Roadmaps for awarding 5G spectrum in the APAC region

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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 APAC region. The study goes on to identify where countries currently sit on this roadmap and identifies recommended actions for countries in the region.

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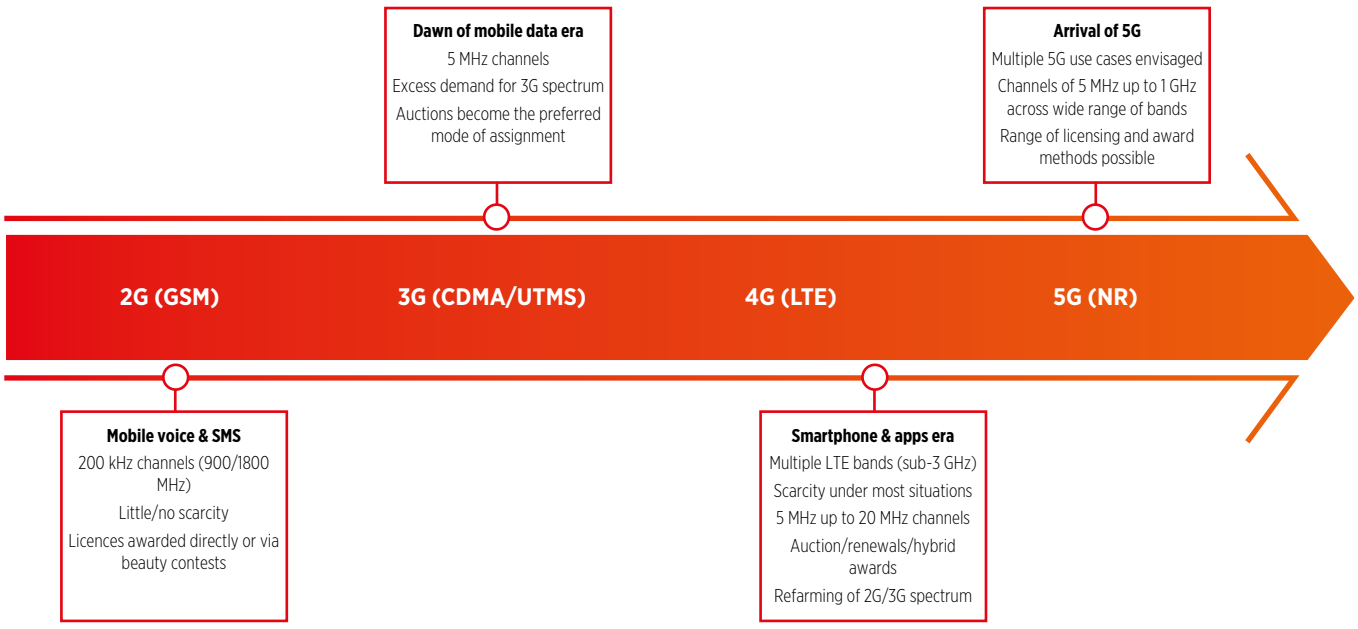
Summary

Countries in the Asia Pacific region have been at the forefront of many mobile technologies, from the first 3G network launching in Japan to the first commercial 5G networks in South Korea, and also significant market changes, as encapsulated by rapidly decreasing average revenue per user (ARPU) and increasing uptake in India. The difference in the historic establishment of fixed telecommunications networks between countries has had some effect on the uptake of mobile – those countries with less fixed infrastructure are those where consumers benefit most from mobile broadband technologies – but all countries have seen a massive growth in the number of subscribers and the capabilities of mobile networks.

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



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 874 operators with launched commercial LTE networks with 216 operators investing in LTE Advanced Pro technologies[1].

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 some countries in APAC, such as Bangladesh, Cambodia and Pakistan, where (as of 2020) over half of all subscribers were on 2G or 3G connections and the migration to LTE is predicted to occur over the next few years. Policy should be designed to help accelerate the transition to 5G, so the full benefits from 5G may be realised earlier.

5G in APAC countries

In the APAC region, there is a wide variety of network deployments and technologies. While the majority of countries are beginning to invest in 5G networks, there is still a lot of LTE investment, particularly in countries where regulators have not been clear with their spectrum release programme. In some countries where LTE roll-out has been slower, operators and policymakers must consider how to balance the need for increased LTE availability against the introduction of new 5G networks.

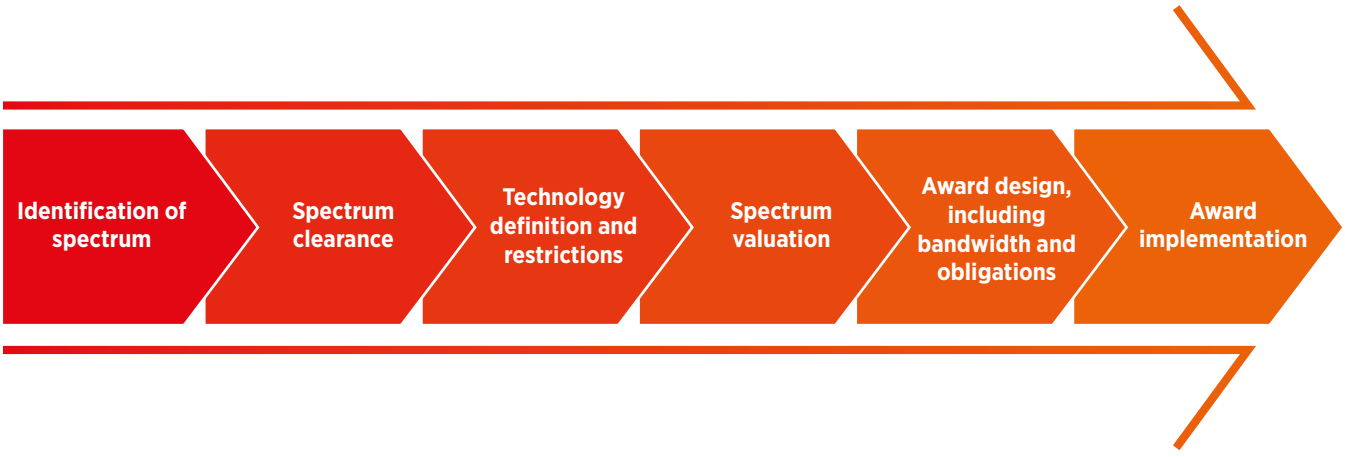
This report looks at the need for 5G spectrum to be made available, and the current status across the APAC region. It then sets out a roadmap to help governments and regulators enable 5G in the most efficient way possible. It also provides recommendations based on international best practices.

Roadmaps

Figure 2 provides a universal roadmap that can be applied to the award of spectrum for 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



1 GSA, GAMBoD database, as at 11 November 2021

2 GSMA, available at 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. In addition, while this roadmap sets out the steps needed for spectrum assignment, there are many other aspects of network deployments – such as trials, ecosystem specification, and market analysis – that must be carried out simultaneously.

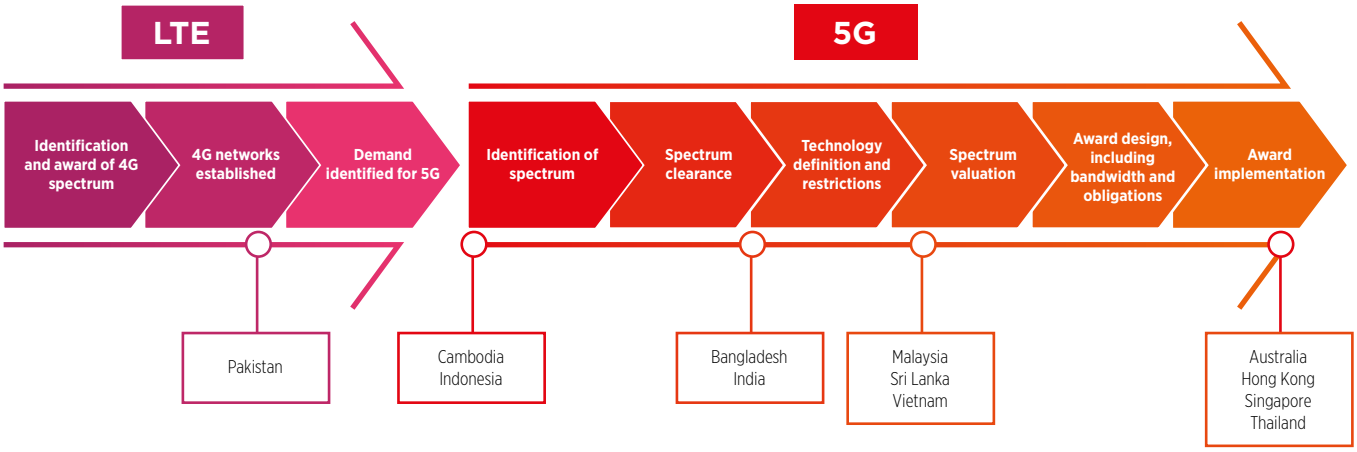
- **Identification of spectrum.** The key frequency bands to prioritise for 5G are the 3500 MHz range, 700 MHz and mmWaves; the last of these is currently mainly aimed at small independent use cases. However, it may be necessary to consider alternative bands – either those that have already been awarded for mobile (and can be refarmed) or other internationally harmonised bands that have yet to be awarded. 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 award: 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 a complete move to 5G; Pakistan appears to be in the process of rolling out or upgrading LTE services, and Cambodia and Indonesia are still investigating the role of 5G as a technology, as shown in Figure 3. This data comes from GSMA Intelligence, operators and inputs from regulators and ministries and other public online sources.

4 For the GSMA auction best practice position see https://www.gsma.com/spectrum/wp-content/uploads/2021/09/Auction-Best-Practice.pdfhttps://www.gsma.com/spectrum/wp-content/uploads/2019/05/Auction-Best-Practice.pdf

FIGURE 3

ESTIMATED CURRENT STATUS ON ROADMAP



While some countries may be more advanced than others, it is clear that all are working towards ensuring that 5G networks are deployed and operational. However, the most successful countries are those with a defined plan for 5G deployment, in terms of where it is needed and which services should be provided. In all cases 5G is set to roll out alongside existing LTE networks, and given the greater complexity of the 5G ecosystem it is important that demand is clearly understood.

Spectrum clearance is generally underway, although some countries are concentrating only on one band (the 3500 MHz band) as a priority which may lead to poorly dimensioned and costly networks. While 5G networks have launched on a commercial basis in a number of countries, and on a trial basis in others, regulators must continue to monitor demand for spectrum to ensure that they are able to release bands in the optimum quantity and location.

Recommendations based on international best practices

A number of general recommendations are based on the current status of spectrum award in the APAC countries and international best practices. In all cases, objectivity, transparency and accountability should be considered as key principles for spectrum allocation.

850, 900, 1800 and 2100 MHz

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

Depending on the configuration of the bands, there is generally up to 380 MHz of spectrum available in the 850 MHz, 900 MHz, 1800 MHz and 2100 MHz bands combined. 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 some countries in the APAC region. Some countries have a reasonable amount of legacy spectrum awarded, but many others, in particular in Cambodia, Bangladesh and Pakistan, have significantly less spectrum awarded. Given this, it is unsurprising that many operators in these countries have asked for more spectrum for both new and legacy services. 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.

The situation around 850 MHz in APAC is quite fragmented and progress has been slow due to incumbents and lack of consensus and harmonisation region wide.

- CDMA: there are still a number of developing APAC countries which have CDMA800 technologies operating, although these should be declining and licences should be technology and service neutral to facilitate refarming, and so therefore this may not be a significant issue in the future.
- PPDR: the 800 MHz band has been identified for PPDR[5] and there are various technologies in use or being considered (TETRA, P25, LTE).
- Interference into 900 MHz: the use of this band plan means countries need a guard band of around 10 MHz, or allow interference to be self-managed (requiring the same operator in adjacent 850 MHz and 900 MHz frequencies).

