2	Infrastructure	Establish a coordinating body for Fibre Builds – to ensure open access, prevent overlap and facilitate RoW issuance at statutory rates
3	Infrastructure	Satellite – Leverage existing NIGCOMSAT infrastructure to reach unserved/rural areas
4	Infrastructure/Policy	Implement and enforce national uniform RoW charges for fibre builds at a rate of N145/m and ensure Open Access/Accounting Separation
5	Policy	Base Station Site Acquisition – Work with States to implement One-stop Shop to accelerate approvals and harmonise fees
6	Policy	Spectrum: Ensure efficient use of Spectrum; Use it or Lose It Policy, open and transparent spectrum planning including TV White Space deployment for broadband
7	Funding Demand Drivers	Affordability - Incentivise low cost smartphone devices and promote local assembly/manufacturing of Telecom network and end device components.
8	Funding Demand Drivers	Co-ordinate Government spending, Schemes and Programs to ensure access in public institutions e.g., schools, hospitals and MDAs

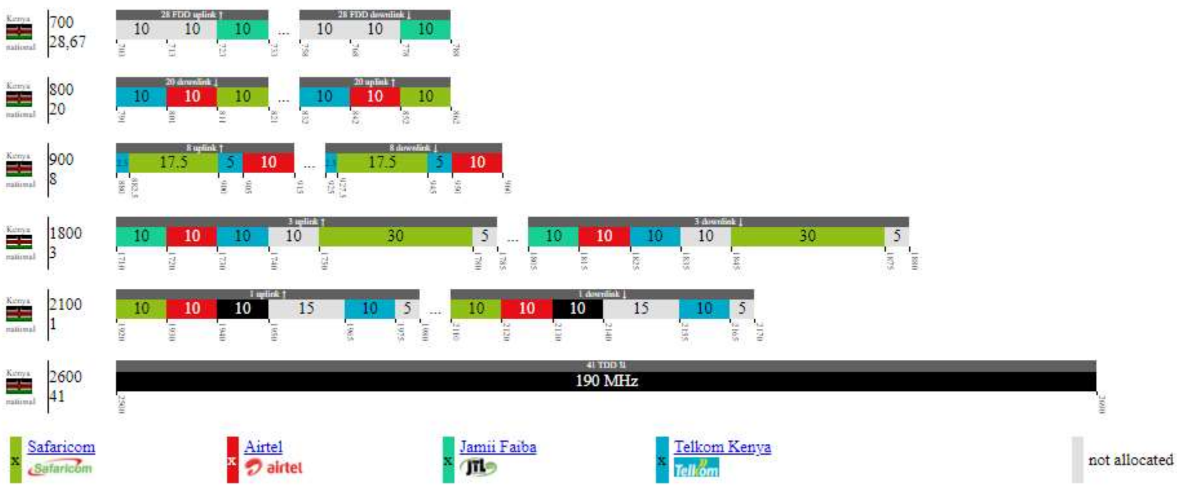
Spectrum allocations: Source: Spectrum Monitoring Global Mobile Frequencies Database by Spectrummonitoring.com

