Roadmaps for 5G Spectrum: Sub-Saharan Africa

August 2021

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The GSMA represents the interests of mobile operators worldwide, uniting more than 750 operators and nearly 400 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces the industry-leading MWC events held annually in Barcelona, Los Angeles and Shanghai, as well as the Mobile 360 Series of regional conferences.

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About this study

This study for the GSMA seeks to identify a roadmap by which governments and regulators can make available spectrum to support the deployment of 5G services in the SSA region. The study goes on to identify where countries currently sit on this roadmap and identifies recommended actions for countries in the region.

Contents

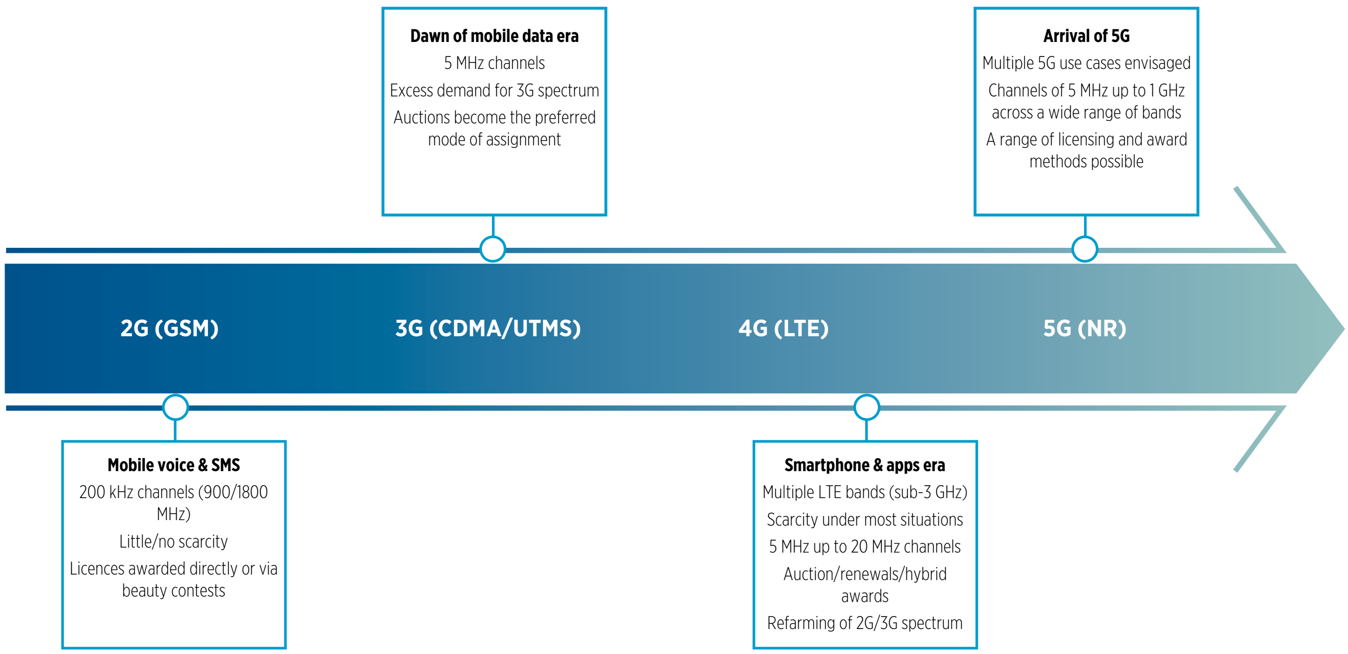
Summary

Mobile communications have quickly grown to be the largest part of the telecommunications industry, and this is particularly the case in Sub-Saharan Africa (SSA), where fixed line connections were scarce and expensive. Mobiles – first voice, and now broadband – have enabled hundreds of millions to be connected and have been a major driver of information and economic prosperity across the region. The GSMA[1] estimates that as of 2019 there were over 477 million unique subscribers across SSA, of which 272 million use mobile Internet; by 2025 it is estimated these numbers will have grown to 614 million and 475 million respectively.

The capabilities of mobiles improve constantly, but roughly every 10 years a new generation of mobile technology comes along, bringing fundamental improvements to the capabilities of mobile networks and changes to spectrum management approaches.

FIGURE 1

EVOLUTION OF MOBILE GENERATIONS AND CHANGES TO SPECTRUM MANAGEMENT APPROACHES



1 GSMA https://www.gsma.com/mobileeconomy/sub-saharan-africa/

Today the mobile industry is in the early stages of the 5G era. According to GSMA Intelligence (GSMAi) in July 2021 there were 174 operators with launched commercial networks in 71 countries and territories (either mobile or FWA). In countries such as China, South Korea, Finland, Germany, the United Kingdom and the United States the markets are relatively mature with high levels of smartphone adoption and 4G penetration, as a result of being among the first to deploy LTE in the early 2010s. There are now 811 operators with launched commercial LTE networks, with 217 operators investing in LTE Advanced Pro technologies.

Widespread 5G adoption will take time, with 1.8 billion 5G connections by 2025, representing a share of approximately 20%[2]. Just as 2G and 3G still continue to exist alongside 4G in many places today, 4G will have a key role, coexisting alongside 5G well into the 2030s[3]. This will be particularly important in SSA, where even as late as 2019 only 9% of total connections were via an LTE network; the GSMA estimates that by 2025 this figure will rise to 27% and there will be 3% of connections on 5G. Anything that can be done to accelerate this take-up should be considered.

5G in SSA countries

In the SSA region, there is a wide variety of network deployments and technologies with the majority of countries currently investing in 4G networks. Some countries, including (but not limited to) South Africa, Kenya, Nigeria and Senegal, have progressed with 5G network trials and deployments, even though spectrum awards have not taken place. As stated above, there remains a low take-up of LTE network connections, meaning that operators and regulators have an opportunity to push forward with 5G technologies and position this as the natural upgrade for many existing subscribers.

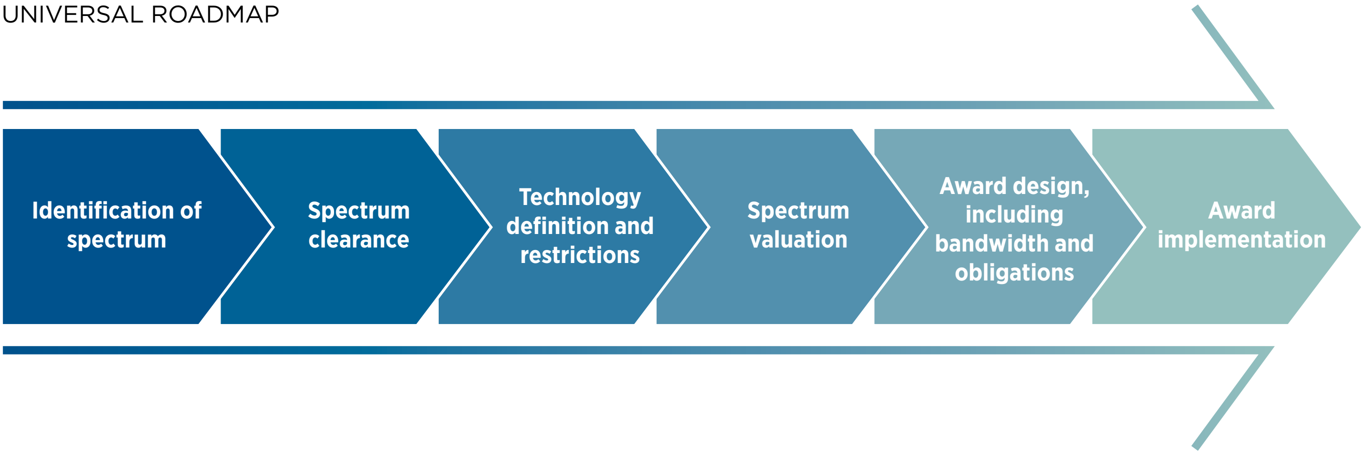
This report looks at the need for 5G spectrum to be made available, and the current status across the SSA region. It then sets out a roadmap to help governments and regulators enable 5G in the most efficient way possible. It also provides recommendations based on international best practices.

Roadmaps

Figure 2 provides a universal roadmap that can be applied to 5G or the introduction of any other previous generation of mobile technology. Prior to developing such a roadmap, governments should agree on general objectives for future digital development. These should guide the availability of spectrum, its management and the methodology of assignment to achieve higher investment levels, better coverage, affordability and extensive digital inclusion.

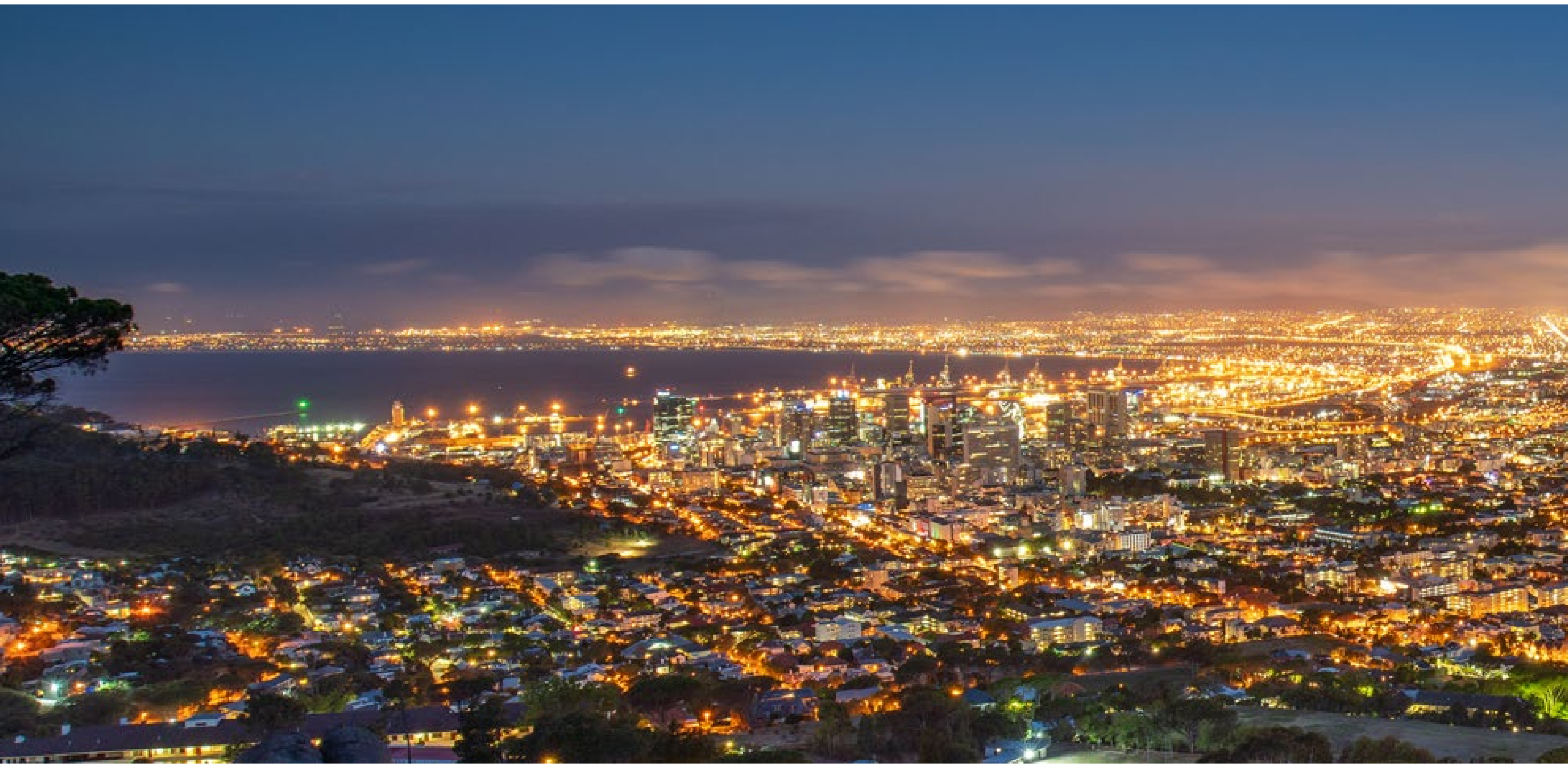
FIGURE 2

UNIVERSAL ROADMAP



2 GSMA https://www.gsma.com/mobileeconomy/

3 According to Ericsson, 4G will continue to be the dominant mobile technology in the mid-2020s, accounting for majority of connections globally. Source: Ericsson Mobility Report, November 2019.



It is important to recognise that although the steps may be the same for each country, the detailed activities under each may vary. Consultation with interested parties during the process is important to achieving optimum outcomes.

- **Identification of spectrum.** The key frequency bands to prioritise for 5G are, the 3.5 GHz range, 700 MHz and mmWaves. However, it may be necessary to consider alternative bands based on what has already been awarded for mobile. As part of this work, regulators must consider the specific spectrum needs of 5G, including the provision of contiguous bandwidths, exclusive use, peakiness of demand, and need for harmonisation.
- **Spectrum clearance.** The approach may vary depending on factors such as the density of use; ease of moving incumbents to alternative frequency bands or alternative technologies; and impact on services and users. Care must be taken to consider the socio-economic benefits that arise from both old and new uses of spectrum. In some cases, the incumbents may be able to remain through geographic sharing (for example, where there is limited governmental use or existing regional licences). For assigned spectrum, it may only be necessary to realign the band assignments to provide contiguous frequencies and maximise spectrum efficiency for 4G and 5G.
- **Technology definition and restrictions.** This will inform the technical licence obligations and the amount of spectrum and geographic availability of the spectrum.
- **Spectrum valuation.** This step calculates the value of spectrum to guide up-front and annual fees. When considering the level of investment necessary for new 5G networks, it will be important that spectrum fees are not set at high levels that will prevent operators from investing, which will impact on network roll-out and quality and drive up the cost of services.
- **Award design.** There are three main approaches to spectrum awards: auctions, beauty contests and direct award[4]. The approach adopted and associated licence obligations will need to take account of policy objectives, available spectrum, and market specifics (for example, the number of operators, or current spectrum holdings). It should be noted that depending on the timescales for availability of different frequency bands and award design it may be appropriate to have a single multi-band award or several separate ones.
- **Award implementation.** The final step is the actual award. This will normally be underpinned by documentation that provides all the necessary details of the award process, spectrum on offer, licence obligations and other essential information for potential licensees.