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, under viable terms and conditions, where limited spectrum is currently available.

We recommend that those countries with limited spectrum already released should investigate the potential to release further spectrum in the existing frequency bands of 850, 900, 1800 and 2100 MHz, and the timescales for release and award. Depending on the configuration, there is potentially a total of 2×45 MHz available across the 850 MHz and 900 MHz bands[6], with 2×75 MHz at 1800 MHz and 2×70 MHz at 2100 MHz; a total of 380 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. Regulators must consider the demand for spectrum against its supply, to ensure that spectrum release is based on an efficient reflection of end-user demand.

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 3500 MHz

The 700 MHz band and in particular the 3500 MHz range are the currently preferred frequencies for 5G and should be the main focus for award wherever feasible. The 3500 MHz range (3300 MHz – 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 3500 MHz varies by country. Many countries have focussed on an initial assignment of 3400 MHz to 3800 MHz, with some also awarding the 3300 MHz – 3400 MHz band, and others considering the wider range at 3800 MHz to 4200 MHz. 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, some of which have only recently been moved to these frequencies to clear the lower 3.5 GHz band. There may be a need for extensive refarming work to ensure that mobile operators have access to spectrum that does not suffer from interference, while maximising the bandwidth available – this may not require guard bands with improvements to VSAT equipment and filters, for example. Part of the regulator's work must be to ensure that legacy demands are balanced against the needs for 5G capacity in these key bands.

5 See https://www.apt.int/sites/default/files/Upload-files/AWG/APT-AWG-REP-73Rev.1_APT_Report_PPDR_Spectrum_Harmonization.docx

6 Malaysia has achieved this with 2×10 MHz in the 850 MHz band, and 2×35 MHz in the 900 MHz band. However, this has led to a few synchronisation issues in border regions.

800 and 850 MHz

Within ITU Region 3, where APAC countries sit, there has traditionally been some use of the 850 MHz band for 2G services. As stated above, this has impacted in many cases on the way that the 900 MHz band could be configured; this also affects the availability of the 800 MHz band – and now the 700 MHz band. This is not only a problem within a single country. Not all countries use 850 MHz spectrum (for example, Singapore has not awarded this band) but where neighbouring countries continue to run this band there will be interference into related spectrum in border areas. In addition, use of the 800 MHz band for PPDR (as described above) will have a further impact on the availability of spectrum.

So that maximum use can be made of sub-1 GHz spectrum, it is crucial that countries liaise to configure all sub-1 GHz spectrum bands in a way that minimises interference and maximises efficiency. This will be particularly important as legacy networks become less used, so spectrum is desired for use on 5G technologies.

Other 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. Indeed, Hong Kong has already awarded some spectrum in the 4.8 GHz band. The GSMA estimates that by 2030, total spectrum demand for 5G services in cities will be approximately 2 GHz – this is likely not achievable in the 3500 MHz band alone. Regulators across APAC 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.

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 4800 MHz and 6 GHz bands may be key mid-band spectrum for 5G expansion, given the likely demands from consumers. Indeed, Hong Kong ha already awarded some spectrum in the 4900 MHz band. The GSMA estimates[7] that by 2030, total spectrum demand for 5G services in cities will be approximately 2020 MHz – this is likely not achievable in the 3500 MHz band alone. Regulators across APAC 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 for its citizens, 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.

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

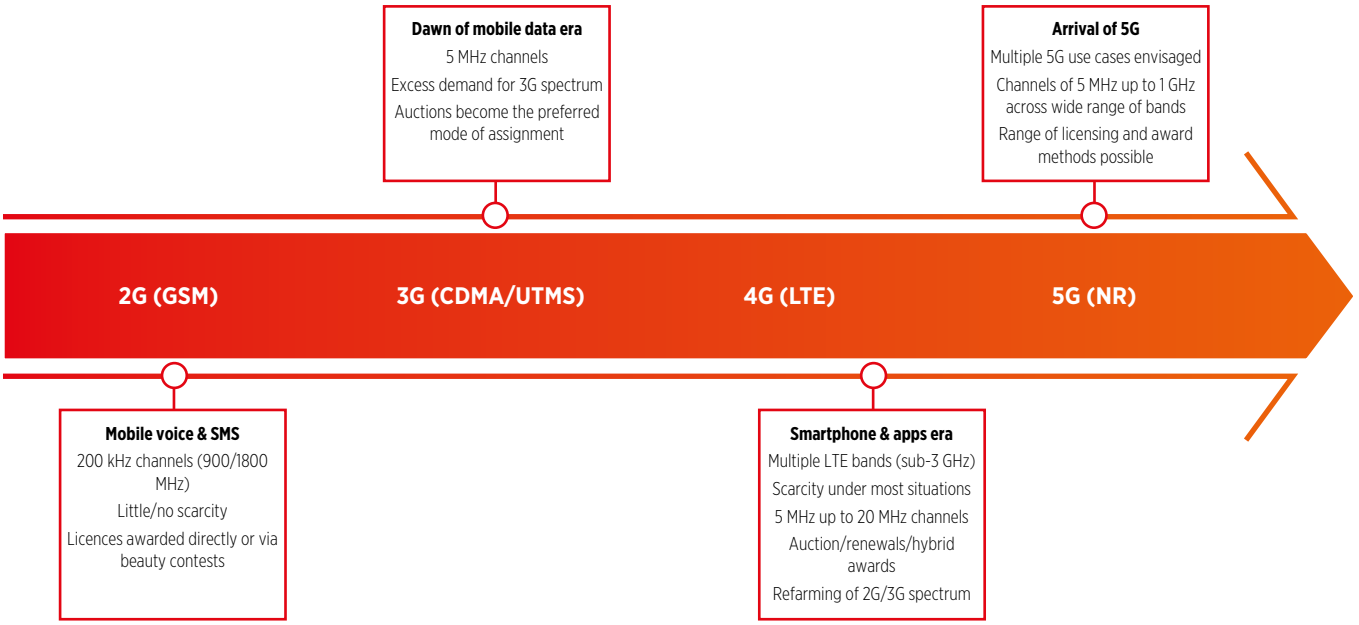
1 Introduction

Countries in the Asia Pacific region have been at the forefront of many mobile technologies, from the first 3G network launching in Japan to the first commercial 5G networks in South Korea, and also significant market changes, as encapsulated by rapidly decreasing ARPU (and increasing uptake) in India. The difference in the historic establishment of fixed telecommunications networks between countries has had some effect on the uptake of mobile – those countries with less fixed infrastructure are those where consumers benefit most from mobile broadband technologies – but all countries have seen a massive growth in the number of subscribers and the capabilities of mobile networks.

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[8].

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.[9] 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.

Across Asia Pacific, some countries – in particular, South Korea, Japan and the Philippines – have been global leaders in the rollout of 5G technologies. The first commercial 5G network in the world was launched in South Korea on 3 April 2019 and Japan had been trialling 5G network technology since 2010 before launching a decade later. Meanwhile, Global Telecom was one of the first FWA providers in the world to launch a 5G network, in June 2019. Not every country is as advanced, however. Sri Lanka has a limited 5G trial in operation, while Bangladesh is still in the process of planning upgrades to LTE-Advanced, let alone 5G deployment. A key component of 5G investment, spectrum, has been awarded in some countries and not others, with operators in the latter category needing to refarm existing holdings away from 2G and 3G to enable services to launch.

This report considers how 5G spectrum needs to be made available and examines the current state of spectrum assignment across a number of countries across Asia Pacific. It then sets out a roadmap for governments and regulators to follow to enable this to be achieved in an efficient and effective way.

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

9 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 3500 MHz 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[10]. High-band spectrum (such as 28 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.

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

FIGURE 2.1

POSSIBLE 5G APPLICATIONS AND THEIR SPECTRUM REQUIREMENTS[11]

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 (400 MHz) Multi-gigabit fronthaul and backhaul, indoor	> 24 GHz
	High-speed radio links	Wide carrier bandwidths, (100 MHz) gigabit fronthaul and 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, such as mmWave, for outdoor operations	< 6 GHz
	High-reliability radio links	Impact of rain and other atmospheric effects on link availability in higher frequencies, such as mmWave, for outdoor operations	< 6 GHz
Ultra-reliable Communications	Short range	Higher frequencies (mmWave)	> 24 GHz
	Medium to long range	Lower frequencies, sub-6 GHz	< 6 GHz
	Ground and obstacle penetration	Lower frequencies, 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[12]	All ranges
	Operation near fast-moving obstacles	Frequency-selective fading channels[13]	All ranges, especially below 6 GHz
	Mesh networking	High-speed distributed wireless back-hauls 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 3300-3800 MHz band. Figure 2.2 provides an overview of the 5G bands.

11 Source: 5G Americas

12 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.

13 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[14]

Range	Main 5G bands	Main incumbent use	Notes
Low-bands	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 a number of countries.
Mid-bands	2300 MHz 2600 MHz 3300-3800 MHz 3800-4200 MHz 4400-5000 MHz 6425-7125 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-bands	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 APAC

There is a wide variety of 5G deployment across the Asia Pacific region. Some of the world leaders in the use of the technology are located in the region, with South Korea and Japan being among the first to launch both test and commercial networks. On the other hand, some countries lag significantly behind, with upgrade to LTE networks only just being deployed.

As part of ITU Region 3, but with significant investments from European and American parent companies, the use of spectrum bands has additional challenges; there is less harmonisation and a mixture of Region 1 and Region 2 band plans are in use. A number of countries implemented 2G networks using the 850 MHz band during the 1980s and 1990s, while others allocated spectrum using the 900 MHz band plan. This led to complications on borders and when spectrum was further released in the 800 MHz band; even today there are limited awards at 800 MHz. 2600 MHz has been similarly impacted; due to a general lack of spectrum in the 3.5 GHz range, a number of countries (such as Thailand and Vietnam) are now adopting the b41/n41 band plan rather than the b7/b38 plan used in other states. Further, some Asia Pacific countries have awarded spectrum in less common bands such as 4.5 GHz, 4.8 GHz and 3.3 GHz.

Linking this variation in 5G deployment and difference in spectrum awards, countries have taken a very diverse approach to awarding spectrum for 5G. A few countries have become the first in the world to award spectrum in the mm-wave bands, with both 26 GHz and 28 GHz spectrum available in selected locations. The 700 MHz which was developed by the APT and adopted as a harmonised band in 2010 has been awarded in some countries but this key band remains unavailable in many major APAC markets due to delays in the switch-off of analogue TV and cross-border coordination issues. There have even been awards at 450 MHz which can be applied to 5G networks. However, there remain a number of countries where spectrum for 5G has not been awarded, and there have been no significant steps towards ensuring this can happen.