D: Country Spectrum allocations

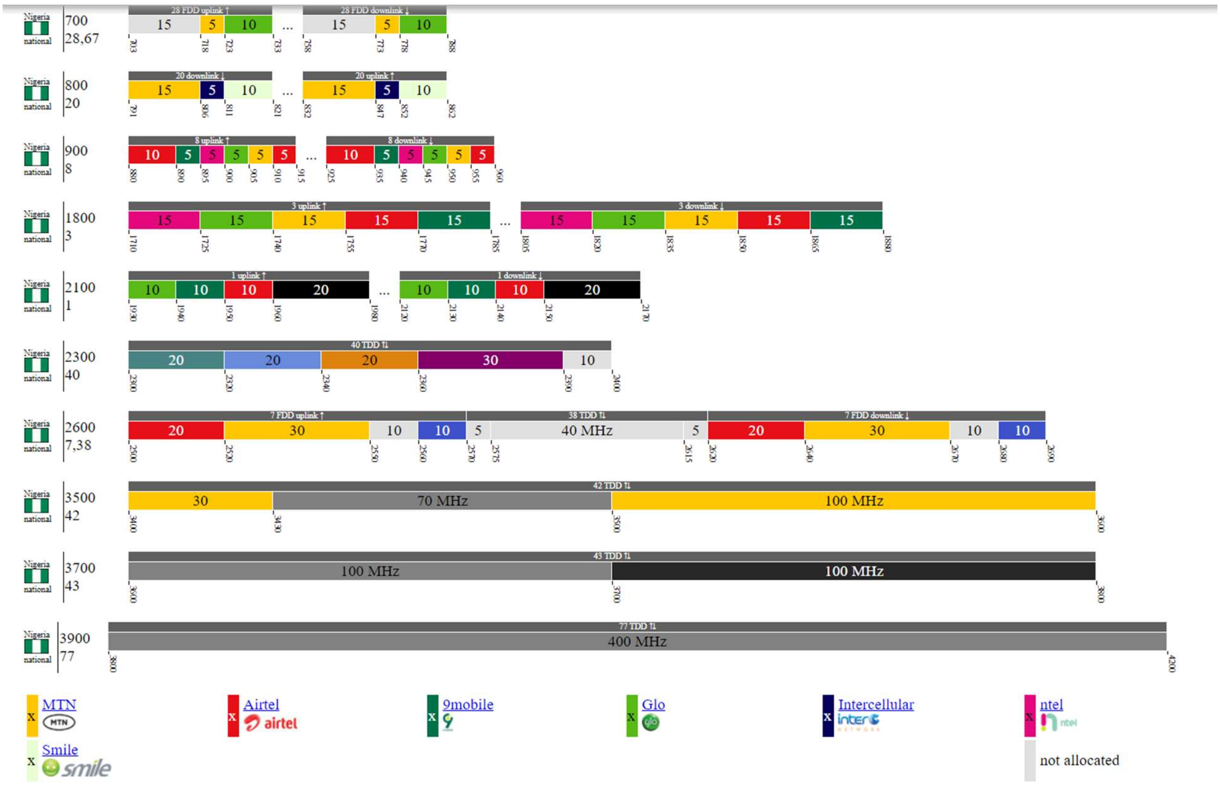
Egypt



Kenya



Nigeria


700
28,67
28 FDD uplink
28 FDD downlink
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20 uplink
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2600
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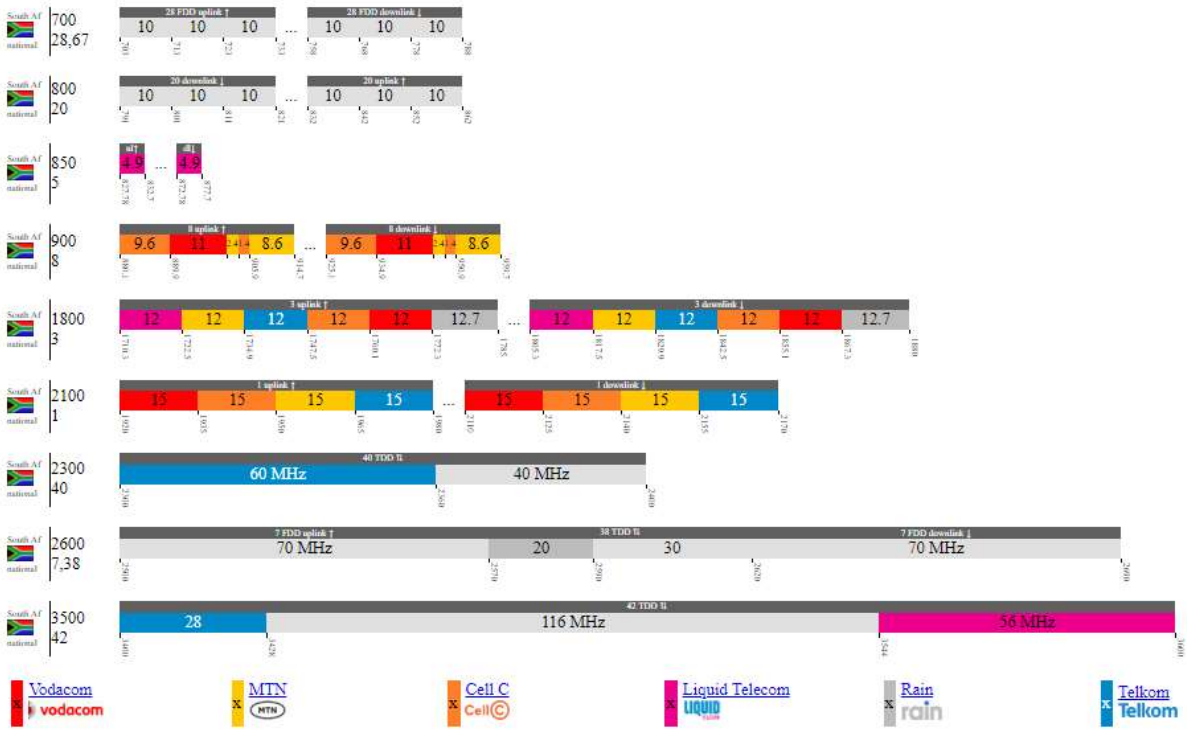
7 FDD uplink
38 TDD
40 MHz
7 FDD downlink
3500
42
42 TDD
70 MHz
100 MHz
3700
43
43 TDD
100 MHz
100 MHz
3900
77
77 TDD
400 MHz
MTN
Airtel
9mobile
Glo
Intercellular
ntel
Smile
not allocated