Not all the countries considered in this report are ready for 5G; some are still in the process of rolling out or upgrading LTE services, as shown in Figure 3. The data comes from GSMA Intelligence, operators and inputs from regulators and ministries and other online sources.

4 For the GSMA auction best practice position see https://www.gsma.com/spectrum/wp-content/uploads/2019/05/Auction-Best-Practice.pdf

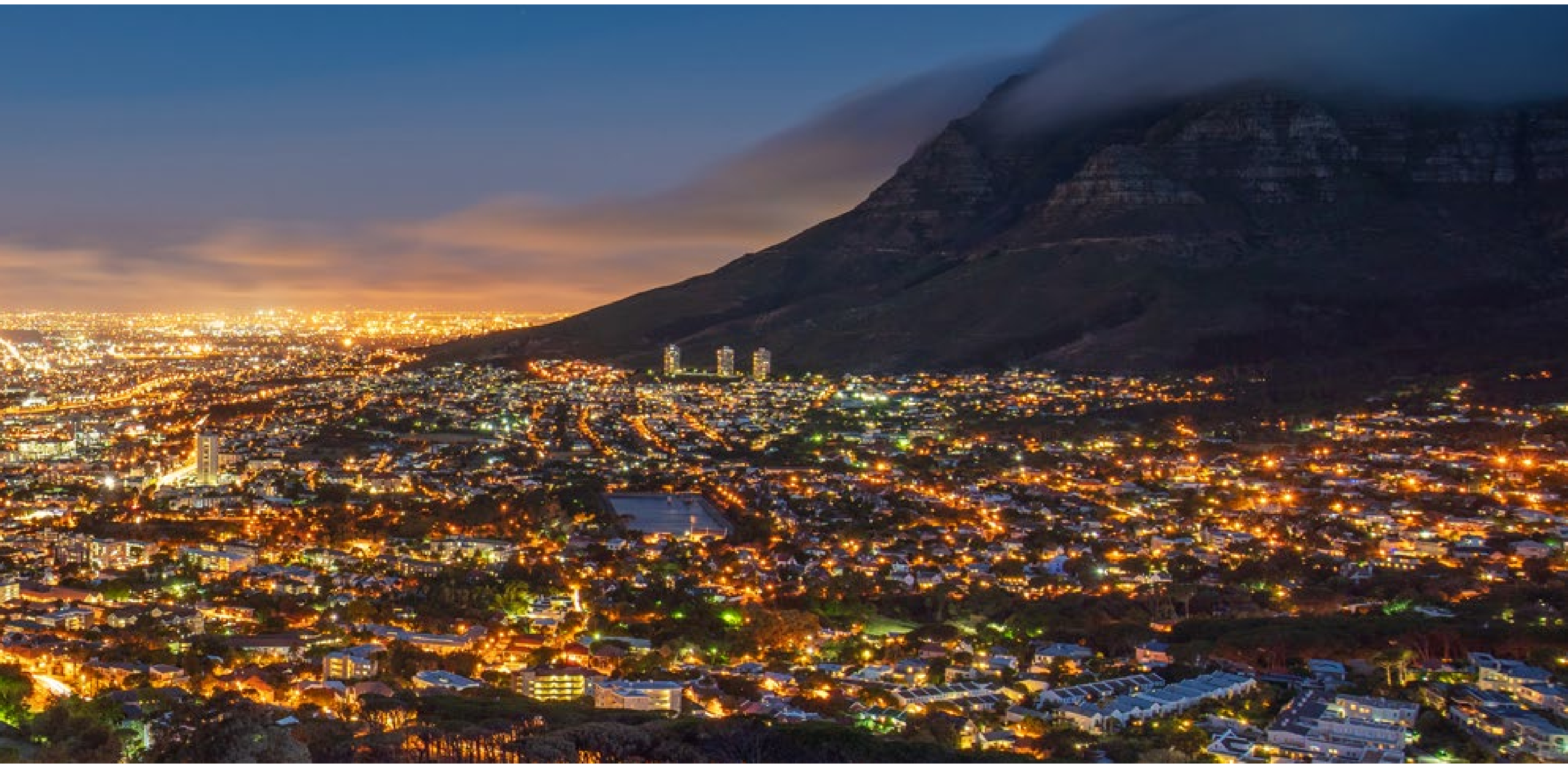
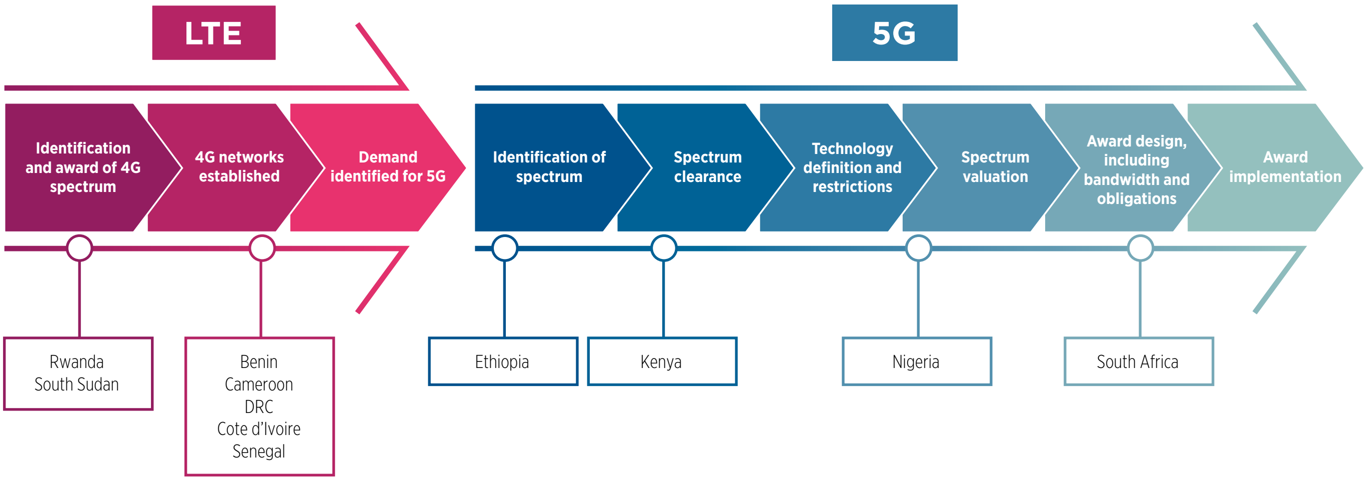


FIGURE 3

ESTIMATED CURRENT STATUS ON ROADMAP



Still, a significant number of countries (in particular, South Africa, Kenya and Nigeria) have started to identify suitable 5G spectrum and the most effective ways of clearing spectrum which will feed into any technical restrictions and associated technical licence obligations. It is anticipated that in these countries 5G networks and services will become available from within the next few years, although in both Kenya and South Africa there are already limited 5G networks available.

In other countries it is understood that 4G networks have been rolled out, and in most countries these have been upgraded to LTE-A technologies, but no demand has been identified for 5G in the short-term. The aim should be to ensure there is sufficient spectrum available for 4G as demand increases whilst starting to identify potential 5G spectrum.

Recommendations based on international best practices

A number of general recommendations are based on the current status of spectrum award in the SSA countries and international best practices.

900, 1800 and 2100 MHz bands

The current level of spectrum availability varies considerably by country, but most states have released spectrum in traditional IMT bands for 2G and 3G services. For 900, 1800 and 2100 MHz, the amount of paired spectrum awarded across the SSA region is, generally, substantially less than in other countries worldwide. Across these three bands, for example, Rwanda has awarded 170.8 MHz, Ethiopia and Kenya have awarded 210 MHz, and Côte d'Ivoire has awarded 240 MHz. This compares poorly to 340 MHz in Germany, 331.9 MHz in the UK, and 330 MHz in Singapore. This lack of spectrum is likely to significantly increase the cost of networks and will hamper growth and likely disincentivise operators from investing in more rural areas.

Access to sufficient spectrum is essential to minimise operator deployment costs and enable countries to benefit from the potential growth in GDP afforded by mobile services. Limited spectrum will require operators to deploy additional base stations to meet traffic demand and this can have an impact on further investment in geographic roll-out, grade and quality of services and prices. It is recommended that regulators and administrations should seek to award further spectrum where limited spectrum is currently available.

It is crucial to note that while the award of these legacy bands is important to operators, this spectrum is most likely to be used to provide additional capacity on the existing 2G, 3G and LTE networks. This is a necessary exercise but is not sufficient for 5G or meeting future demand.

700 and 3.5 GHz

The 700 MHz band and in particular the 3.5 GHz range are the preferred frequencies for 5G and should be the main focus for award. The 3.5 GHz range (3300-4200 MHz) has quickly become the prime option for commercial 5G deployments worldwide. Its ability to provide coverage and capacity combined with spectrum availability makes it that ideal candidate. This initial focus on one range is also resulting in a quickly developing ecosystem, with the launch of increasingly affordable devices.

The precise range of spectrum within 3.5 GHz varies by country. Many countries have focussed on an initial assignment of 3.4 GHz to 3.8 GHz, with some also awarding the 3.3-3.4 GHz band. Given the need for large contiguous spectrum bands for each operator, there is significant pressure on regulators to also clear and assign the 3.8-4.2 GHz band. However, there are significant demands on the upper part of this band from satellite operations in some countries.

800 and 850 MHz

Countries such as Cameroon and DRC have previously awarded the 850 MHz bands for CDMA 2000 technology. Depending on the band plan, the use of CDMA 850 can lead to potential interference with the 900 MHz (E-GSM) band, both within the country and with neighbouring countries. It is recommended that all countries adopt the Region 1 allocations and associated band plans. As part of this process, they should also identify how to migrate away from CDMA.

Removing WiMAX from 2300 MHz, 2600 MHz and 3.5 GHz

A number of countries (for example, Senegal and Côte d'Ivoire) have awarded the 2300 MHz, 2600 MHz or 3.5 GHz bands for wireless access using technologies such as WiMAX. These bands are potentially suitable for deployment of 4G and 5G and provision of mobile services, as well as wireless access; we therefore recommend that administrations should start the process of considering whether the licences should be revoked, and spectrum re-awarded or the current allocations retained. Unlocking these bands for mobile can significantly increase the capacity of mobile networks and enhance user experience. It is possible to award these bands to IMT while retaining the benefits of FWA connections, either by allocating alternative spectrum to the FWA provision, or by moving to a 5G FWA technology solution; the latter would likely provide subscribers with higher quality connections and may be cheaper in the medium term.

Other potential IMT bands

There are significant moves towards awarding further spectrum to mobile operators around the world, even before harmonisation decisions are made at WRC. In particular, the 4.8 GHz and 6 GHz bands may be key mid-band spectrum for 5G expansion, given the likely demands from consumers. The GSMA estimates[5] that by 2030, total spectrum demand for 5G services in cities will be, on average, 2 GHz – this is likely not achievable in the 3.5 GHz band alone. Regulators across SSA must consider the use of these bands and support their allocation to IMT at WRC-23, to ensure there can be high-quality broadband connections available to all citizens in their countries.

Technology neutral licences

For any country that wants to offer the best possible mobile networks, support for technology neutral spectrum licences is key. They provide the necessary flexibility for operators to deploy new technologies based on market demand and their own service and network roadmaps. Without this flexibility uncertainty and delays can lead to reductions in network investment and impact on roll-out, quality, cost and availability of services. This approach should apply to existing and new licences and may require changes to a country's underlying legislation. However, it is important that such changes to licences do not incur an additional cost to spectrum users, as this may discourage uptake of the licence and lead to inefficient use of spectrum.

5 GSMA, https://www.gsma.com/spectrum/resources/5g-mid-band-spectrum-needs-vision-2030/

1 Introduction

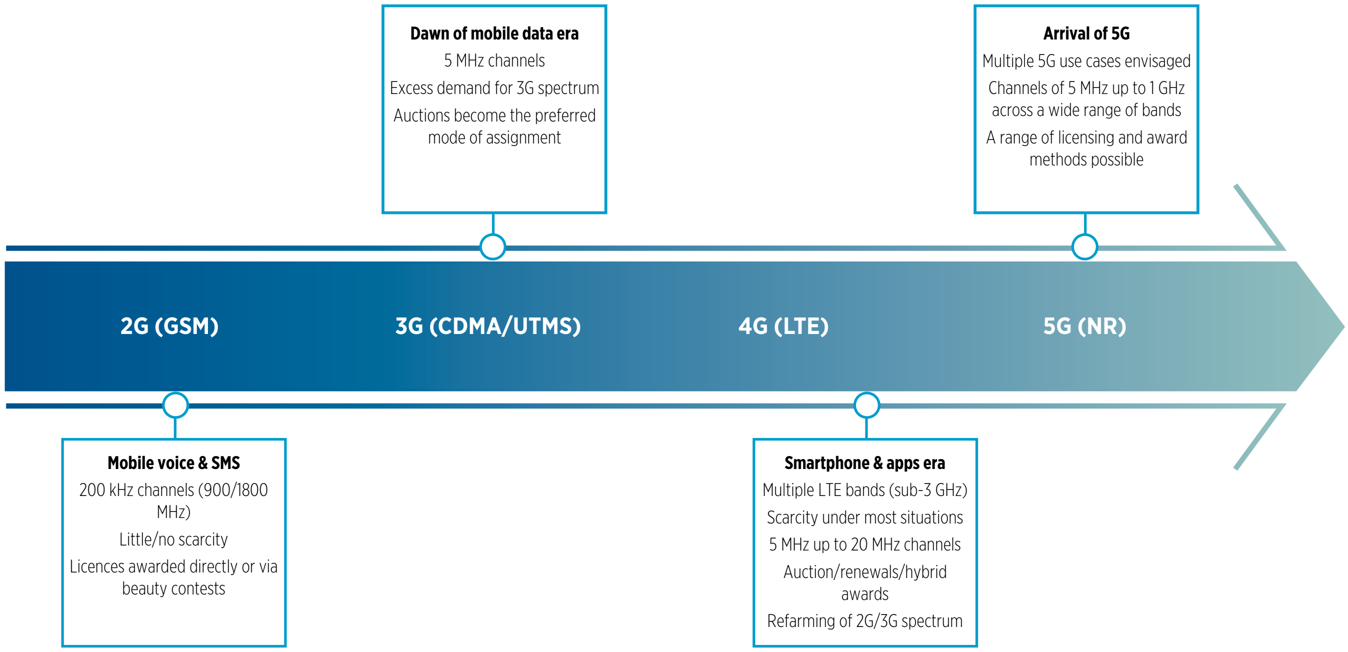
Mobile communications have quickly grown to be the largest part of the telecommunications industry, and this is particularly the case in Sub-Saharan Africa (SSA), where fixed line connections were scarce and expensive. Mobiles – first voice, and now broadband – have enabled hundreds of millions to be connected and have been a major driver of information and economic prosperity across the region. The GSMA[6] estimates that as of 2019 there were over 477 million unique subscribers across SSA, of which 272 million use mobile Internet; by 2025 it is estimated these numbers will have grown to 614 million and 475 million respectively.