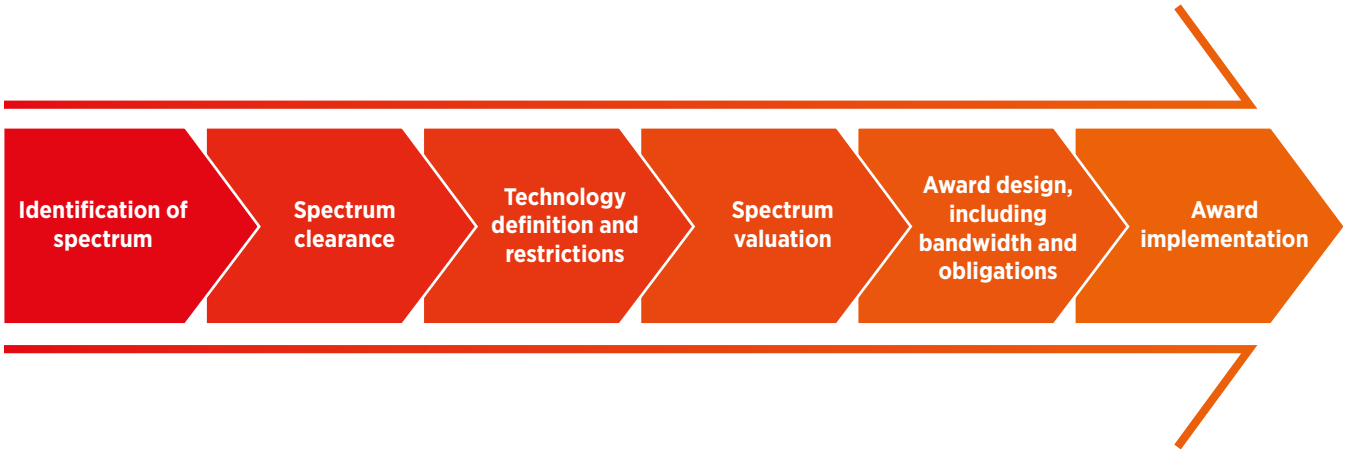
14 The existing mobile frequency bands are also identified for 5G NR but as these are typically already used the focus for 5G has been on new frequency bands.

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[15], 3500 MHz and 26 GHz (and 28 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, 4.8 GHz and 6 GHz bands.

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.

15 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[16]

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 operations in these bands to 5G when it is most efficient. However, particularly in the 2600 MHz band, awards may have already been made using an FDD band plan[17] whereas the market may consider a TDD configuration[18] would be of better use. This may require regulators to reassign existing spectrum between existing users, but it is unlikely that this will be achieved in the short-term due to existing LTE use in many countries and so there is unlikely to be harmonised use of the 2600 MHz band in the near future. For markets where 2600 MHz remains unused or underutilised, a conversion from FDD to TDD could be encouraged. Both options provide great benefits. While the FDD+TDD[19] option has been extensively adopted around the world (in Europe and Latin America especially) and carries an extensive ecosystem, the TDD-only option is getting traction particularly in the 5G era. This decision should consider neighbouring countries in order to have a swift interference-free service, understanding the risks of TDD synchronisation interferences when FDD is used on the same band. Consulting extensively with all interested parties to determine the best option for each market is suggested.

The GSMA estimates[20] that by 2030, total mid-band spectrum demand for 5G services in cities will be, on average, 2 GHz – this is likely not achievable in the 3500 MHz band alone. Regulators across APAC must consider the use of these other 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; it is crucial that operators are able to plan network deployment knowing which spectrum will be awarded and released in the future.

16 GSMA, available at https://www.gsma.com/spectrum/resources/5g-spectrum-positions/

17 LTE Band 7 or 5G Band n7

18 5G Band n41

19 LTE Band 7 (TDD) and Band 38 (TDD)

20 GSMA, available at 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, whether IMT users or other services. The feasibility of band clearance and relocation 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 assess the potential for sharing.[21] Sharing may be possible where there is limited industrial or governmental use, or existing regional licences. If frequencies are already assigned to mobile network operators on a service and technology-neutral basis 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[22], 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).[23]

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.

Note that restrictions included here generally do not include service obligations placed on spectrum users, which will usually be defined along with the award design.

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.[24]

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.

21 For more information and examples on cost-benefit analysis and impact assessments, see https://www.gsma.com/spectrum/resources/mobile-spectrum-maximising-the-socio-economic-benefits/

22 Worst case interference is base station to base station

23 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.

24 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

2.3 Detailed case study: Australia

Australia is one of the leading markets in the Asia Pacific region in terms of the 5G rollout, which was enabled by the timely release of suitable 5G spectrum bands, particularly in the 3500 MHz band. As of Q2 2021 5G population coverage in Australia had reached 76.6%,[25] and 5G speeds in Australia are among the highest in the world.[26] As such it is useful to consider lessons that can be learnt from its spectrum policy and how these can be applied to other countries in the region.

The Australian Government set out its strategy to support the timely rollout of 5G in a policy direction paper published in October 2017.[27] Specifically the Government committed to supporting early 5G deployment by:

- making spectrum available in a timely manner;
- actively engaging in international spectrum harmonisation activities;
- streamlining arrangements to allow mobile carriers to deploy infrastructure more quickly; and
- reviewing existing telecommunications regulatory arrangements to ensure they are fit-for-purpose.

As part of the strategy, a working group, comprising different government departments, mobile operators, equipment vendors and subject matter experts, was convened to identify enablers and barriers in regulations for the use of 5G in Australia and to provide a platform for collaboration on 5G issues.[28]

25 GSMA Intelligence.

26 https://www.gsma.com/membership/resources/5g-speeds-in-australia-are-almost-twice-the-global-average/

27 https://www.communications.gov.au/departmental-news/5g-enabling-future-economy

28 https://www.communications.gov.au/departmental-news/5g-working-group-membership-and-terms-reference

There are three main mobile network operators in the Australian market – Telstra, Optus and Vodafone Hutchinson Australia (VHA). TPG, a retail fixed broadband provider and an MVNO, which had acquired spectrum in the 700 MHz and 2600 MHz bands, merged with Vodafone in 2020. The other key industry player is NBN Co, a wholesale-only broadband provider which offers high-speed broadband access using a mix of fibre, fixed wireless and satellite technologies. NBN Co does not operate a mobile network although it has access to frequencies in the 2300 MHz and 3400 MHz across different regions to support the provision of fixed wireless broadband services.

Figure 2.5 shows the spectrum holdings of the major operators as of April 2021, following the award of the 26 GHz spectrum licences. It should be noted that in the bands where regional licences are assigned, the holdings per band may vary across different regions.

FIGURE 2.5

SPECTRUM HOLDINGS IN AUSTRALIA (MAJOR PLAYERS), AS OF APRIL 2021[29]

Band	Telstra	Optus	VHA	TPG	NBN Co
700 MHz FDD(1)	40	20	10	20	-
850 MHz FDD(1)	20	-	20	-	-
900 MHz FDD(1)	16.8	16.8	16.8	-	-
1800 MHz FDD	80(2)	70(2)	70(2), 10(4), 10(6)	-	-
2100 MHz FDD	30(3), 10(4)	40(3), 10(4)	30(3), 20(2)	-	-
2300 MHz TDD	70(5)	42(2)	-	-	92(7)
2500 MHz FDD(1)	80	40	-	20	-
3.4-3.7 GHz TDD	92.5(2)	94.5(2)	95(2)		~70(8)
26 GHz TDD	1000(9)	800(9)	600(9)		

Notes: (1) Australia-wide. (2) Major cities and regional. (3) Major cities. (4) Regional. (5) Remote areas. (5) Major cities and regional. (6) Darwin, Hobart. (7) Regional and remote areas. (8) Metro, regional and remote areas. (9) Typical amount won in each region. Bandwidths may vary in some regions.

29 Source: APT, ACMA, Plum analysis

ACMA's process for reallocation of spectrum for mobile broadband

The Australian Communications and Media Authority's (ACMA) spectrum management process for identifying potential future spectrum options for mobile broadband (MBB) involves three broad stages as described in Figure 2.6 below.

FIGURE 2.6

ACMA PROCESS FOR CONSIDERATION OF ADDITIONAL SPECTRUM FOR MOBILE BROADBAND[30]

Stage	Description
Stage 0 – Monitoring	'Business-as-usual' **monitoring** of international and domestic MBB spectrum trends.
Stage 1 – Initial investigation	Initial investigation and scoping of potential **options** for domestic re-farming of a band, informed by preliminary technical assessment. If initial scoping and technical assessment shows potential, **preliminary assessment of highest value use** of the spectrum is undertaken.
Stage 2 – Preliminary re-planning	Identification of re-planning/re-farming **proposals** (including mechanisms to address incumbent issues) informed by detailed technical sharing studies and analysis of ongoing incumbent spectrum needs. A **comprehensive assessment of the highest value use or uses** of the band is undertaken.
Stage 3 – Re-farming	**Decisions** made on preferred re-farming proposal.
Refarming sub-stage a – replanning	Detailed band/channel re-planning undertaken to support the change in the use of the spectrum to MBB. Where possible, long-term transition arrangements are put in place, allowing incumbents to transition **voluntarily** over time (incumbents **retain their rights** during the re-planning stage in accordance with the Radiocommunications Act). In this scenario, a change of spectrum use commences at this stage, with final implementation concluded in the allocation sub-stage via an allocation of spectrum to specific MBB users. However, in some cases it may be appropriate for spectrum already available for MBB to be replanned in order to better support new MBB technologies. In this scenario, a change of use of spectrum and subsequent allocation may not be necessary. In such cases, the allocation sub-stage is not required and the process would stop here.
Re-farming sub-stage b – allocation (to MBB users)	Development of final technical framework and allocation instruments and tools for near-term re-farming. Incumbents are **obliged** to transition to new arrangements or cease operations in specified time frame (incumbents **rights are varied or removed** in accordance with the Radiocommunications Act). Mobile broadband users are given the opportunity to acquire and use re-farmed spectrum.

The monitoring programme is undertaken on an ongoing basis by the ACMA and reported annually in the five-year spectrum outlook (FYSO) which sets out the planning priorities for the next five years and the work plan for each upcoming year.[31]

The ACMA has completed spectrum awards in the 3600 MHz (3575-3700 MHz) band in December 2018 and in the 26 GHz band in April 2021. There is ongoing work on reorganisation of the 3400 MHz (3400-3575 MHz) to optimise the arrangements in the band to facilitate more efficient use of spectrum, and also to make available more spectrum for wireless broadband in the 3700-4200 MHz range. Further details on the ACMA's activities relating to these core 5G bands are provided below.

30 ACMA. Mobile broadband strategy – The ACMA's spectrum management strategy to address the growth in mobile broadband capacity. February 2016. https://www.acma.gov.au/publications/2016-02/plan/mobile-broadband-strategy

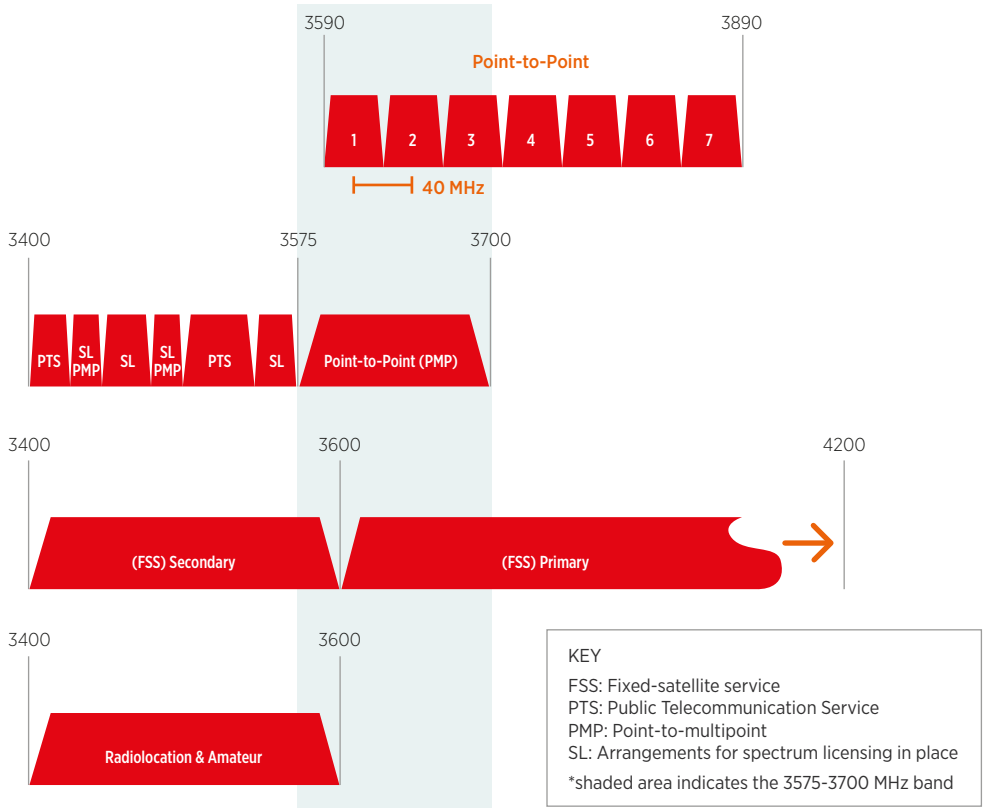
31 https://www.acma.gov.au/five-year-spectrum-outlook