SouthAfrica



References

Asoko Insight (2022). https://www.asokoinsight.com/

Bahia, K., & Castells, P. (2019). *The Impact of Spectrum Prices on Consumers . TPRC47: The 47th Research Conference on Communication, Information and Internet Policy* 2019, doi:10.2139/ssrn.3427173

Bakker, H. (2016). *Spectrum and licensing in the mobile telecommunications market. ITU Regional Workshop on Competition in the Telecommunications Market*. Available from https://www.itu.int/en/ITU-D/Regional-Presence/ArabStates/Documents/events/2016/CT/Final%20Documents/Session9/Spectrum%20and%20licensing.pdf

Bauer, S., Clark, D. & Lehr, W. (2010). *Understanding Broadband Speed Measurements*, Researchgate. Available from: https://www.researchgate.net/publication/228280854_Understanding_Broadband_Speed_Measurements

Blackman, C., & Srivastava, L. (Eds.). (2011) *Telecommunications Regulation Handbook*. 10th edition. Available from https://www.itu.int/en/publications/ITU-D

Bouckaert, J., van Dijk, T., & Verboven, F. (2010). Access regulation, competition, and broadband penetration: An international study. Telecommunications Policy. Vol 34, Issue 11, pp. 661-671. doi:/10.1016/j.telpol.2010.09.001

Broadband Commission Working Group on Broadband for All. Connecting Africa Through Broadband: A strategy for doubling connectivity by 2021 and reaching universal access by 2030. (2019).

Cambini, C. & Garelli, N. (2017). Spectrum Fees and market performance: A quantitative analysis. *TelecommunicationsPolicy*,41(Issue5-6) pp. 355-366. doi:org/10.1016/j.telpol.2017.02.003

Chetty, M., Sundaresan,S., Muckaden, S., Feamster, N., & Calandro, E. (December 2013) Measuring broadband performance in South Africa. Article No.: 1Pages 1–10https://doi.org/10.1145/2537052.2537053

Communications Authority of Kenya. (c2022). Communications Authority of Kenya. Available from https://www.ca.go.ke/

Crandall, R.W (Published October 19 2021) " How Canadas wireless spectrum policy drives up mobile rates", Policy options. How Canada's wireless spectrum policy drives up mobile rates (irpp.org)

das Nair, R., & Roberts, S. (2017). Competition and regulation interface in energy, telecommunications and transport in Southern Africa. doi: https://doi.org/10.18772/22017070909.11

El-Din, M.A. (2016, October). Vodafone loses most after redistribution of 4G frequencies among companies. *Daily News Egypt*. Available from: https://www.dailynewsegypt.com/2016/10/22/vodafone-loses-redistribution-4g-frequencies-among-companies/

Elixirr. (2015). Spectrum Management in Africa: The challenges faced by regulators and operators. Available from https://www.elixirr.com/

Falch, M. (2007). Penetration of broadband services – The role of policies. *Telematics and Informatics*, 24 (4), 246-258, doi:org/10.1016/j.tele.2007.01.008

Gelvanovska, N., Rogy, M. and Rossotto,C.M.(2014). Broadband Networks in the Middle East and North Africa: Accelerating High-Speed Internet Access. *World Bank*. Available from: https://openknowledge.worldbank.org/bitstream/handle/10986/16680/9781464801129.pdf?sequence=1

Gillwald, A., Mothobi, O., & Rademan, B. (2018). The state of ICT in South Africa. *Research ICT Africa*. Available from: https://researchictafrica.net/publication/state-of-ict-in-south-africa/