6 GSMA https://www.gsma.com/mobileeconomy/sub-saharan-africa/

The capabilities of mobiles improve constantly, but roughly every 10 years a new generation of mobile technology comes along, bringing fundamental improvements to the capabilities of mobile networks and changes to spectrum management approaches as illustrated in Figure 1.1. Today the mobile industry is still in the nascent stages of the 5G era although the number of countries that have launched commercial 5G services is steadily increasing[7].

FIGURE 1.1

EVOLUTION OF MOBILE GENERATIONS AND CHANGES TO SPECTRUM MANAGEMENT APPROACHES



While operators in Europe, the United States and other advanced markets in the Middle East and Asia Pacific are expected to ramp up 5G deployments over the next two to three years, widespread adoption is not anticipated until well into the 2020s. Just as 2G and 3G still continue to exist alongside 4G in many places today, 4G will have a key role in the 5G era as well, coexisting alongside 5G in the 2030s. [8] The economics of 5G are challenging and operators expect 5G investment cycles to be longer than 4G. The road towards 5G is thus more akin to a marathon than a sprint to the finish-line, and deployment will be gradual over a number of stages with 4G playing a key complementary role in the deployment of 5G non-standalone networks as well as in the provision of mobile broadband as the 5G ecosystem develops over the 2020s.

In the SSA region, countries such as South Africa have become 5G pioneers, with governments and regulators identifying spectrum and mobile operators deploying the region's first 5G networks. However, this investment has taken place in an environment where spectrum awards are still pending, and temporary licences are used instead, which increases risk to operators and disincentivises investment. This report looks at the need for 5G spectrum to be made available, and the current status across the SSA region; it then sets out a roadmap for governments and regulators to follow to enable this to be achieved in an efficient and effective way.

7 Global mobile Suppliers Association (GSA) identified 174 5G networks, across 71 countries, in July 2021: https://gsacom.com/technology/5g/

8 According to Ericsson, 4G will continue to be the dominant mobile technology in the mid-2020s, accounting for majority of connections globally. Source: Ericsson Mobility Report, November 2019.

2 Spectrum for 5G

To build a 5G network with the best possible performance, operators need access to significant amount of harmonised spectrum. This must be new spectrum separate from what is currently used for existing GSM, UMTS and LTE networks. In this section we discuss which bands are generally used for 5G services.

2.1 5G frequency bands

5G is envisioned to enable a variety of different applications from enhanced mobile broadband service (eMBB) to ultra-reliable and low-latency communications (URLLC) and massive machine type communications (mMTC). To ensure that 5G networks are capable of meeting all performance requirements, spectrum is needed across low, mid and high spectrum ranges.

In general, low-band spectrum (below 1 GHz) is ideal for the provision of 5G coverage across urban, suburban and rural areas and to help support IoT services. Mid-band spectrum (such as the 3.5 GHz range) offers a good balance between capacity and coverage. In this range, the GSMA recommends that regulators should aim to initially make available 80-100 MHz of contiguous spectrum per operator as a start, although by 2030 it is estimated that total demand will require over 2 GHz of spectrum in the mid-band[9]. High-band spectrum (such as 26 and 40 GHz) is suited for short-range, ultra-high-speed applications which require low latencies. In this range, around 1 GHz per operator is recommended by the GSMA. Examples of the possible 5G applications and their spectrum requirements are summarised in Figure 2.1.

9 GSMA, https://www.gsma.com/spectrum/resources/5g-mid-band-spectrum-needs-vision-2030/

FIGURE 2.1

POSSIBLE 5G APPLICATIONS AND THEIR SPECTRUM REQUIREMENTS[10]

Usage Scenario	High-level Requirement	Potential spectrum-related implications	Spectrum ranges considered suitable
Enhanced mobile broadband	Ultra-high-speed radio links	Ultra-wide carrier bandwidths, e.g. 400 MHz Multi-gigabit fronthaul/ backhaul, indoor	> 24 GHz
	High-speed radio links	Wide carrier bandwidths, e.g. 100 MHz gigabit fronthaul/backhaul	3-6 GHz
	Support of low- to high-mobility	Depends on the throughput requirement	All ranges
	Ultra-low latency	Short-range implications	3-6 GHz, > 24 GHz
	Low latency	Mid-short-range implications	3-6 GHz
	Ultra-high-reliability radio links	Severe impact of rain and other atmospheric effects on link availability in higher frequencies, e.g. mmWave, for outdoor operations	< 6 GHz
	High-reliability radio links	Impact of rain and other atmospheric effects on link availability in higher frequencies, e.g. mmWave, for outdoor operations	< 6 GHz
Ultra-reliable Communications	Short range	Higher frequencies, e.g. mmWave	> 24 GHz
	Medium to long range	Lower frequencies, e.g. sub-6 GHz	< 6 GHz
	Ground/obstacle penetration	Lower frequencies, e.g. sub-1 GHz	< 1 GHz
Massive Machine-Type Communications	Operation in a cluttered environment	Diffraction dominated environment in lower frequencies Reflection dominated environment in higher frequencies[11]	All ranges
	Operation near fast-moving obstacles	Frequency-selective fading channels[12]	All ranges, especially below 6 GHz
	Mesh networking	High-speed distributed wireless backhauls operating in-band or out-of-band	> 24 GHz

Activities to identify and harmonise spectrum for 5G have been ongoing for a number of years at the international and regional levels. Over the World Radiocommunication Conferences in 2015 and 2019, a number of bands have been identified and allocated for IMT use. Taking advantage of the work to harmonise mid-band spectrum, the initial phase of 5G rollouts has focused primarily on the 3.3-3.8 GHz band. Figure 2.2 provides an overview of the 5G bands.

10 Source: 5G Americas

11 These are different types of propagation effects. Diffraction is defined as the bending of waves around the corners of an obstacle – for example a building. Reflection is where a radio signal is reflected by obstacles such as walls inside a building.

12 Frequency selective fading is where the wanted signal is reduced (faded) depending on the frequency of operation.

FIGURE 2.2

OVERVIEW OF 5G BANDS AND CURRENT DEVELOPMENTS[13]

Range	Main 5G bands	Main incumbent use	Notes
Low-band	600 MHz 700 MHz	Broadcast TV	700 MHz is much more widely harmonised for IMT than 600 MHz though 4G is currently used in 700 MHz by many countries.
Mid-band	2300 MHz 2600 MHz 3300-3800 MHz 3800-4200 MHz 4400-5000 MHz 6525-7125 MHz	Fixed satellite Fixed service (point-to-point, point-to-multipoint)	Initial phase of 5G rollout has focused mainly on 3400-3800 MHz though some countries are also considering the range 3300-3400 MHz as well as alternative bands
High-band	26 GHz (24.25-27.5 GHz) 28 GHz (27.5-29.5 GHz) 37-43.5 GHz 45.5-47 GHz 47.2-48.2 GHz 66-71 GHz	Earth exploration satellite Fixed satellite Fixed service Space research	Initial phase of 5G has focused mainly on 26 GHz and 28 GHz bands.

2.1.1 Spectrum awarded and status of 5G deployment in SSA

The journey towards 5G in SSA has begun but is still at an initial stage. As of June 2021, there were seven commercial 5G networks in five markets across the region (Kenya, Madagascar, Seychelles, South Africa, Togo) and a few others allowing trials of the technology. These initial investments have been made despite a general unavailability of spectrum in the key 5G bands. There have been no awards of 700 MHz spectrum related to 5G, and while a few countries have awarded 3.5 GHz spectrum to mobile operators this is for use with fixed wireless access networks. As such, even where 5G networks have been deployed or trialled, this has been done on a temporary spectrum licence, or using other spectrum such as the 2600 MHz band, after refarming from other technologies.

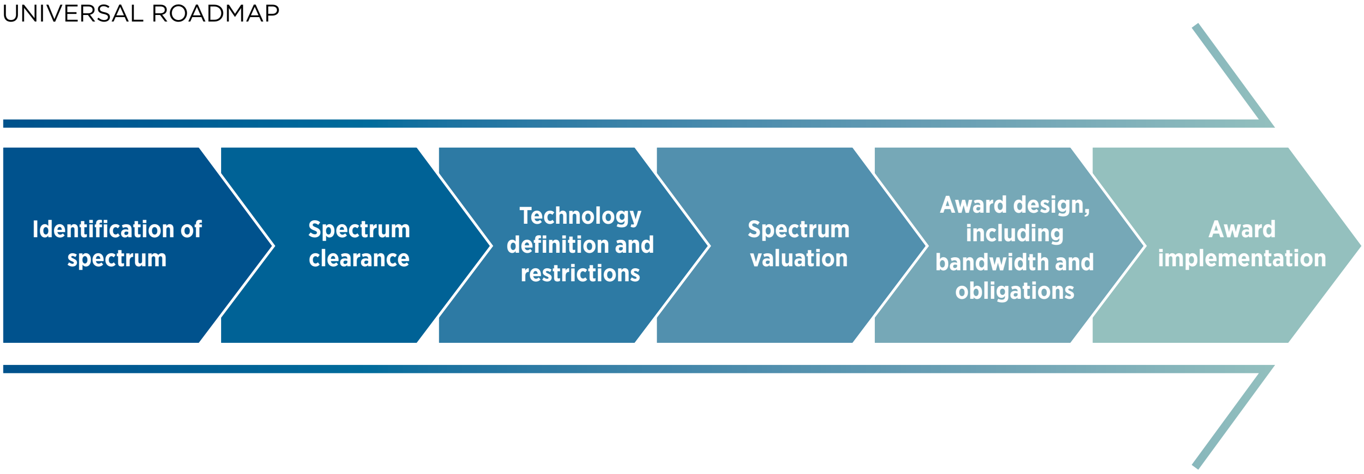
13 The existing mobile frequency bands are also identified for 5G NR but as these are typically already used the focus for 5G has been on new frequency bands.

2.2 A universal 5G roadmap

Figure 2.3 provides a universal roadmap that can be applied to 5G or the introduction of any other previous generation of mobile technology. Prior to developing such a roadmap, governments should agree on general objectives for future digital development. These should guide the availability of spectrum, its management and the methodology of assignment to achieve higher investment levels, better coverage, affordability and extensive digital inclusion.

FIGURE 2.3

UNIVERSAL ROADMAP



It is important to recognise that whilst the steps may be the same for each country the detailed activities under each may vary. Consultation with industry is also an important element of any roadmap to ensure the optimum outcome for all.

Identification of spectrum

The first step is to identify suitable spectrum based on key bands being adopted on a world-wide basis and so providing economies of scale. Whilst the first prime frequency bands for 5G are 700 MHz[14], 3.5 GHz and 26 GHz, it may be necessary to consider alternative bands based on spectrum already awarded for mobile. This is highlighted in the approaches adopted for 5G where in many countries the 3300-4200 MHz spectrum is awarded but there are also examples of the 2300 MHz, 2600 MHz and 4.8 GHz bands. As already discussed, in some countries 5G deployments are taking place in 2600 MHz bands because of a lack of clarity over future spectrum awards.

As part of this work, regulators must consider the specific spectrum needs of 5G, including the provision of contiguous bandwidths, exclusive use, peakiness of demand, and need for harmonisation. The GSMA has identified ten key spectrum positions in relation to the identification of spectrum, shown below.

14 The 700 MHz bands may already have been awarded and 4G networks deployed so it may be necessary to consider 600 MHz bands as alternatives.

FIGURE 2.4

THE GSMA'S 5G SPECTRUM POSITIONS[15]

1. **5G needs significant new harmonised spectrum so clearing prime bands should be prioritised to meet market demand.**
2. **5G needs spectrum across low, mid and high spectrum bands to deliver widespread coverage and support a wide range of use cases.**
3. **Governments and regulators should support new harmonised bands on the international stage to help 5G services grow over the longer term (e.g. UHF, 3.3-4.2 GHz, 4.8 GHz and 6 GHz). This includes engaging in the WRC-23 process to ensure sufficient mid- and low-band spectrum is available.**
4. **Exclusively licensed spectrum over wide geographic areas is vital to the success of 5G.**
5. **Spectrum sharing and unlicensed spectrum can play a complementary role.**
6. **Setting spectrum aside for local or vertical usage in priority bands (i.e. 3.5/26/28 GHz) could jeopardise the success of public 5G services and may waste spectrum. Sharing approaches like leasing are typically better options in these situations.**
7. **Governments and regulators should avoid inflating 5G spectrum prices as this is linked to slower broadband speeds and worse coverage. Key concerns are excessive reserve prices, annual fees, limited spectrum supply (e.g. through set-asides) and poor auction design.**
8. **Regulators should carefully consider 5G backhaul needs including making additional bands available and supporting wider bandwidths in existing bands. Measures should also be taken to ensure licences are affordable and designed effectively.**
9. **Regulators should carefully consider the right 5G spectrum licence terms, conditions and awards approach and consult industry to maximise the benefits of 5G for all.**
10. **Governments need to adopt national spectrum policy measures to encourage long-term heavy investment in 5G networks (e.g. long-term licences, renewal process, spectrum roadmap etc.)**

A key point here is the need for regulators to consider spectrum needs not only for the short-term but also the long-term.