2.3.1 3600 MHz band (3575-3700 MHz) – completed

The ACMA first carried out an initial investigation of the 3600 MHz (3575-3700 MHz) band in 2016 to consider the refarming options of this band for mobile broadband services. At that point the services utilising the spectrum included satellite earth stations, point to multipoint (licensees included Wireless Internet Service Providers), point to point links and radio amateurs as shown in Figure 2.7. A discussion paper was published in October 2016 which set out the current arrangements and use, potential spectrum options, coexistence issues with incumbent services and a preliminary assessment of the highest value use of the band.[32]

FIGURE 2.7

INCUMBENT USE OF 3600 MHz BAND[33]



Following a consultation period and further analysis, a future options paper was published in June 2017 that set out its preferred option for the future use of the 3600 MHz band and mitigation opportunities for incumbents.[34] As part of the planning process ACMA undertook analysis to determine the highest value use of the band and concluded that this was wide-area broadband deployments (fixed / mobile) in metro and regional areas.[35] The ACMA's preferred option for the 3600 MHz band was to establish arrangements optimised for wide-area broadband deployments over the entire 125 MHz of the 3600 MHz band available in metro and regional areas. The spectrum would be assigned as spectrum licences allocated via auction.

32 ACMA. Future use of the 1.5 GHz and 3.6 GHz bands. Initial investigation of the 1427–1518 MHz and 3575–3700 MHz bands for mobile broadband services discussion paper. October 2016. https://www.acma.gov.au/publications/2020-02/report/future-use-15-ghz-and-36-ghz-bands-discussion-paper

33 Source: ACMA

34 ACMA. Future use of the 3.6 GHz band Options paper, June 2017. https://www.acma.gov.au/publications/2020-02/report/future-use-36-ghz-band-options-paper

35 ACMA. Future use of the 3.6 GHz band Highest value use assessment – Quantitative analysis. June 2017. https://www.acma.gov.au/publications/2020-02/report/future-use-36-ghz-band-highest-value-use-assessment-quantitative-analysis

There were a number of incumbent apparatus-licensed services in the 3600 MHz band as shown in Figure 2.8. For point-to-point links there had been an embargo on new licences since 2005 to allow the use of the band for site-based broadband wireless access services – only existing licences could be renewed – and this had reduced the number of links. An embargo on new point-to-multipoint licences has been applied since November 2016 in all capital cities and regional areas. For fixed satellite services earth stations, the majority use the 3700-4200 MHz band. TV receive only (TVRO) use is unlicensed and not afforded protection. There may be around 200,000 TVRO systems in the 3400-4200 MHz band.

FIGURE 2.8

APPARATUS-LICENSED SERVICES IN THE 3600 MHz BAND AS OF 1 MAY 2017[36]

Services	Number of licences	Number of licensees
FSS – Earth receive	19	5
FS – Point to multipoint	413	57
FS – Point to point	47	5
Amateur – repeater	2	2

A key consideration of the analysis was the mitigation options identified by ACMA including:

- Extended transition period for incumbents of seven[37] years. During this period no new licences would be allowed but the incumbents would be protected until their licences are cancelled. There would also be the possibility for incumbents to make commercial agreements with the new licensees to remain for longer.
- Alternative spectrum at 5.6 GHz for point to multipoint services, and
- Identifying geographic location(s) for relocation of satellite earth stations from metropolitan areas and ensuring long-term protection of earth stations. ACMA identified potential locations away from capital cities in areas of low population density where they could protect an area around these sites, while freeing up spectrum in highly populated areas for use by terrestrial services. Developments such as the expansion of optical fibre networks throughout Australia mean there is no longer an overwhelming requirement to maintain or establish all earth stations within capital cities38.

In October 2017, the ACMA announced the outcomes of the review of the 3600 MHz band.[39] The decision confirmed that the frequency band be moved to the re-farming stage of the ACMA's process for the consideration of additional spectrum for mobile broadband uses.

In March 2018, following consideration of the ACMA's recommendation, the Minister for Communications made three spectrum reallocation declarations, based on 3575–3700 MHz being reallocated by issue of spectrum licences.[40] The three declarations provide for different reallocation periods (which commenced on 30 March 2018) as follows:

- Adelaide, Brisbane, Canberra, Melbourne, Sydney: two years
- Perth: five years, and
- Regional Australia: seven years.

The new licensees were required to protect incumbents during the transition period which might lead to restrictions on deploying services in some locations and frequencies.[41]

36 Source: ACMA. Future use of the 3.6 GHz band – Options paper, June 2017

37 The transition period of seven years was based on "providing sufficient time for earth station operators to relocate (periods up to six years had been proposed by industry) and would provide the point to multipoint operators a minimum of around 8 years to recoup investment on installed infrastructure".

38 The ACMA has recognised the value of locating earth stations in areas of low population density and has already established an earth station protection zone around Mingenew in Western Australia.

39 ACMA. Future use of the 3.6 GHz band – Decisions and preliminary views. October 2017. https://www.acma.gov.au/sites/default/files/2020-02/Future%20use%20of%203_6%20GHz%20Decisions%20and%20preliminary%20views.pdf

40 https://www.communications.gov.au/what-we-do/spectrum/spectrum-allocations/36-ghz-band

41 ACMA. 3.6 GHz band auction guide. August 2018 https://www.acma.gov.au/-/media/Spectrum-Licensing-Policy/Information/pdf/3-6-GHz-auction-2018-Auction-guide-pdf.pdf?la=en

The Spectrum Marketing Plan for the auction of the 3600 MHz was published in July 2018 setting out the available spectrum lots (5 MHz blocks), auction format (enhanced simultaneous multi-round ascending auction), rules for the auction, allocation limits (each bidder was to be capped at no more than 60 MHz in metropolitan areas and 80 MHz in regional areas) and licence conditions such as duration (10 years from 2020 to 2030) and coexistence measures.[42] The Applicant Information Package which included the starting prices was released in August 2018.

The auction commenced on 20 November 2018 and concluded on 6 December 2018. The auction comprised:

- a primary stage of 42 rounds of bidding;
- a secondary stage with one round for the allocation of one unsold lot; and
- an assignment stage where specific frequencies were assigned to each successful bidder's lots.

In total 350 lots of 5 MHz were offered in the auction and all lots were sold to Dense Air Australia, Mobile JV, Optus Mobile and Telstra raising total revenue of approximately A$852.8 million as shown in Figure 2.9. The amount of spectrum obtained per winner typically varied between 30 and 60 MHz depending on the availability in each region.[43]

FIGURE 2.9

RESULTS OF THE 3600 MHz AUCTION

Winning bidder	Spectrum sold	Winning price
Dense Air Australia Pty Ltd	29×5 MHz	$18,492,000
Mobile JV Pty Limited	131×5 MHz	$263,283,800
Optus Mobile Pty Ltd	47×5 MHz	$185,069,100
Telstra Corporation Limited	143×5 MHz	$386,008,400
Total	350 lots	$852,853,300

42 https://www.legislation.gov.au/Details/F2018L01064

43 There were also instances of award of a single 5 MHz block to one bidder and 80 MHz (16 blocks) to another. See https://www.acma.gov.au/sites/default/files/2019-10/L2_3.6_Att_Auction%20results.pdf

2.3.2 3400 MHz band (3400-3575 MHz) – ongoing

Spectrum in the 3400-3575 MHz range (3400 MHz band) in Australia had previously been assigned through different mechanisms which include administrative and class licensing, as well as several auctions dating back to 2000. These arrangements authorise a variety of services, including wireless broadband (both fixed and mobile), fixed satellite, radiolocation and amateur services.

In the lead-up to the 3600 MHz auction in 2018, the task of defragmenting and optimising spectrum and apparatus licence arrangements in the 3400 MHz band was identified as a priority for the ACMA in order to secure more efficient use of spectrum and a reduction in network deployment costs. Subsequently, the ACMA published a consultation paper in April 2019 which discussed different the options to facilitate the defragmentation of the spectrum and apparatus licence arrangements and to make more of the band available for wide-area wireless broadband and localised wireless broadband services.[44] The measures and activities to be undertaken over a period of around 30-37 months include the following.

- Maintaining existing arrangements for radiolocation services and devices operating under class licences.
- Extending protection for earth stations in Eastern Australia to cover parts of the band not already subject to spectrum licensing (3400–3442.5 MHz and 3475–3542.5 MHz)
- Restacking (or retuning) of incumbent amateur, point-to-multipoint (PMP), NBN Co's 3500 MHz apparatus licences to achieve the new consolidated arrangements in the band. Once restack is complete, and subject to a decision by the Minister to convert NBN Co's 3500 MHz licences to spectrum licences, this would enable licence trades or variations to occur between NBN Co and Optus to defragment their spectrum holdings.
- Developing arrangements for PMP licensing in those parts of the band that are not identified for spectrum licensing.
- Excising unused urban areas of NBN Co's 3500 MHz licences and making them available for use by other wireless broadband operators.
- Allocating 25 MHz and 42.5 MHz of spectrum in major regional centres and defined regional areas. This may also include the allocation of spectrum from the urban excise.[45]

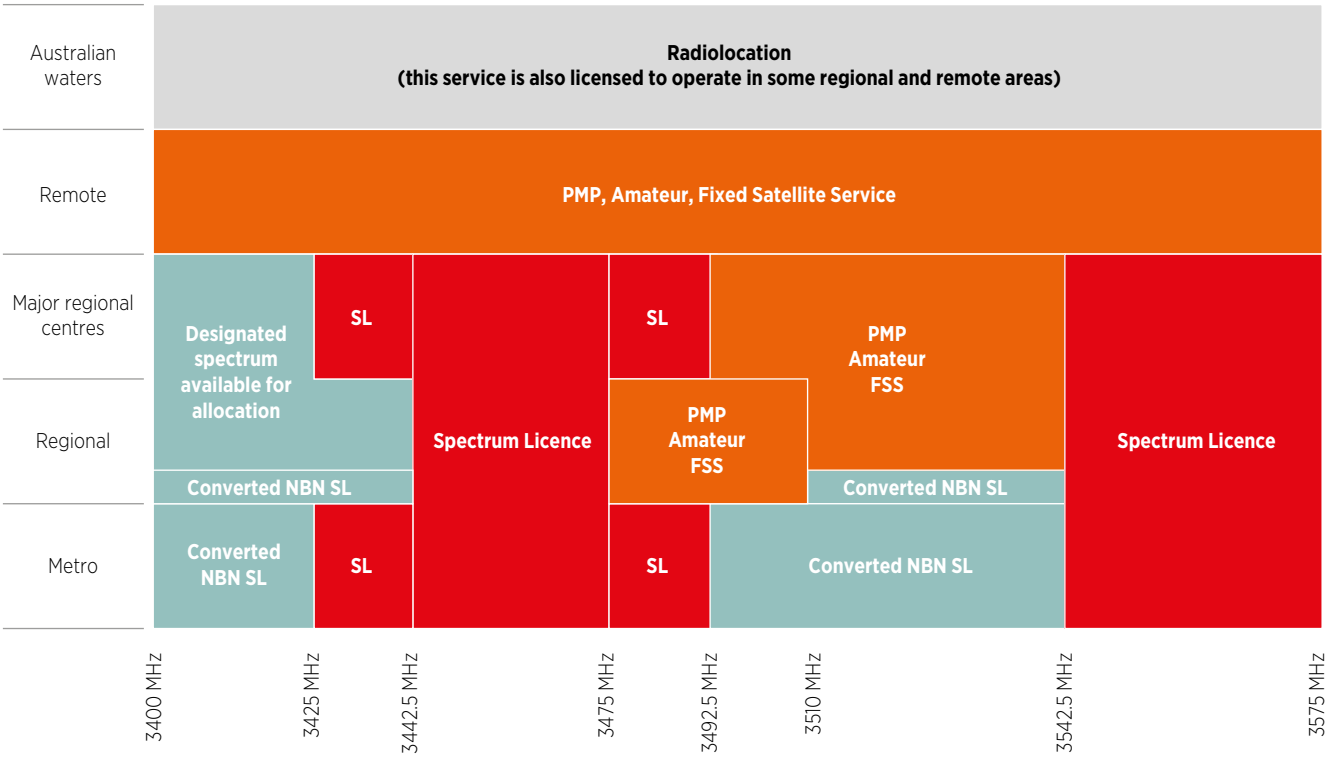
The ACMA considered that this combination of measures would best maximise the overall public benefit derived from use of the band, while minimising the impact on incumbent services. The overall proposed configuration for the 3400-3575 MHz band is shown in Figure 2.10.