Ghayas, A. (2021, November 27). FDD vs TDD: What are FDD and TDD in Mobile Networks?. Commsbrief [Online]. Available from: https://commsbrief.com/fdd-vs-tdd-what-are-fdd-and-tdd-in-mobile-networks/

Ghosh, S. (2017) Broadband penetration and economic growth: Do policies matter, *Telematics and Informatics*, 34(5): 676-693. doi:10.1016/j.tele.2016.12.007

Grechyn, V., & McShane, I. (2016). What influences Differences in Broadband Prices. *Journal of Telecommunications and the Digital Economy*, 4 (4):89.doi:10.18080/ajtde.v4n4.67

Gruber,H. & Koutroumpis, P. (2012). Competition enhancing regulation and diffusion of innovation: The case of broadband networks. *Journal of Regulatory Economics*, 43:168-195. Available from https://link.springer.com/article/10.1007/s11149-012-9205-4

Gulati, G and Yates, D.J (2012). Different paths to universal access: The impact of policy and regulation on broadband diffusion in the developed and developing worlds. Available from Elsevier https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1985792

GSMA (2020) https://www.gsma.com/

Kuroda, T. & Baquero Forero, M.D.P. (2017). The effects of spectrum allocation mechanisms on market outcomes: Auctions vs beauty contests. Telecommunications Policy, Vol 41, Issues 5-6, June 2017, pp 341-354. doi:10.1016/j.telpol.2017.01.006

ICASA. Independent Communications Authority South Africa. Available from https://www.icasa.org.za/

Ijaseun, (2022, Mar 25). Nigeria's broadband penetration rises to 41.6% in January. Business Day Nigeria. Available from https://businessday.ng/news/article/nigerias-broadband-penetration-rises-to-41-6-in-january/

International Communications Union. 2011. Handbook Spectrum Monitoring. Switzerland: International Communications Union. Available at:https://www.itu.int/dms_pub/itu-r/opb/hdb/R-HDB-23-2011-PDF-E.pdf

Katz,R. (2012). The impact of Broadband on the Economy: Research to date and policy issues

Kedama, Y. (2014). Advantages and disadvantages of ICASA's 2011 proposed spectrum licensing models. Masters research report. University of the Witwatersrand.

Kim, Y, Kelly, T and Raja, S. (2010). Building Broadband: Strategies and policies for the developing world.

Lundborg, M., Reichl & W. Ruhle,E. (2012). Spectrum allocation and its relevance for competition. *Telecommunications Policy*, Vol 36, Issue 8, September 2012, pp 664-674 doi:10.1016/j.telpol.2012.04.006

Marks, P., Lewin, D., Wongsaroj, S & Chan,Y.S. (2011). The benefits of releasing spectrum for mobile broadband in Sub-Saharan Africa: A report for the GSMA. Accessed from the GSMA https://www.gsma.com/spectrum/wp-content/uploads/2012/07/Spectrum-Plum-Report-The-benefits-of-releasing-spectrum-for-mobile-broadband-in-sub-Saharan-Africa.pdf

Marsden, R., Ihle,H. & Traber, P. (2017). *The impact of High Spectrum Costs on Mobile Network Investment and Consumer Prices*. Nera Economic Consulting

McMillian, J. (1995) Why auction the spectrum? *Telecommunications Policy*, Vol 19, N.3, pp. 191-199. doi:10.1016/0308-5961(94)00021-J

McNutt, P. (2005). *Law, Economics and Antitrust: Towards a new perspective*.

Mc Kenzie, C (2014) Mobile virtual Network Operator. Techtarget.com

Minges, M. (2015). Exploring the relationship between broadband and Economic growth. Background paper prepared for the World Development Report 2016: Digital dividends

Miller, T., Wonsaroj, S and Hogg, T. (2014). *The Economic and Social Impact of Mobile Broadband in Egypt*: *A report for the GSMA*. London:Plum Consulting. Available from: https://www.gsma.com/spectrum/wp-content/uploads/2014/09/Impact_of_Mobile_Broadband_in_Egypt_v100.pdf

Mitchell, J (2021). African e- Connectivity Index 2021: the final frontier and a huge opportunity Which country tops the African e-Connectivity Index? Investment Monitor