There are significant moves towards awarding further spectrum to mobile operators around the world, even before harmonisation decisions are made at WRC. In particular, the 4.8 GHz and 6 GHz bands may be key mid-band spectrum for 5G expansion, given the likely demands from consumers. Further, it is important that the 2300 MHz and 2600 MHz bands are technology neutral and available for IMT, so that operators can move operation to 5G when it is most efficient. However, particularly in the 2600 MHz band, historic awards may have been made using an FDD band plan whereas mid-band 5G use could require a TDD configuration of optimal use. This may require regulators to reassign existing spectrum between existing users[16].

The GSMA estimates[17] that by 2030, total spectrum demand for 5G services in cities will be approximately 2020 MHz – this is likely not achievable in the 3.5 GHz band alone. Regulators across SSA must consider the use of these bands and support their allocation to IMT at WRC-23, to ensure first that there can be high-quality broadband connections available to all citizens in their countries, and also that network expansion will not be hampered by an overly myopic spectrum release strategy.

15 GSMA, https://www.gsma.com/spectrum/resources/5g-spectrum-positions/

16 Both TDD and FDD configurations are used in the 2.6 GHz band but increasingly TDD is being adopted for the whole band The advantage of using TDD is it supports non symmetric traffic in the uplink and downlinks. Adopting TDD for all the 2.6 GHz band provides the opportunity to allocate wider bandwidths of contiguous spectrum and so offer the advantages of 5G technology as well as greater spectral efficiency. It will be important to address the need for synchronisation between networks if TDD is adopted.

17 GSMA, https://www.gsma.com/spectrum/resources/5g-mid-band-spectrum-needs-vision-2030/

Spectrum clearance

In general, there are two main approaches to releasing spectrum for mobile broadband:

1. Clearance and, if needed, relocation of incumbent services; and
2. Sharing with incumbents through the use of appropriate mitigation measures.

The preferred approach will vary depending on incumbents. The feasibility of band clearance and reallocation will depend on the type and number of users and whether the existing equipment can be reasonably upgraded or replaced to maintain services or whether there are alternatives for users to maintain their current services and the impact of disruption to services and users.

In some cases, the incumbents may be able to remain through geographic sharing provided the separation distances or exclusion zones proposed are not extensive and sterilise large areas of the country. Typically cost benefit analysis would be used to help identify the value of potential sharing. Some examples of where sharing may be possible are where there is limited governmental use or existing regional licences. If frequencies are already assigned to mobile network operators and they can implement new 4G or 5G technologies, then it may only be necessary to realign the band assignments to provide contiguous frequencies and maximise spectrum efficiency. However, where TDD networks are deployed, simultaneous uplink and downlink transmissions can occur at the same time but in a different direction (uplink from one network, downlink from another). To avoid potential interference between operators[18], in country or cross-border, the operators should agree between themselves the necessary TDD synchronisation parameters. These parameters address the time of the Download (D), Special Slot (S) and Upload (U) elements in each time period (the frame).[19]

Technology definition and restrictions

It will be necessary to define clearly any technical conditions and restrictions that will need to be met when deploying networks. Technical conditions can include, for example, limits on transmitter powers, use of block edge masks and any other obligations that may be necessary to avoid interference. Restrictions may be necessary to allow, for example, geographic sharing with incumbent users that are not being migrated from the spectrum.

Spectrum valuation

Spectrum fees should promote the efficient use of spectrum and reflect the opportunity cost of the spectrum though this is sometimes difficult to determine in practice, particularly in the case of 5G where use cases and business models are still uncertain. Fees can be set administratively by governments and regulators, or through market-based mechanisms such as auctions. 5G deployment will require significant investment and the business model for 5G is still under development at present. In assessing the appropriate fee levels or reserve prices, it will be important to take account of the impacts of high spectrum costs on the financial ability of operators to invest in network rollout and on consumer outcomes.[20]

Award design

The design of the award will need to take account of policy objectives, available spectrum and the market (for example, the number of operators, or current spectrum holdings). The method of award (auction, beauty contest and direct assignment) is an important consideration as are the licence obligations that may be applied, such as spectrum caps, coverage or rollout requirements and spectrum leasing and trading.

Award implementation

The final step is the actual award process as defined in the award documentation. It should be noted that it may not necessarily be a single award but a number depending on spectrum release timings and market demand.

18 Worst case interference is base station to base station

19 The frame configuration that the GSMA suggested for the 3.5 GHz band is DDDSU (3 downloads followed by a special slot followed by an upload). This provides a compromise between download and upload speeds with low latency, while respecting the current IMT-2020 requirements for 5G.

20 GSMA.: The impact of spectrum prices on consumers. September 2019. https://www.gsma.com/spectrum/wp-content/uploads/2019/09/Impact-of-spectrum-prices-on-consumers.pdf

3 Current status of markets in SSA region

This section provides an overview of mobile networks and spectrum awards in the SSA countries considered in this study. Where available predictions are provided on expected market growth and information on plans for award of spectrum for 5G. The data has been sourced from the GSMAi, inputs from regulators and operators and web sources.

In this table, demand forecasts are labelled according to the following convention.

FIGURE 3.1

KEY TO DEMAND FORECASTING SYMBOLS

Symbol	Meaning
↓↓	Significant decrease in connections
↓	Noticeable decrease in connections
–	Little change in number of connections
↑	Noticeable increase in connections
↑↑	Significant increase in connections

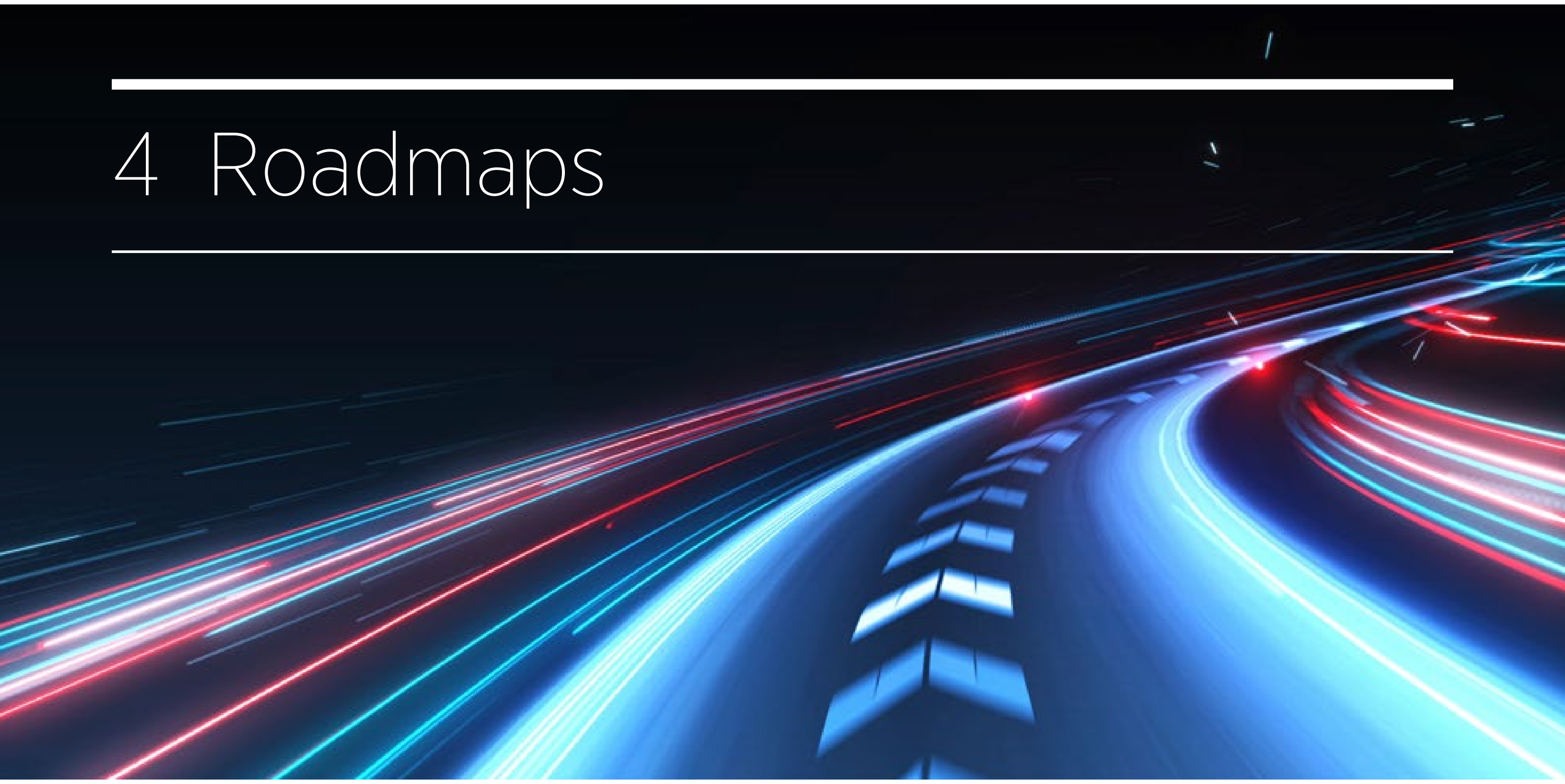
FIGURE 3.2

COMPARISON OF COUNTRIES

Country	No. of operators	Total spectrum (MHz)	Frequency bands awarded (MHz)	Demand forecasts (2018 to 2025)	4G introduction & 5G forecast	5G status	Comments
Benin	3	383.2	800, 900, 1800, 2100, 2600	2G ↓ 3G - 4G ↑↑	4G 2015 5G > 2025		
Cameroon	4	414.2	700, 800, 900, 1800, 2100, 2600	2G ↓↓ 3G - 4G ↑↑		The regulatory framework is being revised and modernized through a 5-year plan to prepare for 5G.	
Congo, Democratic Republic	8	352	450, 700, 800, 900, 1800, 2100, 2600, 3500	2G↓↓ 3G ↑ 4G ↑	4G 2017 5G 2024		3G commenced in 2011. Aiming to extend LTE coverage. Annual growth in mobile traffic threefold.
Côte d'Ivoire	5	580	800, 900, 1800, 2100, 2300, 2600, 3500	2G ↓↓ 3G 6 4G ↑↑		4G networks are still being deployed. Workshops were held in 2019 to discuss the opportunities and specificities of 5G. This resulted in a roadmap which was validated in July 2021 and work is due to commence in Q3 2021.	
Ethiopia	2	330	800, 900, 1800, 2100, 2600	2G- 3G ↑ 4G ↑↑	4G 2015 5G 2022	Safaricom Ethiopia plans to first deploy 4G network and thereafter introduce 5G. Ethio telecom is undergoing network infrastructure and system enhancements to pilot 5G networks in the coming year.	
Kenya	4	290	700, 800, 900, 1800, 2100	2G ↓↓ 3G ↑ 4G ↑↑	4G 2014 5G 2021	5G commercial network deployed by Safaricom and trials ongoing in 4 cities since March 2021. Trials will be expanded to 9 cities by the end of the year[22]	2nd country in Africa to deploy 5G network
Nigeria	8	610	700, 800, 900, 1800, 2100, 2300, 2600, 3500	2G ↓↓ 3G - 4G ↑↑	4G 2013 5G 2023	4G LTE network has been upgraded in 2019 to improve capacity and connectivity[23]. MoU signed with Israel in November 2020 to exchange opportunities and ideas on technologies, including 5G networks	Trials in the 3.5 GHz and 26 GHz bands
Rwanda	3	455.8	700, 800, 900, 1800, 2100, 2600	2G ↓↓ 3G - 4G ↑↑	4G 2014 5G > 2025	4G LTE network has been upgraded in 2019 to improve capacity and connectivity[24]. MoU signed with Israel in November 2020 to exchange opportunities and ideas on technologies, including 5G networks	
Senegal	4	377.1	800, 900, 1800, 2100, 2300, 3500	2G ↓↓ 3G ↑ 4G ↑↑	4G 2016 5G > 2025	First 5G trials staged in November 2020 by Orange. Company officials have stated 5G trials could take place in the next two years, subject to regulatory approval[25]	
South Africa	6	528.25	850, 900, 1800, 2100, 2300, 2600, 3500	2G ↓↓ 3G ↓↓ 4G -	4G 2012 5G 2020	First commercial 5G networks in Africa deployed in 2020. Operators are using temporary allocated spectrum.	Spectrum Auction of 700MHz, 800MHz, 2600MHz and 3500MHz bands delayed due to legal challenge[26].