44 ACMA. Optimising arrangements for the 3400–3575 MHz band. Planning decisions and preliminary views. November 2019. https://www.acma.gov.au/consultations/2019-08/optimising-3400-3575-mhz-band-consultation-122019

45 The decision to designate additional spectrum for the issue of spectrum licences has been made by the Minister for Communications, Cyber Safety and the Arts in December 2020. https://www.communications.gov.au/departmental-news/minister-has-made-designation-notice-34-ghz-spectrum-band

FIGURE 2.10

ACMA PLANNING ARRANGEMENTS FOR THE 3400-3575 MHz BAND[46]



Following this the ACMA carried out the restacking of incumbent services in the band. In December 2020 the Minister for Communications, Cyber Safety and the Arts made a notice designating parts of the 3400 MHz band encompassing apparatus licences held by NBN Co for spectrum licensing.[47] This then allowed the ACMA to convert NBN Co's apparatus licences, which are used for fixed-wireless services in regional and outer-metropolitan areas, to spectrum licences facilitating defragmentation of the 3400 MHz band.

In August 2021 the ACMA published a consultation on the technical options for the use of the 3400 MHz for wireless broadband in urban areas.[48] This will be followed by decisions on regulatory arrangements, including the licence type. The timeframe for the release of the refarmed 3400 MHz is expected to be during Q2 2022 to Q2 2023.

46 FSS = fixed satellite service, PMP = point-to-multipoint, SL = spectrum licence. Source: ACMA. Optimising arrangements for the 3400–3575 MHz band. Planning decisions and preliminary views. November 2019

47 https://www.communications.gov.au/departmental-news/minister-has-made-designation-notice-34-ghz-spectrum-band

48 https://www.acma.gov.au/consultations/2021-08/planning-wireless-broadband-use-urban-areas-3400-3475-mhz-band-consultation-312021

2.3.3 3700-4200 MHz – ongoing

The 3700-4200 MHz band has gained interest globally as suitable mid-band spectrum for wireless broadband (WBB) applications including 5G. In Australia the 3700–4200 MHz band support a mix of incumbent uses including apparatus licensed point-to-point fixed service links (PTP), coordinated fixed satellite service (FSS) receive earth stations and various low power class licensed devices.

The ACMA published an options paper in July 2020 setting out the case for reviewing and potentially changing the spectrum management framework in the band.[49] The ACMA's objectives were to set out plans to:

- introduce new wireless broadband uses (wide area and local area),
- support continued uses in the band for FSS earth stations, PTP use, radiodetermination services (operated by the Department of Defence), Earth Station Protection Zones, and class licences for building material and ultra-wideband devices, and
- ensure coexistence with adjacent band services, particularly radio altimeters above 4200 MHz and services below 3700 MHz.

Three broad replanning options were identified:

1. Option 1: Introduce arrangements to allow for WBB exclusively in one frequency segment, with no change to current arrangements in the remaining segment
2. Option 2: Introduce arrangements to allow for WBB sharing with existing services in one frequency segment, with no change to current arrangements in the remaining segment.
3. Option 3: Introduce arrangements to allow for WBB both exclusively and shared with existing services in some segments, with no change to current arrangements in the remaining segment.

In its outcomes papers published in January 2021[50] the ACMA confirmed its preferred option (Option 3) which would add 100 MHz of spectrum for WBB in the 3300–4200 MHz band, making a total of 400 MHz available in metropolitan areas and 335-365 MHz in regional areas. It was noted that this arrangement is consistent with the regular claims from the mobile sector that 100 MHz per operator is necessary in metropolitan areas and 60–80 MHz in regional areas.

49 https://www.acma.gov.au/consultations/2020-07/planning-options-3700-4200-mhz-band-consultation-222020

50 https://www.acma.gov.au/sites/default/files/2021-01/Replanning%20the%203700-4200%20MHz%20band_Outcomes%20paper.docx

The key planning decisions and preliminary views for the 3700-4200 MHz involves a combination of measures which the ACMA considered would maximise the overall public benefit from the band, namely:

- introducing arrangements for wide area wireless broadband (WA WBB) in 3700–3800 MHz in metropolitan and regional areas on an exclusive basis
- introducing arrangements for local area wireless broadband (LA WBB) in 3700–3800 MHz in remote areas, and in 3800–4000 MHz Australia-wide on a shared basis with existing fixed satellite service (FSS) and fixed point-to-point (PTP) service types
- maintaining apparatus licensing in 4000–4200 MHz for PTP and FSS only
- removing arrangements for new PTP in 3700–3800 MHz Australia-wide and grandfathering existing services for a minimum of 5 years
- removing arrangements for new FSS in the 3700–3800 MHz range in metropolitan and regional areas and grandfathering existing services for a minimum of 5 years.
- maintaining existing arrangements for the licensed radiolocation services and devices operating under class licenses
- maintaining existing Earth Protection Zones (ESPZs) and associated protection arrangements.
- changing arrangements for scientific unassigned services so they cannot be operated in areas/segments for exclusive WA WBB use. The timing of this change would take into account the timeframe and method of allocation of licences for WA WBB use.

The ACMA is currently in the process of implementing the outcomes of the review and this includes development of the licensing and technical frameworks for the band. The award of the licences is expected to be during Q1 2023 and could be combined with the 3400 MHz band. In February 2022, the Australian Government affirmed the ACMA's decisions on the allocation of the 3400-3575 MHz and 3700-4000 MHz for new and innovative technologies including 5G.[51]

2.3.4 26 GHz and 28 GHz – completed

The 26 GHz band (24.25-27.5 GHz) is a key mm-wave band identified globally for 5G following WRC-19. The adjacent 28 GHz (27.5-29.5 GHz) was not among the bands identified for 5G at WRC-19 although some countries have assigned part of it for 5G uses.

The ACMA had released an options paper in September 2018, outlining the various planning and configuration options for the **26 GHz band**, and seeking views on the proposal that the band proceeds to allocation. Three broad categories of potential wireless broadband use were identified:

- type 1 – traditional subscriber-based wide-area mobile or fixed network operator deployments
- type 2 – smaller market/local subscriber-based networks
- type 3 – uncoordinated ad hoc deployments within the confines of private premises or property.

This was followed by a decision paper in April 2019 detailing decisions and preliminary views for the introduction of wireless broadband in the 26 GHz band.[52] That paper concluded that a combination of spectrum, apparatus and class licences is the best way to facilitate access to the band for these three user types. In addition to class licensing 24.25–25.1 GHz (as a guard band to protect passive EESS operating in 23.6-24 GHz), three distinct approaches for the 26 GHz band were proposed:

- 25.1-27.5 GHz in defined areas (metropolitan and regional centres): spectrum licences allocated via auction
- 25.1-27.5 GHz in all other areas: apparatus licences
- 24.7-25.1 GHz Australia-wide: apparatus licences.

51 Department of Infrastructure, Transport, Regional Development and Communications. Ministerial policy statement for the 3.4-4.0 GHz spectrum band, 10 February 2022. https://www.infrastructure.gov.au/department/media/news/ministerial-policy-statement-34-40-ghz-spectrum-band

52 ACMA. Future use of the 26 GHz band. Planning decisions and preliminary views. April 2019.

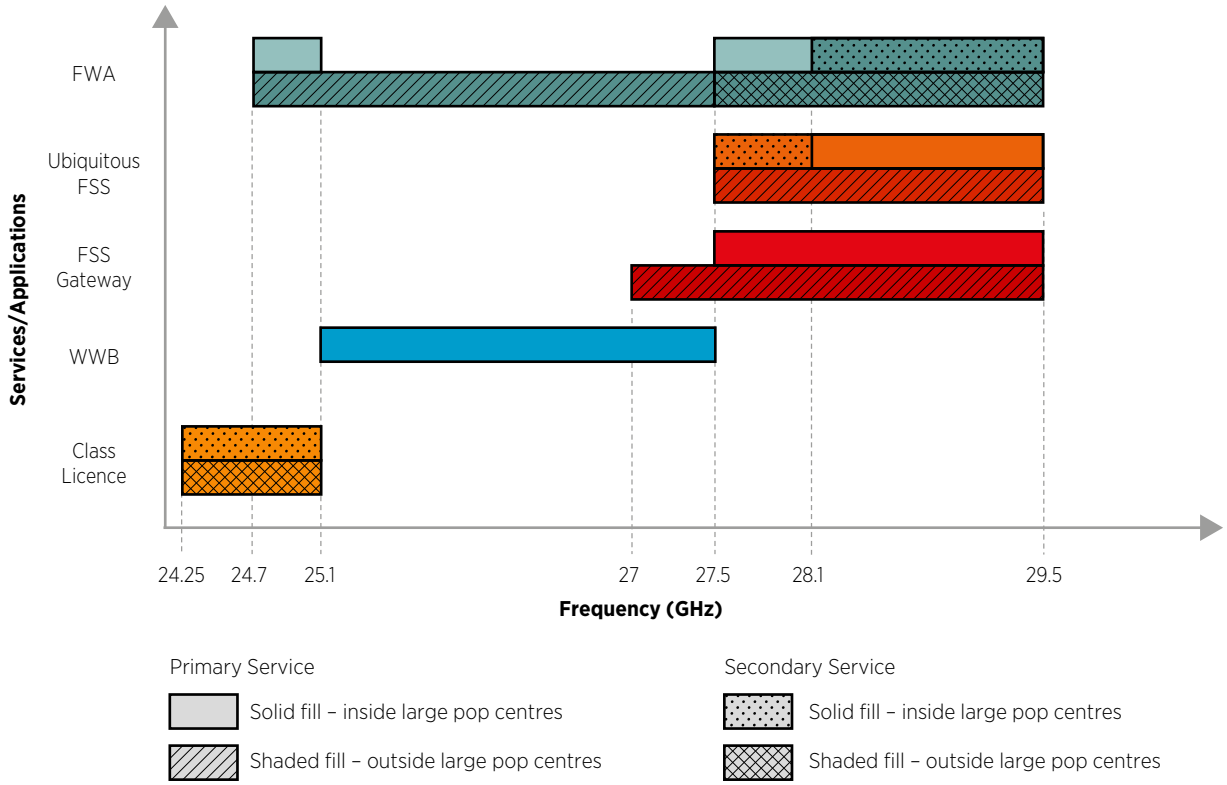
Alongside the 26 GHz decision paper, the ACMA also published an options paper for the 28 GHz band in April 2019 discussing planning options, taking account of the outcomes of the 26 GHz band review process in light of potential use across both bands for terrestrial wireless broadband.[53] This was followed a 28 GHz decision paper in September 2019 that specified arrangements including:

- Introduction of arrangements for fixed wireless access (FWA) services across the entire 28 GHz band, on a co-primary basis with apparatus licensed FSS earth stations in large population centres in the 27.5–28.1 GHz frequency range, and on a secondary (no protection) basis to the FSS in other areas and frequencies. The apparatus licences for FWA would be allocated by administrative process.
- Removal of arrangements for new fixed point to point (PTP) services in the 28 GHz band and grandfathering existing services for a minimum seven years.[54]
- Increase in the amount of spectrum available for ubiquitous fixed satellite services (FSS) use
- Continuation of apparatus licensed arrangements for FSS earth stations across the entire 28 GHz band Australia-wide.