Muente-Kunigami, A., & Navas- Sabater, J. (2010). Options to increase access to telecommunications services in rural and low-income areas. World bank working paper no 178, retrieved from Proquest Ebook Central

Nkordeh, N., Stanley, U., Olu, V.M., Popoola, S., Bobmanuel, I., & Aderemi, A. (2018). Impact of number portability on revenue of mobile operators in Nigeria: Comparing churning rate in

MTN, Glo, Etisalat and Airtel. *Proceedings of the International Conference on Industrial Engineering and Operations Management Washington DC, USA, September 27-29, 2018.*

Odendaal, N. (2022, April 15). A step forward as South Africa embarks on first spectrum auction in over a decade. [Newspaper clipping]. *Engineering news* Accessed from https://m.engineeringnews.co.za/article/first-spectrum-auction-in-over-a-decade-a-milestone-for-south-africa-2022-04-15

OECD (2017), "Connectivity, in OECD Science, Technology and Industry Scoreboard 2017: The digital transformation, OECD Publishing, Paris

Research ICT Africa. (2022). *Research ICT Africa Mobile Pricing Index(RAMP).* Available from: https://researchictafrica.net/research-ict-africa-ramp-index-2/

Simbanegavi, N. Sitko, I. Valodia, et al. (Authors) & J. Klaaren (Ed.), Competition Law and Economic Regulation in Southern Africa: Addressing Market Power in Southern Africa (pp. 120-148). Wits University Press.

Song, S., Rey-Moreno, C. & Jensen, M. (2019). *Innovations in Spectrum Management: Enabling community networks and small operators to connect the unconnected*. Available from: https://www.internetsociety.org/wp-content/uploads/2019/03/InnovationsinSpectrumManagement_March2019-EN-1.pdf

Song, S. (21 April 2017). The failure of Spectrum Auctions in Africa. Available from: https://manypossibilities.net/2017/04/the-failure-of-spectrum-auctions-in-africa/

Statista (2022) Internet usage in Africa - statistics & facts
Available from: https://www.statista.com/topics/9813/internet-usage-in-africa/#topicOverview

Statista (2022). Market share held by mobile network providers in Germany from 2015 to 2021 Available from: https://www.statista.com/statistics/778856/market-share-mobile-service-providers/#:~:text=Germany%3A%20market%20share%20of%20mobile%20service%20providers%20from%202015%2D2021&text=This%20statistic%20shows%20the%20market,total%20share%20of%2038.7%20percent.

Strusani, D., & Hounghbonon, G.V. (February 2020). *Accelerating digital connectivity through Infrastructure sharing*. Available from: https://www.ifc.org/wps/wcm/connect/publications_ext_content/ifc_external_publication_site/publications_listing_page/emcompass-note-79-digital-infrastructure-sharing/

Sutherland, E. & Abrahams, L. (2021). *Policy brief: Spectrum Regulation, South Africa*. Prepared for the Presidential Economic Advisory Council: Macro-dynamics Working Group. Available from: https://www.wits.ac.za/media/wits-university/faculties-and-schools/humanities/research-entities/link/documents/public-policy-series/Public%20Policy%20Series%20-%202021%20-%20Spectrum%20Regulation,%20South%20Africa%20-%20Sutherland-Abrahams.pdf

World Economic Forum: delivering Digital Infrastructure: Advancing the internet Economy (April 2014)Delivering Digital Infrastructure - Reports - World Economic Forum (weforum.org)

Wymmersch, H. and Eryilmaz, A (2016). Multiple access control in wireless networks. Academic Press Library in Mobile and Wireless Communications, Academic Press, Pages 435-465. doi:10.1016/B978-0-12-398281-0.00012-0

Wyrzykowski, R (2020). Mobile connectivity in Sub- Saharan Africa: 4G and 3G connections overtake 2G for the first time, *GSMA*, 16 November 2020 [Blog]. Available at https://www.gsma.com/mobilefordevelopment/blog/mobile-connectivity-in-sub-saharan-africa-4g-and-3g-connections-overtake-2g-for-the-first-time/

Wryzykowski, R (2022). Mobile Network Experience Report February 2022: South Africa, *Opensignal*. Accessed from http://opensignal.com/reports/2022/02/southafrica/mobile-network-experience/

Zaballos, A.G, & Foditsch, N. (2014). Universal access to broadband and service programs: A comparative study. Inter-American Development Bank. Available at https://publications.iadb.org/en/universal-access-broadband-and-service-programs-comparative-study