21 https://actucameroun.com/2021/06/18/telecoms-le-cameroun-prepare-larrivee-de-la-5g-en-2025/
22 https://qz.com/africa/1990724/kenya-becomes-the-second-african-country-to-launch-5g/
23 https://guardian.ng/technology/as-nigeria-awaits-fgs-nod-on-5g-deployment/
24 https://www.commsupdate.com/articles/2019/12/02/usd10m-upgrade-for-rwandan-4g-network/
25 https://www.commsupdate.com/articles/2020/11/27/orange-senegal-conducts-5g-test/
26 https://www.commsupdate.com/articles/2021/03/29/icasa-extends-temporary-spectrum-allocations-to-may-2021/

4 Roadmaps

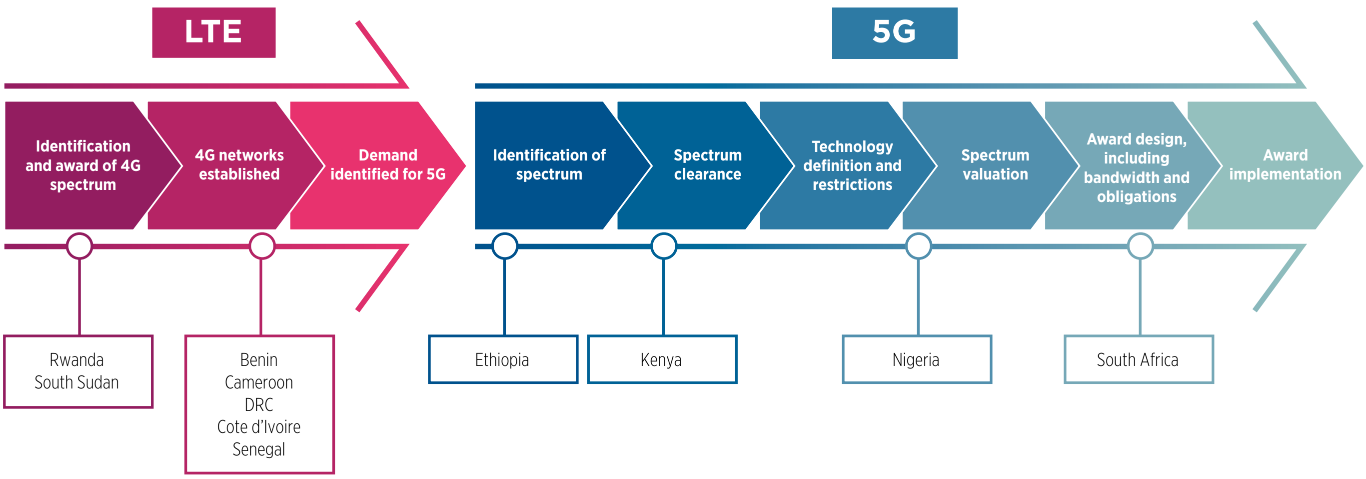


This section looks at how the universal roadmap in Section 2.2 can be applied to each of the countries studied.

In Figure 4.1 the current status of each country on the road map to 5G award is identified based on available information shown in Figure 3.2.

FIGURE 4.1

ESTIMATED CURRENT STATUS ON ROAD MAP



The roadmaps recommended are based on the grouping of countries above. Kenya, Nigeria, Ethiopia and Rwanda have been included in more detail as example case studies. In addition, some general recommendations are provided based on international best practice.

4.1 Roadmap for Kenya

One of the strategic objectives of Kenya's National Broadband Strategy[27] (2018-2023) is to develop an effective 5G network by 2023, by identifying "incentives to attract investment and demand/use of 5G networks" and by promoting "testing of 5G technology". 5G is considered as "essential to meet business and consumer demands by providing faster speed broadband" and as being likely to "facilitate new use cases, such as the Internet of Things, as well as broadcast-like services and lifeline communication in times of natural disaster". The regulator (Communication Authority of Kenya) has also published the Frequency Spectrum Management Guidelines[28] in 2020 that establish a framework for the management of radio frequency spectrum.

Following WRC-19, with the allocation of additional spectrum for IMT-2020, the Communications Authority of Kenya (CAK) allocated additional spectrum to mobile services in the frequency bands 24.25-27.5 GHz, 37.0-43.5 GHz, 47.2-48.2 GHz and 66-71 GHz. These were designed to facilitate implementation of 5G mobile services in the country; however, there were no decisions at the time on other key 5G bands. Later, in March 2020, the regulator granted one-year 5G test and trial authorizations to 2 mobile operators. The licences are for the frequencies 2659-2670 MHz and 2670-2690 MHz. These bands had not previously been awarded to operators for use on LTE technologies.

5G spectrum decisions in Kenya were complicated by a previous award of 700 MHz to JTL, as well as further decisions to award the 700 MHz band to tier 2 operators or a wholesale access network. By 2018, at least ten companies were bidding for one of the two remaining 700 MHz blocks. A proposed wholesale network was designed to run using LTE technology, despite a limited device ecosystem, and the accompanying award prevented the 700 MHz band being used by 5G services. To date, assignments of the remaining 700 MHz blocks remain unclear and the wholesale network was not successfully launched.

Partially because of the lack of clarity on long-term licencing of standard 5G spectrum bands, but also because of a continuing low adaption rate of LTE in the market, in January 2021 Safaricom – the largest operator in the country with 63.8% of market share in 2020 – announced that it would continue to prioritise 4G expansion and upgrades over 5G roll out[29]. It focused on moving 2G and 3G customers to 4G. Similarly, its competitor Airtel signed a three-year agreement with Nokia in the same period (late 2020) to modernize its 4G network. "Kenya has assigned one of the highest amounts of coverage spectrum per operator in Africa (43MHz[30], 2019), and its mobile broadband has reached close to 90 per cent population coverage (spectrum per operator includes assignments below 3.7 GHz and excludes 5G-specific licences)"[31]. This investment was recognised by the government; the Digital Economy Blueprint 2019[32] underlined that efforts have been made to bridge the digital divide, including investment by the private sector to "expand backbone and last-mile access networks using" 4G and other technologies.

However, alongside this concentration on LTE upgrades, in March 2021 Safaricom launched its 5G commercial trials for consumers and businesses in Nairobi, and in Western Kenya (including in Kisumu and Kisii). The main goal is to provide access speeds up to 700 Mbps (and to 1000 Mbps in the future). Three use cases were showcased by Safaricom at the launch event: 5G hologram, ultra-HD video communication and virtual fashion shopping. This service is planned to be expanded to 150 additional sites in 9 cities during 2021; the current plans concern mobile, but the operator also plans to deploy 5G for FWA in the future.

Kenya is in the process of drafting a 5G roadmap for stakeholder engagement. There are no 5G network sharing or spectrum sharing agreements in place for the time being.

Given the existing trials of 5G against the lack of spectrum awards, the roadmap for Kenya is complicated. The steps required are shown below.

27 https://www.ict.go.ke/wp-content/uploads/2019/05/National-Broadband-Strategy-2023-FINAL.pdf

28 https://ca.go.ke/wp-content/uploads/2020/01/Frequency-Spectrum-Management-Guidelines-January-2020.pdf

29 Safaricom had said beforehand that it would expand 4G coverage nationwide by the end of 2020 by increasing its capital expenditure by 25.5%.

30 This figure for spectrum per operator included assignments below 3.7 GHz and excluded 5G-specific licences.

31 https://www.gsma.com/spectrum/wp-content/uploads/2020/11/Effective-Spectrum-Pricing-Africa.pdf

32 https://www.ict.go.ke/wp-content/uploads/2019/05/Kenya-Digital-Economy-2019.pdf

4.1.1 Steps 1 and 2: Identification of spectrum and clearance

The regulator, CA, has seemingly not identified standard spectrum bands for 5G, but initially instead issued temporary trial licences in the 2600 MHz band. The use of this spectrum slightly reduced the device ecosystem, although after the 2600 MHz trials expired Safaricom began to refarm existing spectrum holdings in 3.5 GHz bands which were previously used for FWA over WiMax; this corrected the issues with ecosystems. Further, the lack of 700 MHz spectrum will also ensure that operators will struggle to roll out 5G services in more rural locations. The standard 5G bands are considered in turn below.

700 MHz

We understand that the 700 MHz band has been awarded to a number of telecommunications operators, though not the tier 1 MNOs, for the provision of LTE services. In particular:

- Jamii Telecom was awarded 2×10 MHz in the 700 MHz band in April 2017[33], and was granted a licence to run 4G mobile services in May 2019.
- The other 2×20 MHz was set to be awarded in early 2018[34], but with multiple operators requesting the spectrum the regulator asked all operators to form a consortium to acquire the spectrum. We do not believe that this took place.

In each case, this spectrum has been awarded for use on LTE networks only, severely restricting the rollout of 5G services in rural areas. The awarded band plan appears to be as shown below

FIGURE 4.2

CURRENT 700 MHZ BAND PLAN IN KENYA

This is the standard European band plan for 700 MHz, meaning that there will be an established ecosystem of devices available if 5G is enabled in the bands. However, with the spectrum being assigned to parties other than the main operators[35], it is unclear how such investment would be made.

To get around this, the regulator may wish to consider enabling spectrum resale or leasing or making the licences on 700 MHz spectrum technology-neutral. Even with these measures there may be significant constraints to MNOs making investments in 5G networks given a lack of certainty.

33 https://www.telecompaper.com/news/ca-gives-jamii-telecom-4g-licence-without-auction--1195518

34 https://innov8tiv.com/telecom-firms-bid-get-700-mhz-frequency-supply-4g-internet-kenya/

35 Although JTL has since submitted an application to run full mobile services, it currently has a very small market share and caters to a niche market.

3400-3600 MHz

According to the National Tables of Frequency Allocations[36], the band 3300-3400 MHz is allocated to mobile; while 3400-3600 MHz is allocated to fixed links, fixed satellite and mobile; and no spectrum in the C-band above 3600 MHz has any mobile allocation. Despite this, we have not been able to identify any specific award of C-band spectrum to mobile operators, and the initial trails of 5G networks were run in the 2600 MHz band.

While there have been no specific mobile awards, part of the 3.5 GHz band was previously held by Onecom, a telecommunications operator providing fixed wireless services using WiMax. This operator was acquired by Safaricom, and customers appear to have been migrated to LTE or 5G technologies, allowing Safaricom to use the 3.5 GHz spectrum for 5G services.

Other than this, it appears that the rest of the spectrum in the 3.4-3.6 GHz band is currently being used for fixed links, and as of 2014 there were nine operators with paired holdings in the band (ranging from 2×7 MHz to 2×28 MHz). Both Telkom Kenya and Airtel held some spectrum, but as we understand it, they are not able to use this for 5G services since it is licenced on a link-by-link basis only.

As this band is the key 5G band in many countries, it is crucial that CA examines whether it is possible to clear fixed links from this band. To do this, and to defragment the band from the current allocations, the following may be needed.

- Early termination of incumbent licences which would expire after the planned date for award.
- Moving incumbents to alternative frequency bands or technologies.
- Implement trading and leasing between licensees which allows spectrum to be re-allocated without the revocation and award of licences.
- Move incumbent licences into one part of the band to provide contiguous spectrum.

Finally, CA must consider whether there is potential to expand the C-band allocation to mobile above 3600 MHz, so that larger contiguous bandwidths are available for all operators.

26 GHz

While the 26 GHz band, alongside other mmWave bands, has been allocated to mobile, it is unclear whether this has been assigned to operators as yet. The CA must ensure that there is a clear statement on award and availability of these bands so that operators can make informed network plans.

4.1.2 Step 3: Technology definitions and restrictions

Once spectrum has been defined, CA will be able to more accurately define technical licence conditions for its use. However, it is clear from the initial use of 2600 MHz spectrum by Safaricom to launch 5G services, and the subsequent use of 3.5 GHz spectrum, that such exercises have already been carried out in this band. Similar exercises must be carried out in all other bands to ensure that other or adjacent use is maintained.

In addition to co-existence other important technical considerations are the use of guard bands, block edge masks and synchronisation between networks (in country and cross border) to avoid base station to base station interference. The use of synchronisation requires all operators to use a specific downlink to uplink transmit ratio and frame length[37].

4.1.3 Step 4: Spectrum valuation

Spectrum valuation is an important element of the road map. If spectrum fees or auction reserve prices are set too high, it can lead to spectrum not being awarded and slow roll-out of 5G. It is noted that there is an increasing number of 5G awards, particularly in the lower and mid-bands, to inform spectrum valuations if they are based on prices paid at auction. Further information is provided in Section 2.2 and Appendix A

36 https://ca.go.ke/wp-content/uploads/2021/03/National-Table-of-Frequency-Allocations-2020.pdf

37 ECC Report 296 provides options for synchronisation.

4.1.4 Step 5: Award design

It is important that the policy objectives associated with the award of 5G spectrum are taken into account in the design of the award and associated licence obligations. Further information is provided in Section 2.2 and Appendix A.

In the case of the Kenyan market, it is crucial that competition and market concerns are taken into account in the award design. CA must attempt to balance two competing demands:

- As Safaricom has the highest market share in the market, it will argue that it should have access to large bandwidths of spectrum so that its users will not suffer from congestion or service unavailability.
- Safaricom's competitors will argue that any imbalance in spectrum holdings will give a natural advantage to Safaricom in terms of quality of service or capacity.

With a move to 5G, regulators must not only consider coverage and capacity, but must also think about the quality of that coverage. Providing operators with 2×5 MHz of spectrum in the 700 MHz band will allow for 5G coverage but will not allow for a "5G experience" using that spectrum alone. This is also the case at higher frequencies: the GSMA has stated that each operator should have at least 80 MHz of spectrum in the C-band to provide a good quality 5G service.

The method of award will also need to be decided – direct award, beauty contest or auction are options and the advantages and disadvantages of each are provided in Appendix A. With the fragile financial situation of Safaricom's competitors, CA must think carefully about impacts on competition of an auction process but must also ensure that they award the spectrum in the most efficient way. Further, care must be taken on whether different bands are awarded simultaneously or separately; if spectrum is awarded separately, it is important that information is made available on when further spectrum (frequency bands and amount of spectrum) will become available to allow operators to determine their award strategies.

4.2 Roadmap for Nigeria

Our research indicates that, while there is currently no commercial 5G deployment in Nigeria, the regulator is significantly more advanced with spectrum management processes than in Kenya. In particular, NCC have developed a detailed consultation document[38], issued in August 2020, setting out their plans for the deployment of 5G in Nigeria; this consultation includes several details on the technologies to be used, the 5G ecosystem in devices and networks, and (crucially) plans for spectrum awards. This document provides a clear roadmap for spectrum award, particularly when combined with the NCC's spectrum management policy objectives:

- To control and encourage the use of spectrum as an instrument for developing telecommunication (being) which is an essential infrastructure for stimulating the economic growth and social development of the nation.
- To promote competition in the assignment of frequency in order to ensure innovative and efficient use of the radio spectrum (as a scarce resource).
- To achieve optimum pricing of spectrum in order to discourage wastage or speculative acquisition of the scarce resource.
- To generate moderate revenue for government.
- To ensure equitable and fair allocation of spectrum to benefit the maximum number of users.