Figure 2.11 provides an overview of the arrangements for the 26 GHz and 28 GHz bands in Australia.

FIGURE 2.11

SUMMARY OF ACMA'S PLANNING ARRANGEMENTS FOR THE 26 GHz AND 28 GHz BANDS[55]



53 https://www.acma.gov.au/consultations/2019-08/planning-options-28-ghz-band-consultation-092019

54 It was noted that area-wide apparatus licence arrangements are implemented in the band, new PTP services could be deployed within individual licence areas. The ACMA would also revise PTP arrangements in the 38 GHz band to provide an alternative option for new wide-channel systems.

55 Source: ACMA. Future use of the 28 GHz band. Planning decisions and preliminary views. September 2019.

The spectrum for wide-area wireless broadband (WWB) in 25.1-27.5 GHz was assigned as spectrum licences via an auction. The Spectrum Marketing Plan for the 26 GHz auction was published in November 2020 setting out the available spectrum lots (360 lots of 100 MHz or 200 MHz blocks), auction format (enhanced simultaneous multi-round ascending auction), rules for the auction, allocation limits (each bidder was to be capped at no more than 1000 MHz in each designated area) and licence conditions such as duration (15 years from 2021 to 2036) and coexistence measures.[56] The Applicant Information Package which included the starting prices was released in December 2020.

The auction commenced on 12 April 2021 and concluded on 21 April 2021. Of the 360 lots available in the auction, 358 were sold, raising a total revenue of A$647.6 million as shown in Figure 2.12.[57]

FIGURE 2.12

RESULTS OF THE 26 GHz AUCTION (SPECTRUM LICENCES)

Winning bidder	Number of lots won	Winning price
Dense Air Australia Pty Ltd	2	$28,689,900
Mobile JV Pty Limited	86	$108,186,700
Optus Mobile Pty Ltd	116	$226,203,100
Pentanet Limited	4	$7,986,200
Telstra Corporation Limited	150	$276,576,200
Total	358 lots	$647,642,100

For the apparatus licences in the 26 GHz and 28 GHz bands the ACMA proposed the introduction of area-wide apparatus licences (AWL) which are intended to offer more flexibility with the following attributes:

- **Area-based:** A licence will authorise radiocommunications devices within a specified area, rather than at specific location(s). Interference with other services is primarily managed through the use of technical conditions that apply to the geographic and frequency boundary of the licence, rather than by detailed technical specifications for radiocommunications devices authorised under the licence.
- **Broad application:** The licences may be used for a wide range of purposes, uses, services, applications and technologies. However, an individual licence, when issued, may include special conditions that limit the operation of a radiocommunications device under the licence to an identified purpose, use or service.
- **Scalable:** The licences will be capable of being adapted to a variety of technologies and/or uses, with different-sized areas and frequency bandwidths.
- **Aggregable:** A number of AWLs adjacent in geography, frequency, or both, can be aggregated into a single transmitter licence, with boundary conditions applying only to the boundary of the aggregated licence, not the component licences. Aggregation is expected to require the surrender of the component licences and the issue of a new transmitter licence that covers the areas of the component licences.

The application process and guidelines for the AWLs in the 26 GHz and 28 GHz have been made available for applicants as of October 2020.[58]

56 https://www.legislation.gov.au/Details/F2020L01450

57 https://www.acma.gov.au/26-ghz-band-auction-results

58 https://www.acma.gov.au/area-wide-apparatus-licensing-26-and-28-ghz-bands

2.3.5 850 MHz expansion – completed

The ACMA is reconfiguring the 850 MHz band as part of its plan to release the 850 MHz expansion band (809–824/854–869 MHz) for 4G/5G services. This band is adjacent to the 850 MHz assignments (825-845/870-890 MHz) currently used by Telstra and TPG/VHA for 3G services.

To enable the release 850 MHz expansion band, the ACMA has had to (a) reduce existing allocations for incumbent users, such as trunked land mobile and fixed links, and (b) remove allocation for services no longer in demand such as cordless telephone service and digital short-range radio. The plan also involves a 1 MHz downshift of the existing 850 MHz assignments to align the full 850 MHz band with international standards[59], and to create a 1 MHz guard band at 889-890 MHz between the 850 MHz and 900 MHz bands to mitigate interference issues arising from the 'reverse duplex' arrangement[60] between the two bands.

The 850/900 MHz auction which involving 2×10 MHz of the 850 MHz expansion band (814-824/859-869 MHz) along with 2×25 MHz in 900 MHz (890-915/935-960 MHz) was completed in December 2021[61]. Separately, the Australian Government has identified 2×5 MHz at the lower end of the 850 MHz expansion band for a national public safety mobile broadband (PSMB) service[62].

2.3.6 700 MHz – completed

Australia was among the first countries in the Asia Pacific region to assign the 700 MHz band for IMT services. The 700 MHz auction, which was completed in May 2013, also featured the 2.5 GHz band. Six of the nine national lots of 2×5MHz in the 700 MHz available were sold to Optus (2×10 MHz) and Telstra (2×20 MHz) with three lots (2×15MHz) left unassigned.[63] The remaining three lots were assigned in a residual auction in April 2017 to TPG (2×10 MHz) and VHA (2×5 MHz).

Due to early timing of the release of 700 MHz in Australia, the band has primarily been used for LTE so far. In July 2021, TPG announced that it had launched the world's first 5G standalone 700 MHz service.[64]

2.3.7 Other support measures

Alongside the various spectrum work activities described above, the Australian Government also announced in September 2020 that it would allocate some A$30million to improve the allocation and management of spectrum and trial 5G use across different industry sectors.[65] The specific measures include:

- A$22.1 million to establish the Australian 5G Innovation Initiative, to encourage 5G commercial trials and testbeds in key industry sectors
- A$1.8 million over two years to invest in systems that allow more efficient spectrum allocation, and
- A$5.3 million over two years to update and simplify the digital spectrum licence system.

59 Namely with 3GPP Band 26 (n26) and Band 5 (n5).

60 This refers to a situation where base station transmitter frequencies (850 MHz in this case) and receiver frequencies (900 MHz) are immediately adjacent to each other.

61 https://www.acma.gov.au/articles/2021-12/outcome-850900-mhz-band-spectrum-auction

62 https://www.infrastructure.gov.au/media-technology-communications/spectrum/spectrum-government-use

63 https://www.acma.gov.au/auction-summary-700-mhz-digital-dividend-and-25-ghz-band-reallocation-2013

64 https://www.nokia.com/about-us/news/releases/2021/07/05/nokia-and-tpg-telecom-launch-worlds-first-live-5g-standalone-700mhz-service-in-australia/

65 https://minister.infrastructure.gov.au/fletcher/media-release/supporting-australias-5g-future

2.4 Case study: Singapore

In Singapore there are four mobile network operators – Singtel, Starhub, M1 and TPG. TPG had entered the market following a multiband auction in 2016/17 in which it won the new entrant set-aside spectrum in the 900 MHz and 2300 MHz bands. Spectrum for 5G in the 3500 MHz, 26 GHz and 28 GHz bands was awarded in 2020, with the 2100 MHz band being awarded in 2021. The current spectrum holdings are shown in Figure 2.13.

FIGURE 2.13

SPECTRUM HOLDINGS IN SINGAPORE, AS OF DECEMBER 2021

Band	Singtel	Starhub	M1	TPG
700 MHz FDD(1)	40	30	20	-
900 MHz FDD	20	10	10	20
1800 MHz FDD	60	50	40	-
2100 MHz FDD	50	50		20
2300 MHz TDD	-	-	-	40
2500 MHz FDD	40	40	40	-
2500 MHz TDD	15	20	-	10
3500 MHz TDD	100	100		-
26/28 GHz TDD	800	800	800	800

Note: (1) Assigned in 2017 but not yet in use pending harmonisation with Indonesia and Malaysia.

Source: IMDA

2.4.1 5G spectrum planning

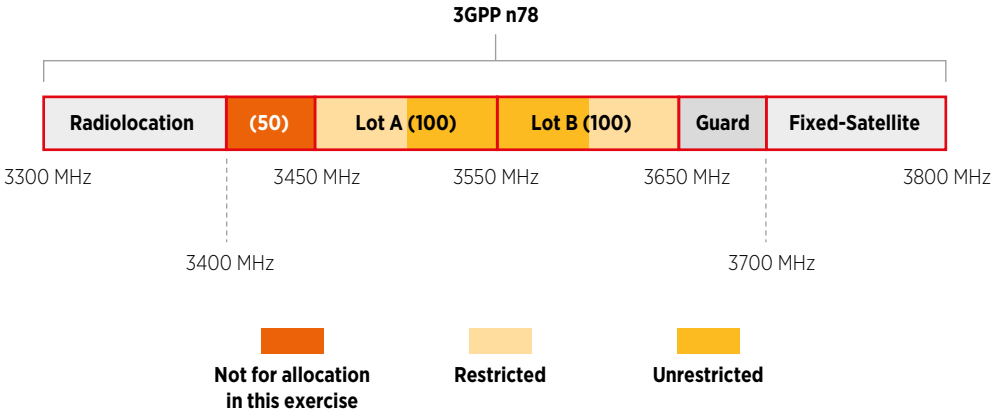
The regulator IMDA began planning for 5G in 2016 with a first 5G consultation paper was published in May 2017 which set out the use cases and spectrum requirements for 5G across the low-band (sub-1 GHz), mid-band (1-6 GHz) and high-band (above 20 GHz) frequency ranges.[66] One of the key focus areas was the 3400-4200 MHz range and the options for managing interference issues between IMT and FSS services. The small geography of Singapore meant that co-channel operations of both services would be challenging due to the need for geographic separation distances. In Singapore, most of the key FSS operations operate in the 3700-4200 MHz range of the C-band, while the extended C-band in the 3400-3600 MHz range is generally used for the purpose of satellite signals reception for TVRO stations to individual sites (e.g., hotels, hospitals).

Following a second consultation in May 2019[67] the IMDA published its decision to release 5G spectrum in two waves.[68] The initial wave would comprise of the 3500 MHz and 26/28 GHz bands with spectrum in the 700 MHz, 1400 MHz, 2100 MHz, 2500 MHz TDD, 3500 MHz (remaining) and 4500 MHz bands to be released at a later stage.

For the 3500 MHz range, the IMDA decided to change the primary allocation in the 3400-3700 MHz range from FSS (space-to-Earth) to mobile, with primary allocation for FSS (space-to-Earth) retained in 3700-4200 MHz. There would be two lots of 100 MHz spectrum in 3450-3650 MHz available for mobile with restrictions to indoor and underground deployments in parts of the two lots as shown in Figure 2.14.

FIGURE 2.14

AVAILABLE SPECTRUM FOR IMT IN 3500 MHz BAND[69]



Other mitigation measures were also required including the installation of band pass filters by FSS users in the 3700-4200 MHz and implementation of exclusion and precautionary zones to protect critical FSS operations.[70]

For the 26 GHz and 28 GHz bands (24.25-29.5 GHz range), the IMDA decided that four lots of 800 MHz spectrum would be made available. It was noted that coexistence between 5G and satellite use in the 28 GHz for aeronautical and maritime connectivity would be feasible and operational guidelines would be put in place to mitigate interference issues.

In addition, the IMDA has considered the possibility of allocating parts of the 800 MHz (806-834/851-879 MHz) band for 4G/5G enterprise use and broadband PPDR.[71] A final decision has not yet been made.

66 https://www.imda.gov.sg/-/media/Imda/Files/Inner/PCDG/Consultations/consultation-paper/Public-Consultation-on-5G-Mobile-Services-and-Networks/5G-Public-Consultation.pdf

67 https://www.imda.gov.sg/-/media/Imda/Files/Regulation-Licensing-and-Consultations/Consultations/Consultation-Papers/Second-Public-Consultation-on-5G-Mobile-Services-and-Networks/Second-5G-Public-Consultation-7-May-2019-Final.pdf

68 https://www.imda.gov.sg/-/media/Imda/Files/Regulation-Licensing-and-Consultations/Consultations/Consultation-Papers/Second-Public-Consultation-on-5G-Mobile-Services-and-Networks/5G-Second-Consultation-Decision.pdf

69 Source: IMDA

70 The status of the exclusion zones would be reviewed at the end of 2022.

71 https://www.imda.gov.sg/-/media/Imda/Files/Regulation-Licensing-and-Consultations/Consultations/Consultation-Papers/Public-Consultation-Paper-for-800-MHz.pdf

2.4.2 5G spectrum award

The IMDA issued the 5G Call for Proposal (CFP) in October 2019.[72] Instead of an auction process, the award was a hybrid beauty contest format featuring two spectrum packages, each comprising one 100 MHz lot in the 3500 MHz band and one 800 MHz lot in the mmWave (26/28 GHz) band. The remaining two mmWave lots will be assigned to other requesting MNOs.

The IMDA's objectives for the award are to ensure at least two nationwide 5G networks capable of delivering full-fledged 5G capabilities based on standalone (SA) networks. The two nationwide operators are required to achieve at least 50% outdoor coverage within 24 months and to provide wholesale services to other MNOs and MVNOs for locations where 3500 MHz is used for 5G deployment. The IMDA's evaluation criteria for the proposals were:

- network design and resilience (40%);
- network rollout and performance (35%);
- price offered for one lot of 3500 MHz band (15%); and
- financial capability (10%).

Three bids were submitted – Singtel, Starhub-M1 joint venture (Antina) and TPG – and it was announced in April 2020 that Singtel and the Starhub-M1 JV were the winners of the CFP, each receiving 100 MHz of the 3500 MHz spectrum. Singtel, Starhub, M1 and TPG also individually received 800 MHz of the 26/28 GHz spectrum.[73]

2.4.3 Reassignment of 2100 MHz

The 2100 MHz spectrum band had previously been licenced to Singtel, Starhub and M1, but these licences were due to expire at the end of 2021. The 2100 MHz spectrum was the main band supporting 3G services in Singapore, though there had also been some 4G deployment in this band. The IMDA, noting that operators in several leading markets such as Germany, Hong Kong and the UK are deploying 5G in this band, decided 2100 MHz would be used primarily for 5G and this should be deployed as 5G SA networks, in line with requirements of the CFP for the 3.5 GHz band.[74] To ensure 3G service continuity, MNOs could continue to use part of the band for this purpose until 3G networks are switched off. However, further expansion of 4G use in the 2100 MHz band would not be allowed.

Unlike the CFP approach for the first tranche of 5G spectrum, an auction format was used to assign the 2100 MHz spectrum. Of the 12 lots of 2×5MHz, the existing 3G MNOs (M1, Singtel and Starhub) would each have first-right-of-refusal (FROR) for one lot. The remaining nine lots would be open to all four existing MNOs subject to a spectrum cap of five lots, which could be raised to six should there be unsold lots from the first stage. The reserve price for the RFOR lots (S$3 million) were set at a quarter of the open lots (S$12 million) with a top-up price[75] to be paid once the 3G network in the 2100 MHz band has been ceased.

The auction concluded with Singtel being awarded five of the 5MHz paired blocks (a total of 50 MHz), and a consortium between Starhub and M1 being awarded another five blocks. TPG was awarded the remaining two blocks (a total of 20 MHz).

72 https://www.imda.gov.sg/regulations-and-licensing-listing/spectrum-management-and-coordination/spectrum-rights-auctions-and-assignment/5G-CFP-2020

73 https://www.imda.gov.sg/regulations-and-licensing-listing/spectrum-management-and-coordination/spectrum-rights-auctions-and-assignment/5G-CFP-2020

74 https://www.imda.gov.sg/-/media/Imda/Files/Regulations-and-Licensing/Regulations/Consultations/2021/Next-Wave-of-5G-Growth-and-Deployment-in-Singapore/IMDA-Decision--21-GHz-Policy-and-Regulatory-Framework.pdf?la=en&hash=F6858B0C7251B64AFF5E3B95688C47ED

75 Based on the differential between the clearing price and S$3 million, pro-rated to the remaining period of the 15-year spectrum rght.

3. Current status of markets in APAC region

This section provides an overview of mobile networks and spectrum awards in the APAC 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

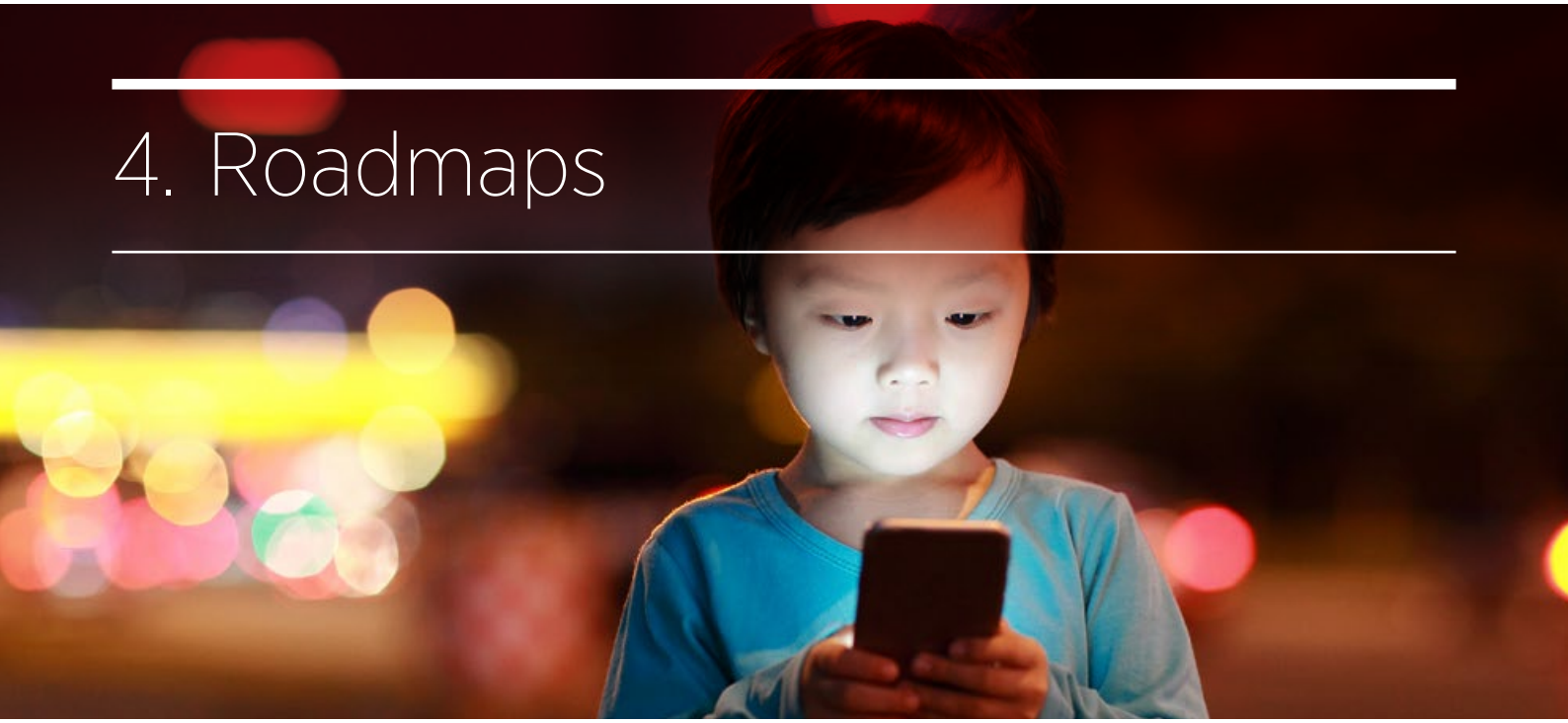
Symbol	Meaning
↓↓	Significant decrease in connections
↓	Noticeable decrease in connections
–	Little change in number of connections
↑	Noticeable increase in connections
↑↑	Significant increase in connections

FIGURE 3.2

COMPARISON OF COUNTRIES

Country	No. of operators	Total spectrum (MHz)	Frequency bands awarded	Demand forecasts (2019 to 2025)	4G introduction & 5G forecast	5G status	Comments
Australia	3 (plus regional operators)	498.2 (national, plus various regional awards)	700, 850, 900, 1800, 2100, 2300, 2600, 3500, 3700	3G: ↓↓ 4G: ↓ 5G: ↑↑	4G introduced in 2011, upgraded in 2014 and 2018	5G introduced in 2020 using spectrum in 700 MHz, 2300 MHz and 3500 MHz.	3G connections predicted to disappear by 2024
Bangladesh	4 (3 private and 1 state)	313.4	900, 1800, 2100	2G: ↓ 3G: ↓ 4G: ↑↑ 5G: ↑	LTE launch in 2018. Limited 5G trials expected in late 2021, general launch in 2023		
Cambodia	4 (plus some smaller operators)	504[76]	850, 900, 1800, 2100, 2300, 2600	2G: ↓ 3G: – 4G: ↑ 5G: ↑	5G expected in 2023		No spectrum availability
Hong Kong	4	2163.4	850, 900, 1800, 2100, 2300, 2600, 3300, 3500, 4800, 28000	2G: ↓ 3G: – 4G: ↓↓ 5G: ↑↑	5G launched in 2020	Operators report 95% 5G coverage. Predictions are that LTE will move to 5G very quickly.	
India	4	391 (although this varies by region)	850, 900, 1800, 2100, 2300, 2600	2G: ↓↓ 3G: – 4G: ↑↑ 5G: ↑	General networks due in 2022	Auctions expected in 2022	
Indonesia	4	497	450, 850, 900, 1800, 2100, 2300	2G: ↓↓ 3G: ↓ 4G: ↑ 5G: ↑	Select cities launched 5G in June 2021; widespread networks expected in 2023		
Malaysia	6	680	850, 900, 1800, 2100, 2300, 2600	2G: ↓ 3G: ↓ 4G: – 5G: ↑	Wholesale 5G network expected in 2022	5G network is to be run on a national wholesale basis only.	
Pakistan	4	269.2	850, 900, 1800, 2100	2G: ↓ 3G: ↓ 4G: ↑↑ 5G: ↑	5G expected in 2023	Spectrum being specified to enable 1 Gbps connections.	
Singapore	4	4037.7	700, 900, 1800, 2100, 2300, 2600, 3500, 26000	2G: – 3G: ↓ 4G: ↓↓ 5G: ↑↑	5G launched in 2020	Two wholesale networks – Singtel and Antina (Starhub-M1 JV)	
Sri Lanka	4	345	900, 1800, 2100, 2300	2G: ↓ 3G: – 4G: – 5G: ↑	Full 5G networks expected in 2022	Trial 5G networks launched in 2019 and still operational – offered free of charge to subscribers	
Thailand	3	3308	450, 700, 850, 900, 1800, 1900, 2100, 2300, 2600, 26000	2G: ↓↓ 3G: ↓ 4G: ↑ 5G: ↑↑	5G launched in 2020		
Vietnam	4	339.6	900, 1800, 2100	2G: ↓↓ 3G: – 4G: ↑ 5G: ↑	5G launched in 2020	5G has been launched commercially but using spectrum assigned on a trial basis, with long-term spectrum availability still unclear	

76 Note that some sources are unclear on this point; at least one operator has 232 MHz assigned but information on other operators' holdings is not publicly available.