Given this, several parts of the universal roadmap have already been fulfilled, although it is useful to discuss some of the idiosyncrasies of the market.

38 Available at https://www.ncc.gov.ng/docman-main/legal-regulatory/legal-other/918-draft-deployment-plan-for-5g-network-in-nigeria/file

4.2.1 Steps 1 and 2: Identification of spectrum and clearance

NCC has identified two sets of spectrum to be released: one set which will form the initial 5G deployment; and one set which will provide further capacity and capability. A key difficulty faced in Nigeria is the number of potential operators, with eight mobile operators (of which four operate nationwide). This large number of operators means that the limited spectrum available must be divided into small blocks, which means that each operator has a limited capacity. Further, Nigeria is one of the few countries to have awarded 700 MHz spectrum, with 2×5 MHz awarded to MTN and 2×10 MHz awarded to Glo; however this band is currently used for LTE-A services due to a lack of additional spectrum in other sub-1 GHz bands.

NCC has therefore not included any low-band spectrum in its 5G plans. Instead, the initial spectrum allocations are as follows.

- 2100 MHz. Currently each of MTN, 9mobile, Glo and Airtel have a 2×10 MHz holding in the band, and there is one further holding of 2×10 MHz in Lagos with a legacy operator, which expires in December 2021. Therefore, as of January 2022 there will be two 2×10 MHz blocks available for assignment.
- 2300-2400 MHz. Currently this is assigned to Mobitel, Clear Sky, Spectranet, and Bitflux. However, each of these operators have a use-it-or-lose-it condition in licences, and NCC believes that there will be at least 50 MHz recovered from these licences (with 70 MHz outside Lagos).
- 2600-2690 MHz. MTN and Airtel have existing FDD assignments in this band. There is a further 2×10 MHz block, assigned to Openskys, which the NCC believes is not deployed, and another 2×10 MHz block which was not assigned previously. Further, there is a 40 MHz TDD block available in the centre of the band.
- 3300-3400 MHz. This block is not currently used.
- 3500-3600 MHz. 30 MHz of this band is assigned to MTN; 120 MHz is used by Nigerian Communications Satellite (NCS), and the remainder is generally assigned to regional operators, which are largely unused other than in Lagos. NCC believes a significant portion of this band can be recovered and reassigned, and further the NCS satellite has an end of life in 2027 after which that spectrum band will also be made available.
- 3600-3700 MHz. This is currently used by satellites; NCC plans to refarm at least 80 MHz of this band from satellite use, although details of how this will happen are unclear.
- 4800-4990 MHz. This block is not currently used.
- 24.25-27.5 GHz. This band is currently used by one operator for a point-to-multipoint link system. The NCC plans to recover this spectrum and reassign it.
- 37.0-43.5 GHz This block is not currently used.

Following these awards, the NCC also plans to study demand for 1427-1518 MHz, 45.5-47 GHz, 47.2-48.2 GHz, and 66-71 GHz.

4.2.2 Step 5: Award design

The NCC has provisionally determined that spectrum will be awarded by auction in late 2021, and in June 2021 a committee was formed to oversee this process[39]. However, no details have yet been revealed over final timings or auction design.

One of the biggest challenges that the NCC faces is the number of spectrum bands it is looking to award and the number of operators who may be interested in bidding for these. While the obvious candidates are the large MNOs, the introduction of new operators with LTE technologies means that there will be many competitors. As set out above, there are multiple bands which look set to be awarded – some immediately, and some following clearance or licence expiry – and operators may have different valuations for different packages of spectrum, meaning a combinatorial auction may lead to more efficient outcomes. Finally, the quality of service of 5G connections depends on the amount of contiguous spectrum available to an operator. The NCC must choose between:

- Providing spectrum to every operator so there is a level playing field, or
- Allocating spectrum in large blocks to provide consumers with the highest possible speed and quality, with the consequence that not all operators will be granted spectrum.

These both appear within the NCC's objectives – as shown above – but in addition the NCC aims to "generate moderate revenue for government", meaning that direct awards or uncompetitive auctions may not be acceptable.

To mitigate against these issues, it is important that the NCC clears as much spectrum as quickly as possible and provides clear indications of when and where further spectrum will be made available.

39 See https://www.ncc.gov.ng/media-centre/news-headlines/1017-press-statement-danbatta-inaugurates-committee-on-spectrum-auction-for-5g-deployment

4.3 Roadmap for Rwanda

Rwanda is in the unique situation of all spectrum for LTE being awarded to a single whole network operator, which resells capacity to other operators. These other operators hold spectrum in the 900 MHz, 1800 MHz and 2100 MHz bands, and provide 2G and 3G services only. The wholesale operator, kt Rwanda Networks, is a joint venture between the Rwandan government and Korea Telecom. It holds spectrum at 2600 MHz (2×70 MHz), 1800 MHz (2×15 MHz), 800 MHz (2×30 MHz) and 700 MHz (2×42.5 MHz).

The wholesale network has had varied success. While the network saw a successful launch, it initially consistently failed to meet coverage targets but later improved significantly. Due to the structure of the market, LTE services are significantly more expensive than 3G services, reflecting the additional costs that operators must pay. For example, MTN offers a post-paid package of 500 MB of data per day at a monthly fee of FRW 10,000 when using the 3G network, but the same bundle costs FRW 16,949 if LTE data is included. Finally, while the purpose of the wholesale network was to encourage greater retail competition through MNOs, there has been very limited update of such offers – again, these are significantly more expensive than existing 3G tariffs.

The wholesale network has a 25-year exclusivity licence, which covers not only LTE technologies but all future technologies as well. However, as the 700 MHz band has been awarded exclusively to ktRN, it would appear that the ability of any MNO to roll out their own 5G networks would be constrained in any case. The roadmap to 5G in Rwanda is therefore complicated by the question of which operators are eligible to operate a network, and, given the low uptake for LTE services (caused by a lack of affordable smartphones, and high prices caused by wholesale arrangements), how much spectrum is required. Further, it appears that there have been limited, and possibly no, upgrades carried out to the LTE network to implement LTE-A technologies.

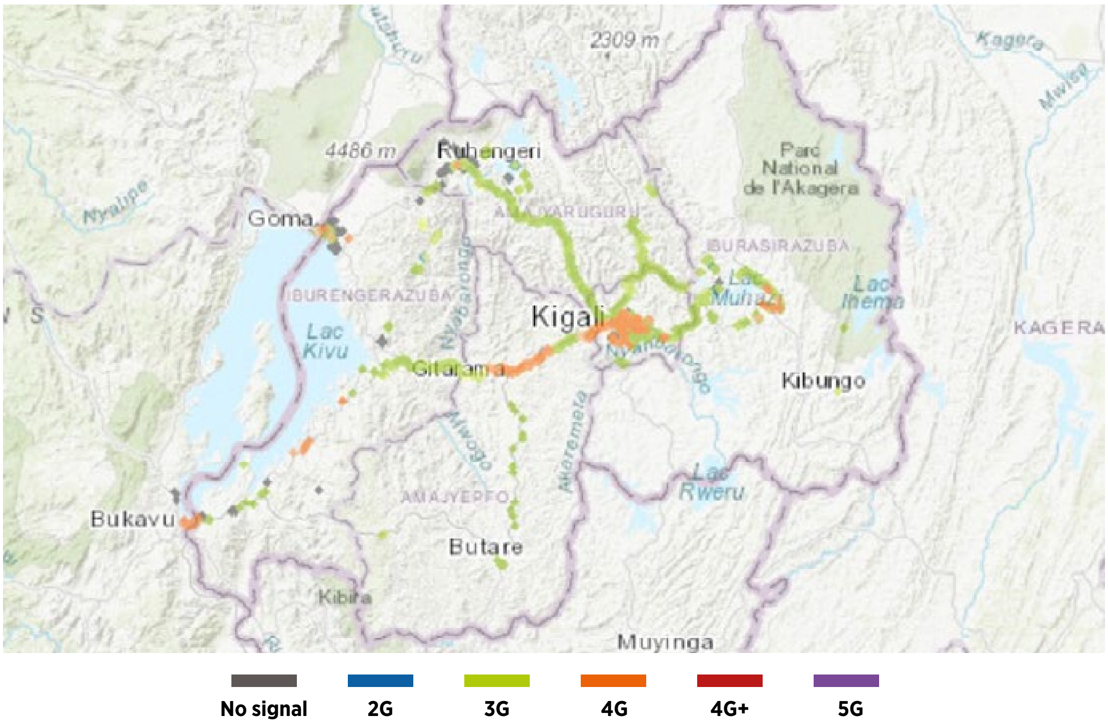
Given this, there are some key steps to be taken before 5G networks can be fully implemented.

4.3.1 Step 0: Upgrade LTE networks and identify demand

There are several news reports stating that ktRN has commenced a rollout of LTE-A upgrades[40], but to date there have been no observations of LTE-A connections collected by signal monitoring services, as shown below.

FIGURE 4.3

CURRENT COVERAGE IN RWANDA MEASURED BY nPERF[41]



40 See, for example, https://www.commsupdate.com/articles/2019/12/02/usd10m-upgrade-for-rwandan-4g-network/

41 Source: https://www.nperf.com/en/map/RW/-/223575.MTN-Mobile/signal/?ll=-1.834403827149967&lg=28.39259460568428&zoom=8

Upgrades to LTE-A will enable not only faster connections, but also additional capacity on the radio access network. Combined with the large spectrum bandwidths assigned to ktRN, this will ensure that citizens are able to receive high quality connections and, given the low demand, there will be no capacity constraints. This should therefore be the first task undertaken.

These upgrades may also allow ktRN to reduce the cost of data and pass these cost savings to MNOs. A reduction in the wholesale price, along with improved capabilities of the network, may encourage greater uptake of LTE services, allowing the government to better assess demand for 5G connections.

4.3.2 Step 1: Identification of spectrum

As stated above, the 700 MHz band has already been assigned to ktRN, and it should be expected that this can be used as the coverage layer for a 5G network. However, this will not be sufficient to provide a full 5G experience, and additional spectrum, in the 3.5 GHz band or similar, should also be made available.

There have been a number of reports of ktRN carrying out 5G trials in major cities, and media reports of engineers fitting 5G antennas to phone boxes[42]. However, the range of these antennas is very short, indicating that spectrum may have been assigned in mmWave bands. No information on mmWave spectrum appears to have been released by RURA, the regulator, and the National Frequency Allocation Table indicates that most common mmWave bands are allocated to fixed links.

If ktRN is to launch a wholesale 5G service, it is crucial that retail operators are able to understand the nature of the services to be launched – this means knowing the likely spectrum availability as well as the equipment being installed.

4.4 Roadmap for Ethiopia

Ethiopia is in a different situation to other SSA countries with the market being, until very recently, a monopoly with the state-owned operator, Ethio telecom, providing services to Ethiopia's 117 million people of which it is reported there are 54.3 million mobile voice subscribers[43]. In May 2021 the Ethiopian Government announced a Safaricom-led consortium had won a new telecommunications licence valid for 15 years. Expectations are the new licensee, registered locally as Safaricom Telecommunications Ethiopia PLC will first roll out 4G services and quickly introduce 5G. It was reported that "Safaricom Telecommunications Ethiopia PLC is expected to start rolling out telephony services from the start of 2022, with a proposed commercial launch in April 2022, and put a low Earth orbit satellite in place that will provide nationwide 4G coverage by 2023. The consortium forecasts it will create up to 1.5 million new jobs, help millions of businesses and bring in investment of $8.5 billion over the next decade."[44]

Ethio telecom has been investing in and deploying 4G including LTE-A with coverage concentrated on Addis Ababa. The entry of a new mobile operator is already incentivising Ethio Telecom to invest in 4G in the south- west of Ethiopia and make plans for the deployment for 5G in the future. In June 2021 the Government started the process to sell a 40% stake in Ethio telecom.

It is understood that the Government of Ethiopia is intending to retender the second telecommunications service licence with the same total amount of spectrum (160 MHz) and frequency bands. This is likely to lead to an even more competitive market with three mobile network operators with comparable spectrum holdings.

To provide the potential for the introduction of 5G in the key 700 and 3.5 GHz bands it is proposed that the Ethiopia Communication Authority (ECA) should investigate the potential to release sufficient spectrum to support three operators. This is likely to require the replanning of digital terrestrial TV frequencies and switch off of analogue TV transmitters. The latter is already in progress. The 3.5 GHz band is, we understand, used to provide VSAT services and the potential to refarm or share part of the band should be investigated. The ECA should also develop a 5G policy to inform the mobile operators of potential future options for further spectrum release and associated timescales.

42 https://taarifa.rw/how-soon-will-rwanda-embrace-5g-internet/

43 Ethio Telecom reports a 22% jump in subscribers to 56.2m - Developing Telecoms

44 Safaricom granted Ethiopian licence amid funding doubts? (capacitymedia.com)

4.5 Roadmap for South Africa

While South Africa is well advanced in terms of deploying and commercialising 5G networks, the coverage of these networks remains restricted to major cities. This is likely due to a continuing delay to spectrum availability and award in South Africa. The regulator, ICASA, has attempted to award spectrum many times over the last decade, but due to issues with incumbent users, award design and competition concerns, several awards have been cancelled. This meant that spectrum for LTE deployment was unavailable without significant refarming; the 2600 MHz band has not been awarded to mobile operators, and the 800 MHz band was constrained by legacy awards of spectrum following an 850 MHz plan – as a result only 2×5 MHz was available for LTE deployment.

With six operators holding spectrum in various bands, it is crucial that ICASA moves quickly to clear sufficient spectrum in the mid-band and mmWave bands for 5G deployments. Currently Telkom holds 26 MHz of spectrum in the 3.5 GHz band, and Neotel holds 58 MHz, but these are not designed for 5G use. All 5G deployments and trials are currently underway using temporary spectrum assignments; to provide operators with sufficient spectrum for a full 5G experience there will need to be large parts of the C-band cleared of alternate use.

4.6 Roadmaps for Benin, Cameroon, DRC, Côte d'Ivoire and Senegal

In Benin, Cameroon, DRC, Côte d'Ivoire and Senegal, there are existing LTE networks, running on traditional spectrum bands including 800 MHz, 1800 MHz, and 2600 MHz. The awards for this spectrum were made at various times between 2012 and 2017, meaning there is significant time remaining on the licences, and operators in all countries have taken advantage of this to invest further in their LTE networks, upgrading to LTE-A and (in a few cases) LTE-A Pro.

In most of these countries, there is expected to be a large increase in LTE traffic over the next few years, and while these upgraded networks will go some way to meeting this demand it is important that regulators are able to supply additional spectrum. This spectrum must be released in two areas:

- Spectrum for additional LTE capacity. Of the countries listed, only Côte d'Ivoire and Senegal have assigned any spectrum in the 2300 MHz band (with Senegal's spectrum used for FWA), and a number of countries have not released 2600 MHz spectrum. Adding additional spectrum bands to existing networks is the most cost effective and efficient way of increasing capacity. This is particularly true in countries where there are large numbers of operators,
- Spectrum for 5G networks. Other than in DRC and Cameroon, no awards have been made in 700 MHz or mmWave bands in any of this country group, and limited amounts of 3.5 GHz spectrum have been awarded in DRC, Côte d'Ivoire and Senegal – although it is unclear whether this is cleared for 5G use or if it is restricted to fixed links or FWA.

Given the current demand levels in each country, it is unlikely there will be significant demand for 5G networks and capacity before 2025, as shown in Figure 3.2, but this does not mean that regulators should not start work on the 5G roadmap now to identify and clear spectrum.

Step 1, as shown in Figure 2.3, will be to identify potential spectrum for 5G in prime bands of 700 MHz, 3.5 GHz range and 26 GHz as well as investigate other potential bands in case there are issues with releasing this spectrum due to incumbents. In the case of Côte d'Ivoire, it will be important to consider the spectrum used by VipNet in the 3.5 GHz band, and how this will be demanded by other networks. In DRC, the large number of operators will prove a challenge to accommodate in limited spectrum bands.

Having said that, DRC and Cameroon appear to be further advanced than other countries, with awards of 700 MHz already having taken place. However, there are no clear indications how mid-band spectrum will be allocated.

Only once this spectrum has been identified can regulators continue to further steps on the roadmap.

5 Recommendations

In this section we identify a number of general recommendations based on the current status of spectrum award in the SSA countries and international best practice.

5.1 Existing spectrum

The current level of spectrum availability varies considerably by country, but most states have released spectrum in traditional IMT bands for 2G and 3G services.

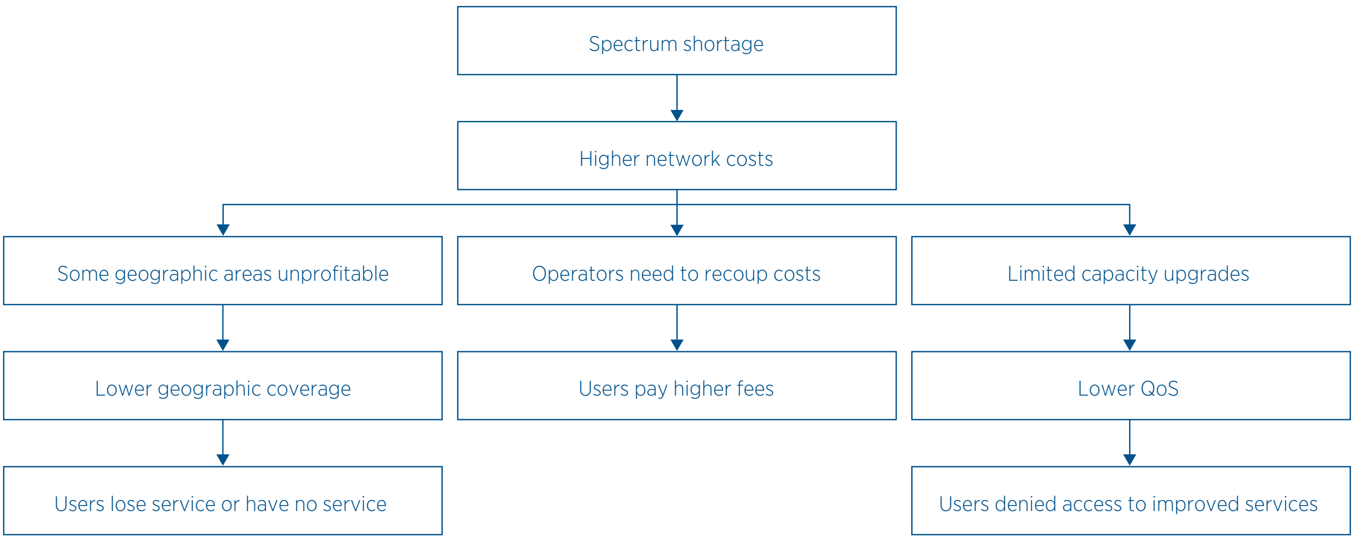
5.1.1 900, 1800 and 2100 MHz

Depending on the configuration of the bands, there is generally up to 340 MHz of spectrum available in the 900 MHz, 1800 MHz and 2100 MHz bands combined[45]. In many developed countries, such and Germany, the UK, Singapore, Hong Kong and France, this spectrum has been fully, or nearly fully, awarded. However, this is not the case in the majority of countries in the SSA region. Some SSA countries have a reasonable amount of legacy spectrum awarded, particularly in South Africa and Nigeria, but many others have significantly less spectrum awarded. For example, Benin and Cameroon have only 213.2 MHz and 214.2 MHz awarded in these bands respectively, while Ethiopia and Kenya both have 210 MHz awarded. Of the countries studied, Rwanda has the least amount of spectrum already awarded, at 170.8 MHz. Given this, it is unsurprising that operators in these countries have asked for more spectrum for both new and legacy services.

It is important that operators can minimise deployment costs by having access to sufficient spectrum to enable countries to benefit from the potential growth in GDP afforded by mobile services. Limited spectrum will require operators to deploy additional base stations to meet traffic demand and this can have an impact on further investment in geographic roll-out, grade and quality of services and prices as shown in Figure 5.1.

FIGURE 5.1

IMPACT OF SPECTRUM SHORTAGES



45 Approximately 70 MHz in the 900 MHz band, 150 MHz in the 1800 MHz band, and 1200 MHz in the 2100 MHz band. Some countries have smaller guard bands between other services allowing for larger amounts. Further, some legacy band plans – such as the interaction between the 850 MHz and 900 MHz band plans – may allow for greater spectrum use at the cost of compatibility.

We recommend that those countries with limited spectrum already released should investigate the potential to release further spectrum in the existing frequency bands of 900, 1800 and 2100 MHz, and the timescales for release and award. There is potentially a total of 2×35 MHz available at 900 MHz, 2×75 MHz at 1800 MHz and 2×60 MHz at 2100 MHz; a total of 340 MHz. While there may be some legacy issues around the use of guard bands and other equipment, this should have a marginal impact on the amount of spectrum available.

Steps involved in identifying and releasing spectrum are as follows.

- Discuss with existing users the potential to release further spectrum. Important considerations are how they can be migrated from the band and associated timescales and migration costs.
- As necessary discuss with mobile operators the options to rearrange the bands once additional spectrum is available to provide contiguous spectrum. In particular for the 1800 MHz band these should ideally be in 10 MHz blocks, which can support LTE (4G) technology.

It is crucial to note that while the award of these legacy bands is important to operators, this spectrum is most likely to be used to provide additional capacity on the existing 2G, 3G and LTE networks. This is a necessary exercise but is not sufficient for 5G or meeting future demand.

5.1.2 700 and 3.5 GHz

The 700 MHz band and in particular the 3.5 GHz range are the preferred frequencies for 5G and should be the main focus for award wherever feasible. The 3.5 GHz range (3300-4200 MHz) has quickly become the prime option for commercial 5G deployments worldwide. Its ability to provide coverage and capacity combined with spectrum availability makes it that ideal candidate. This initial focus on one range is also resulting in a quickly developing ecosystem, with the launch of increasingly affordable devices.

The precise range of spectrum within 3.5 GHz varies by country. Many countries have focussed on an initial assignment of 3.4 GHz to 3.8 GHz, with some also awarding the 3.3-3.4 GHz band. Given the need for large contiguous spectrum bands for each operator, there is significant pressure on regulators to also clear and assign the 3.8-4.2 GHz band. In some countries this may prove difficult given the traditional use of this spectrum by satellite operators; in remote locations there may be extensive use of VSAT networks which will require continued access to spectrum. Part of the regulator’s work must be to ensure that these legacy demands are balanced against the needs for 5G capacity in these key bands.

5.1.3 850 MHz

It is noted that a few countries (including Cameroon) originally awarded the 850 MHz band for CDMA 2000 technology. Depending on the band plans the use of CDMA 850 can lead to potential interference into the 900 MHz (E-GSM) bands within the country or cross-border to neighbouring countries. It is recommended that all countries should adopt the Region 1 allocations and associated band plans and identify how to cease the current use of CDMA as soon as possible and ideally within the next 2 to 3 years to take account of 5G network roll-out and the potential to refarm 2G frequency bands as demand decreases.

5.1.4 Removing WiMAX from 2300 MHz, 2600 MHz and 3.5 GHz

A number of countries (for example, Senegal and Côte d'Ivoire) have awarded the 2300 MHz, 2600 MHz or 3.5 GHz bands for wireless access using technologies such as WiMAX, or for other FWA networks. These bands are potentially suitable for deployment of 4G and 5G and provision of mobile services, as well as wireless access; see Section 2.1. It is possible to award these bands to IMT while retaining the benefits of FWA connections, either by allocating alternative spectrum to the FWA provision, or by moving to a 5G FWA technology solution; the latter would likely provide subscribers with higher quality connections and may be cheaper in the medium term.

We therefore recommend that the following should be considered to determine whether the licences should be revoked, and spectrum re-awarded, or the current allocations retained.

- Are the assignments being used and if not, can they be revoked?
- Are the licences technology and service neutral so the licensees can upgrade to 4G and 5G technologies as they consider necessary based on market developments?
- Does the current licensing provide sufficient spectrum to support 4G or 5G deployments i.e. a minimum bandwidth of 10 MHz and 80-100 MHz contiguous spectrum for each licensee for 4G and 5G respectively?
- Are the current spectrum allocations spectrally efficient or could it be improved by moving licensees within the band or to alternative spectrum?
- Are there competition concerns if licences are not revoked and allowed to be used for mobile?
- Is the current use of the spectrum such that the existing licensees would take part in any award procedure? This would enable the spectrum to be allocated on a market basis to those that would maximise the economic and technical efficiency through an appropriate award process.

Answers to the above and consultation with interested parties should provide a way forward for these bands to be unlocked for mobile and so significantly increase the capacity of mobile networks and enhance user experience.

5.1.5 Other potential IMT bands

There are significant moves towards awarding further spectrum to mobile operators around the world, even before harmonisation decisions are made at WRC. In particular, the 4.8 GHz and 6 GHz bands may be key mid-band spectrum for 5G expansion, given the likely demands from consumers. The GSMA estimates[46] that by 2030, total spectrum demand for 5G services in cities will be approximately 2020 MHz – this is likely not achievable in the 3.5 GHz band alone. Regulators across SSA must consider the use of these bands and support their allocation to IMT at WRC-23, to ensure there can be high-quality broadband connections available to all citizens in their countries.

5.2 Technology neutral licences

It is important that technology neutral licensing is adopted to provide the necessary flexibility to operators to deploy new technologies based on market demand and their own service and network roadmaps.

Uncertainty and delays can lead to reductions in network investment and impact on roll-out, quality, cost and availability of services. This approach should apply to existing and new licences and may require changes to a country's underlying legislation.

46 GSMA, https://www.gsma.com/spectrum/resources/5g-mid-band-spectrum-needs-vision-2030/

Appendix A
Roadmap considerations

This Appendix provides further information on the considerations for the steps shown in the universal roadmap in Section 2.2 that are based on international experience and best practice.

A.1 Spectrum clearance considerations

In general, there are two main approaches to releasing spectrum for mobile broadband:

1. Clearance and, if needed, relocation of incumbent services; and
2. Sharing with incumbents through the use of appropriate mitigation measures.

The feasibility of band clearance and timescales involved are dependent on a number of factors, including:

- The type of service and number of users – for example in the C-band the number of consumers using DTH satellite TV is likely to be many times that of enterprise users of VSAT data communications.
- The possible impact on consumers and how this can be managed if there is a need to replace or upgrade equipment to maintain services (e.g. for DTH users, what are the other forms of receiving TV services)?
- The availability of alternatives for users to maintain their current service output, e.g. through alternative frequencies or wired technologies
- The cost of migration to alternatives identified above and measures which need to be put in place to address potential disruption to services.

Typically, a cost benefit analysis will be undertaken to assess if clearance of the band is the optimum approach or if other options such as mitigation and coexistence measures are more appropriate. The feasibility of coexistence measures will also depend on the nature and extent of incumbent usage. For example, sub-1 GHz bands (e.g. 600 MHz, 700 MHz) are typically used for broadcast TV services over wide geographic areas which means coexistence with 5G is impractical. On the other hand, usage by incumbents in other bands, such as fixed links and fixed satellite, may be highly localised which increase the opportunities for shared use.

The types of coexistence measures which can be considered include:

- Protection of existing users (e.g. FSS or FS) through methods such as
  - Shielding or use of exclusion zones
  - Using improved FSS receivers
  - Addition of filters to FSS receivers
- Restrictions on IMT deployments such as
  - Limitations on locations deployed
  - Antenna down-tilt or pointing, taking account of the location of existing users
  - Reduced transmitter power
- Detailed coordination between new and existing users
- Use of guard bands to separate new and incumbent users into different sub-bands.

More novel techniques for sharing spectrum such as licensed shared access (LSA) and dynamic spectrum access (DSA) could also be potential solutions. These involve active control of interference through the use of geolocation databases and sensing technologies. Examples of initiatives involving such techniques include the Citizen Band Radio Service (CBRS) in the 3.5 GHz band in the US and the LSA framework in the EU. Depending on specific local circumstances, a combination of coexistence measures and clearance can also be considered, if clearance is not feasible.

A.2 Timing for 5G spectrum release

For governments and regulators planning for their 5G spectrum roadmaps, the prioritisation and timing of release of specific bands depend on two main factors, namely

1. The ecosystem around specific 5G bands which will drive economies of scale in the availability and cost of devices and equipment; and
2. The challenges in clearing the band or in implementing the necessary mitigation measures.

The three main priority bands being considered for 5G to date are the 700 MHz[47], 3.3-3.8 GHz and the 26/28 GHz bands. The timing for the release of these bands and the potential amount of spectrum available in each band is contingent on the spectrum clearance considerations and the mitigation measures discussed above.

Some countries, particularly those where there is extensive use of C-band satellite services, have faced difficulties in releasing the 3.3-3.8 GHz band.[48] Potential alternatives to mid-band spectrum include the 2.3 GHz and 2.6 GHz bands,[49] although the feasibility of using these bands for 5G depends again on the extent of current deployments which may include broadband wireless access (BWA) and multichannel multipoint distribution systems (MMDS). Ensuring a timely and orderly transition of incumbent services will be necessary to the efficient release of these bands for 5G.[50]

A.3 Objectives of award

Radio spectrum is a public resource and is an essential input into the provision of communications services as well as an enabler of various functions performed by both private and public sector entities across different sectors of the economy and society. Thus, the first and foremost objective of spectrum management is to ensure the efficient use of spectrum, particularly in situations of scarcity which hitherto has been the case when it comes to spectrum for IMT use. In addition, many governments are putting 5G as a core aspect of industrial policy and see it as a key enabler of digital transformation across different industry sectors and as an engine for economic growth. As a result, promoting investment in 5G infrastructure and facilitating network deployment have also become important policy objectives.

One of the main challenges of 5G is the need for denser networks at the RAN level with a significantly higher number of small cells being introduced. Mobile operators are keen to deploy 5G to tap into new revenue streams, including new consumer applications such as multimedia, augmented reality and virtual reality services, and industrial and enterprise applications related to massive Internet of Things (IoT) and ultra-reliable low latency communications across different sectors such as manufacturing, logistics, utilities, transport, and healthcare. At the same time, they are also concerned about the associated costs and the risks that the investment will not pay back. The responses from policymakers and regulators to these concerns have been reflected in a number of ways including:

- Longer duration for spectrum licences,
- Promotion of, or greater openness to, network sharing including spectrum sharing,
- Introduction of measures to reduce administrative and regulatory barriers to network deployment,
- Reduction in licence fees in some cases, and
- Incorporating measures in spectrum award design to ensure equitable distribution of spectrum and to reduce uncertainty for operators (for example, spectrum caps and floors).

The suitability of these measures varies according to the specific market conditions and policy objectives. The design of the spectrum award and the licence conditions will need to take account of pressures on the current market structure and consider appropriate measures to mitigate risks and facilitate investment in 5G.

47 The 700 MHz bands may already have been awarded and 4G networks deployed so it may be necessary to consider 600 MHz bands as alternatives.

48 These include countries in South-east Asia. See Plum. Roadmap for C-band spectrum in ASEAN. Report for GSMA, August 2019. https://plumconsulting.co.uk/roadmap-for-c-band-spectrum-in-asean/

49 The 2.3 GHz and 2.6 GHz bands have been earmarked for 5G in countries as China, Saudi Arabia and Thailand.

50 Plum. It is all down to timing – spectrum transitioning. Insight paper, January 2020. https://plumconsulting.co.uk/it-is-all-down-to-timing-spectrum-transitioning/

A.4 Method of award

There are three main approaches to award spectrum – auction, beauty contest and direct assignment. Direct awards are suitable in situations where there is no scarcity, supply exceeds demand, but this tends to be rare for harmonised IMT bands with well-developed ecosystems. For 5G spectrum, some administrations (such as Hong Kong, UK) have chosen to use direct assignments for high-band spectrum due to the relative abundance of the mmWave frequencies and the uncertainty of the use cases and value of these bands at present. Direct assignments are also sometimes used for reassignments or renewal of spectrum as they are most simple to administer.

Auctions have been widely used globally for the award of mobile spectrum, and a well-designed auction would be able to address policy objectives and ensure that the spectrum is assigned to the bidder who values the spectrum the highest (and is thus likely to use it most effectively and efficiently). For 5G spectrum, particularly that in the low and mid bands, where the supply is scarce, many administrations have continued to adopt auctions as the preferred mechanism for assignment.

Beauty contests or comparative tenders are an alternative option for awards where there may be other policy objectives beyond the pure economic value of spectrum. This was adopted by Japan in their 2019 multiband 5G award and has been considered by MCMC in Malaysia (700 MHz, 3.5 GHz, 26 GHz) as well. Factors which are used in the evaluation process may include coverage, quality of service, rollout plans, financial viability, technical experience and service pricing. A hybrid, involving a beauty contest with financial bidding, is also possible, for example, this was proposed by France (3.5 GHz) and Singapore (3.5 GHz and 26/28 GHz).

Figure A.1 provides a comparison of the general aspects of the three types of awards and the situations in which they are suitable.

FIGURE 5.1

FIGURE A.1: KEY FEATURES OF DIFFERENT TYPES OF AWARDS[51]

Features	Auction	Comparative tender	Direct award
Design aspects (efficiency, competition, cost)	Allows for greater freedom and flexibility for bidders to express their demand for spectrum. Delivers an economically efficient outcome with spectrum sold at market clearing price. Spectrum caps can be used to address competition issues, but intervention reduces economic efficiency. High costs of implementation but can vary depending on auction format and spectrum lots sold.	Less freedom and flexibility as bidders are required to abide by set evaluation criteria. Risk of inefficient allocation if evaluation criteria too subjective. Price of spectrum may not reflect opportunity cost. Cost can vary but typically lower than auction. Regulators have better opportunities to influence awards to meet their economic objectives.	Risk of inefficient allocation in cases where there is excess demand. Price of spectrum may not reflect opportunity cost. New entry either prohibited or enforced, without full consideration of business case reality. Simple, quickest and least costly process to administer.
Public policy objectives	Policy goals can be incorporated but requirements or obligations (e.g. coverage) need to be formulated upfront.	Allows regulator more flexibility to include elements relating to policy goals such as coverage, deployment and quality of service. Bidders can make bids in accordance with their ability and willingness to take on specific obligations. Subjective criteria harder to evaluate.	Can be addressed through imposition of obligations. Potentially less say for licensees but there could be extensive consultations in advance. Results in minimal disruption to operators and end users (in case of renewals).
Situations where these are used	Supply is less than demand (number of lots exceed number of bidders) and where there is uncertainty over efficient allocation Newly released bands (where there are no incumbent users).	Control of the assignment process is necessary (e.g. in the case of distorted markets or where there is a preference for more focus on non-price aspects and specific policy objectives). Appropriate when the number of licences is limited.	No scarcity of supply, or demand is unclear. Renewal of existing spectrum (e.g. 1800, 2100 MHz) which is being utilised efficiently. Appropriate when there are no market distortions that could jeopardize long term interest of end-users.

51 See also GSMA Public Policy Position on Auction Best Practice, May 2019. https://www.gsma.com/spectrum/wp-content/uploads/2019/05/Auction-Best-Practice.pdf

A.5 Licensing and obligations

Government policies on spectrum management usually involve allocation decisions and related matters, such as access by different users or uses, market competition, public safety and security needs, industry development and social objectives (e.g. digital inclusion). Spectrum awards provide a good opportunity for regulators to address and promote specific policy objectives and outcomes.

Public policy objectives are usually taken into account in the design of the award process and the obligations or conditions placed on the spectrum licences. In administrative awards or comparative tenders, these objectives can also be reflected in the evaluation criteria and the commitments made by the bidding parties. These can be related to aspects such as

- network coverage, in terms of geographic or population covered, indoor or outdoor, transportation links (for example, road or railway);
- service quality, in terms of average or minimum data throughput;
- network rollout, in terms of deployment timescales; and
- access requirements (for example, wholesale or interconnection for MVNOs).

Spectrum awards can also be a mechanism for promoting competition by facilitating market entry by new players or to address potential issues of market power and enable more effective competition between players in the market.[52] While the incorporation of public policy goals in spectrum award processes is increasingly common, it is important in designing the award and obligations to take into account the local market context and ensure that the measures are appropriate and do not place undue burden on businesses.

Another important aspect of 5G is that unlike previous generations of mobile technology, 5G is envisaged to serve a multitude of applications with heterogenous performance and spectrum requirements. Techniques such as Software Defined Networking (SDN) and Network Function Virtualisation (NFV) will allow 5G connectivity to be much more flexible, simultaneously addressing different use cases. From the regulatory perspective this is likely to require new approaches to spectrum award and authorisation.

With the variety of frequency bands identified for 5G – low, mid and high, this form of geographic licensing may no longer be appropriate for the types of use cases in the 5G era. New users (industry verticals) and applications will not necessarily require spectrum access on a wide geographic scale. Often these will be on a limited, highly localised basis and may involve a range of frequency bands. For example, agriculture uses may require wide area coverage in rural areas and so require spectrum below 6 GHz, but other industrial applications, such as those in indoor environments may be better suited to mmWave bands.

The range of options being considered by regulators to address these industrial sector uses include:

- **Spectrum leasing** – where the mobile network operator (MNO) leases some of their spectrum which they have identified will not be required in the short to medium term at a specific location, generally on a commercial basis, to another user.
- **Spectrum sharing solutions** – this is similar to leasing but in this case the regulator will issue a licence for the specific spectrum and location, and the conditions to be met by the new user. For example, Ofcom has adopted this approach in the UK for already licensed bands (3.8-4.2 GHz, 2.3 GHz, 1800 MHz) to support innovative use.[53] Another option is Dynamic Spectrum Access (DSA) where the usage of a band at a location can be determined through use of a geo-location database, possibly with beacons or sensors, before being utilised and so avoid interference to the primary or other licensed users.[54]
- **Identifying spectrum specifically for new users.** There is currently no single approach adopted but there are proposals for licence exemption or light licensing in the mmWave bands.[55]

With 5G, there is no ‘one size fits all’ licensing solution. Instead, a range of licensing approaches, including licence exempt spectrum, will be considered. As new 5G use cases, not just eMBB, are starting to emerge, it will be timely for regulators to review existing licensing approaches and consider new forms of spectrum access to cater to innovative uses in new 5G bands.

52 These are usually done through spectrum set-asides or spectrum caps.

53 Ofcom. Statement: Enabling wireless innovation through local licensing. 25 July 2019.

54 Examples include TV White Spaces and the Citizens Broadband Radio Service (CBRS) in the 3.5 GHz band in the US.

55 For example, Australia has proposed to make the band 24.25-24.7 GHz available for class licensing for indoor use and 24.7-25.1 GHz for outdoor and indoor use.

A.6 Fees

The primary economic objective of spectrum management is to ensure an efficient distribution of resources to maximise the benefits to society. Spectrum fees are an important mechanism to promote the efficient use of spectrum in cases where there is excess demand. In principle, fees should reflect the opportunity cost of the spectrum though this is sometimes difficult to determine in practice, particularly in the case of 5G where use cases and business models are still uncertain.

Fees can be set administratively by governments and regulators, or through market-based mechanisms such as auctions. With auctions, governments and regulators determine the auction design and set the reserve prices which will have an important influence on the award outcomes and the spectrum prices. As discussed above, 5G deployment will require significant investment and the business model for 5G is still under development at present. In assessing the appropriate fee levels or reserve prices, it is important to take account of the impacts of high spectrum costs on the financial ability of operators to invest in network rollout and on consumer outcomes.[56]

With the award of 5G spectrum, governments are increasingly aware of the challenges faced by mobile operators and the potential role of 5G in transforming industries and enabling the delivery of national policy objectives. This has led to some regulators either opting for more conservative fees or adopting comparative tenders or hybrid awards with a focus on non-price criteria. For example, in Qatar there were no upfront fees and the annual fees for the 3500 and 3700 MHz bands awarded to Vodafone and Ooredoo were QAR 624,000 (US$ 171k) for 100 MHz of spectrum[57]. Japan allocated the 5G spectrum licences at no cost to MNOs (including mid-range spectrum in 3.7 GHz) via a competitive tender. Instead of auctioning the spectrum, the tender process awarded the spectrum licences based on a number of criteria including the best 5G investment proposals[58]. Additionally, in China, where there is no upfront spectrum charge, 5G spectrum usage fees for the first three years are waived, followed by a staged reduction of 25%, 50% and 75% for years four, five and six respectively. Full fees apply from year seven onwards. It is also vital that the regulator awards long-term (e.g. 25 years) with the expectation of renewal[59].

56 GSMA. The impact of spectrum prices on consumers. September 2019. https://www.gsma.com/spectrum/wp-content/uploads/2019/09/Impact-of-spectrum-prices-on-consumers.pdf

57 Source CRA Qatar and Decision on radio spectrum fees.

58 chrome-extension://bocbaocobfecmglnmeaeppambideimao/pdf/viewer.html?file=https://www.soumu.go.jp/main_content/000613734.pdf

59 http://www.gov.cn/fuwu/2018-04/28/content_5286546.htm

Appendix B
Country abbreviations

Acronym	Full form
BEN	Benin
CAM	Cameroon
CIV	Côte d'Ivoire
COD	Congo; Democratic Republic
DEU	Germany
ETH	Ethiopia
FRA	France
GBR	United Kingdom
JPN	Japan

Acronym	Full form
KEN	Kenya
KOR	South Korea
NGA	Nigeria
RWA	Rwanda
SEN	Senegal
SGP	Singapore
TWN	Taiwan
ZAF	South Africa

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