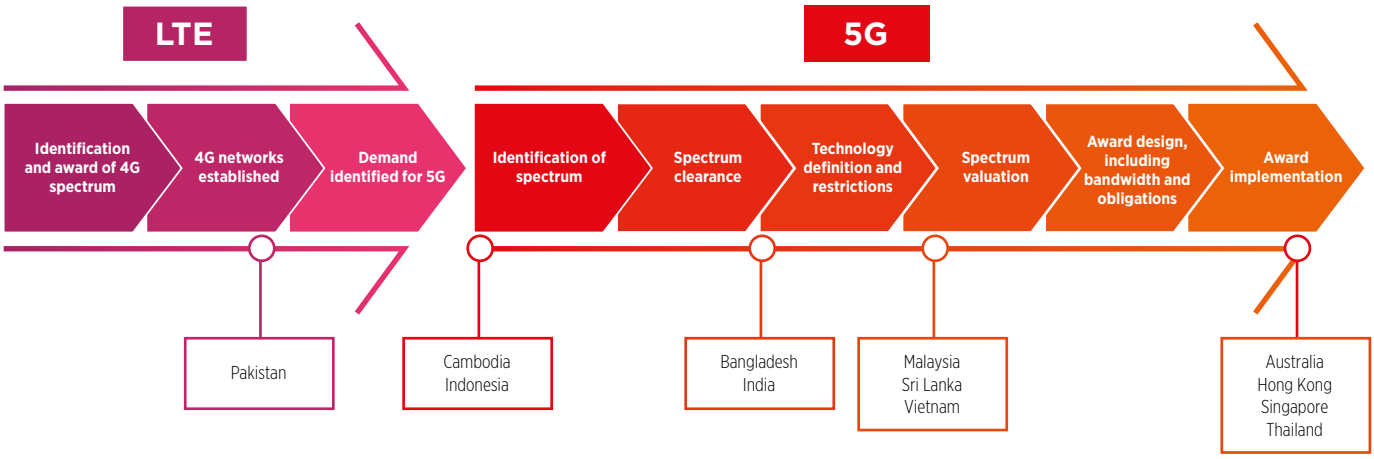
4. Roadmaps

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



It is clear from our research that a number of countries are well advanced in rolling out 5G networks and configuring spectrum. However, further analysis shows how this is not the end of the roadmap; even once spectrum has been identified and awarded there is a need for further work to identify additional spectrum in other bands to build capacity.

The roadmaps recommended are based on the grouping of countries above. Thailand, Indonesia, India and Pakistan have been included in more detail to demonstrate the work that must be completed; Australia and Singapore have been included in Section 2 as case studies for countries where spectrum has already been awarded. In addition, some general recommendations are provided based on international best practice.

4.1 Roadmap for Thailand

In the drive towards a connected society, Thailand's National Broadcasting and Telecommunications Commission (NBTC) set 5G spectrum allocation as a key part of its policy priority. This means that a programme for the release of frequency bands for 5G was published in 2019. Spectrum bands identified for 5G use and earmarked for assignment in 2019 and 2020 were the 700 MHz, 2600 MHz and 26 GHz and 28G Hz bands.[77] These have since been assigned through auctions that took place in June 2019 in February 2020. Figure 4.2 shows the licensees and the respective frequency ranges that have been awarded to them in each spectrum band.

FIGURE 4.2

5G-DESIGNATED SPECTRUM BANDS IN THAILAND AND THEIR LICENSEES[78]

Frequency band	Band plan	Licensee	Frequency range
700 MHz	703-748 & 758-803 MHz (FDD)	AWN (AIS)	733-738/778-793 MHz
		TUC (True Corp)	703-713/758-768 MHz
		DTN (DTAC)	713-723/768-778 MHz
		NT	738-748/793-803 MHz
2600 MHz	2500-2690 MHz (TDD)	AWN (AIS)	2500-2600 MHz
		TUC (True Corp)	2600-2690 MHz
26GHz	24.25-27.0 GHz (TDD)	AWN (AIS)	25.2-26.4 GHz
		TUC (True Corp)	24.3-25.1 GHz
		DTN (DTAC)	26.8-27.0 GHz
		NT	26.4-26.8 GHz

The assignment of the above frequency bands enabled all three major operators, AIS, True Move and DTAC to launch 5G service in 2020 on a limited basis. AIS and True Move deployed their initial 5G network using the 2600 MHz spectrum, while DTAC used frequencies in the 26GHz band. The 700 MHz also became available for use in early 2021, following the completion of broadcasting service migration. All operators have since been active in using the 700 MHz spectrum to expand their 5G coverage.[79] For example, by November 2021, DTAC had added 700 MHz to its 5G network in three further provinces, including Nonthaburi, Samut Prakan and Pathum Thani, taking its 5G service beyond the nine initial provinces of Bangkok, Chiang Mai, Khon Kaen, Nakhon Ratchasima, Phuket, Surat Thani, Chonburi, Rayong, and Ubon Ratchathani.[80] As a result, 5G deployment in Thailand is comparable with more developed countries in the region such as Singapore and Taiwan, even though the country previously lagged behind its peers in assigning 3G and LTE spectrum.

77 5G Preparation in Thailand, NBTC-5GMF Joint Workshop on 5G, June 2019

78 Source: NBTC, APT. Note: The company in brackets in the licensee column is the company that owns the licensee – that is, AWN is a wholly-owned subsidiary of AIS, TUC is a subsidiary of True Corp, DTN is a subsidiary of DTAC. NT is the merged entity that results from the consolidation between former state operators, TOT and CAT.

79 The exception is NT, which has yet to announce its 5G rollout plan.

80 https://dtacblog.co/en/dtacs-700-mhz-network-to-back-up-thailand-reopening-2/

The NBTC also plans to release frequencies in the range 3400-3700 MHz for 5G in the future. The band has hitherto been used for satellite service. According to the preliminary timeframe for auction published in the official 5-year Spectrum Roadmap (2019 – 2024), the process for recalling the spectrum was scheduled to start in the fourth quarter of 2019, along with licensing rules and band plans' determination. From the start of 2020, preparatory works to re-farm the extended C-Band for use with IMT (Satellite Relocation & Implementation Phase) would take place, with an expected completion of the end of 2021. The NBTC would then reassign the 3400-3700 MHz spectrum for mobile service along with spectrum in the 28GHz spectrum through an auction, following the expiry of the concession on the C-Band in 2021.[81]

However, no progress appears to have been made on re-farming the C-band for mobile use so far, and the preliminary timeline published appears to have slipped. The NBTC is currently still conducting a feasibility study for co-existence of FSS and IMT and has yet to identify how to migrate the incumbent out of the band or the process for re-farming the spectrum that would ensure that interference is mitigated. This means the 3.5 GHz range, which is the most widely deployed 5G spectrum, is expected to be unavailable for the foreseeable future. This may be partially due to delays in the appointments of NBTC commissioners, following an extension of the previous board's term from their original end date on October 2017; a process early in 2021 was abandoned, with selection of new commissioners proposed in September 2021 – however, at the time of this report, no appointments have been made.

Another issue with the re-farming of currently available spectrum for 5G relates to the way in which some spectrum is held and used. The mobile market in Thailand consists of four MNOs, including a State-Owned Enterprise, NT. NT continues to have rights to spectrum in 850 MHz, 2100 MHz and 2300 MHz bands, which had been given to its predecessors, TOT and CAT, under the concessionary system. The spectrum has been used by True, AIS and DTAC for the provision of HSPA and LTE services under a partnership agreement that involves a network build and infrastructure leasing or roaming. However, cross-carrier aggregation is still not permitted in Thailand, which means the 2300 MHz cannot readily be used for 5G service by its main user, DTAC, even though the band has become one of the staples for 5G in recent years. This presents another bottleneck in the release of additional 5G spectrum.

81 https://telecom-license.nbtc.go.th/getattachment/Information/spectrumroadmap/spectrumroadmap/spectrumroadmap.pdf.aspx

4.1.1 Steps 1 and 2: Identification of spectrum and clearance

The NBTC has identified five bands for use with 5G in Thailand. These are the 700 MHz, 2600 MHz, 3500 MHz, 26 GHz and 28 GHz bands. The 2600 MHz and 26 GHz have been cleared and made available to for IMT deployment since the start of 2020. However, frequencies in the range 2600-2620 MHz were still being used by non-IMT incumbents in several large provinces and would only be available for deployment of mobile service when these incumbents discontinue their service.[82] The 700 MHz was still being cleared at the time of its auction in 2019. The band was eventually made available for mobile licensees in January 2021. Clearance of the band was hampered by the delay to the MUX operators' procurement of equipment to retune their network frequencies.[83]

The C-band has been used by the satellite operator Thaicom on their Thaicom 5 satellite under a government concession. The service that Thaicom provides over this band is fixed satellite service. It is expected that the Thaicom will exit the spectrum in 2021, when the current concession expires. The spectrum can then be re-allocated for IMT use. The NBTC will be compensating Thaicom's customers to clear the spectrum for future IMT service. As previously mentioned, the NBTC states in their spectrum roadmap that the 3.5 GHz range would be released at the same time as the 28 GHz, of which the primary user is High Throughput Satellite operators. However, there now appears to be a delay in the processes around the re-purposing of the 3.5 GHz range, and migration will not be completed in 2021.

4.1.2 Step 3: Technology definitions and restrictions

All spectrum bands have so far been awarded on a technology-neutral basis, with the only stipulation that an IMT technology be used for mobile service deployment. There is little concern over interference with other users except in the 2600 MHz band and the 3.5 GHz range. For the frequency range 2600-2620 MHz, use for IMT will not be possible in several provinces until the current incumbents' service has ceased, as previously mentioned. The frequencies can be used without restrictions elsewhere in the country.[84]

For the 3.5 GHz range, 5G field trials have been carried out to determine the optimal parameters for sharing with fixed satellite service providers. There will still be FSS providers (including TVROs) in the adjacent band (3700-4200 MHz) even after the band has been cleared for IMT, and so technical parameters still need to be finalised to ensure compatibility between the two systems. The key technical parameters include the separation distance between FSS and IMT base stations, guard band size and specification of filters to mitigate cross-band interference.[85]

The size of the guard band is one of the most important issues in the release of 3.5 GHz range. Due to the risk of interference with TVROs, the NBTC is considering a guard band of at least 100 MHz, which would substantially reduce the amount of usable IMT spectrum. In reality, a significantly shorter guard band would be possible.[86] This may involve adding filters to the LNB, but it would increase the bandwidth that can be re-assigned to IMT use. The result will be an improvement in the efficiency of use of valuable spectrum, which should be one of NBTC's primary objectives.[87] In this respect, FSS operators (including TVROs) should also be encouraged to expediently start the process of clearing the band so that it can be available for 5G service deployment once the auction is held. Only then would an efficient use of spectrum be achieved in the long term.

82 https://spectrumauction.nbtc.go.th/getattachment/News/Announce/53/T_0014.PDF.aspx

83 https://www.bangkokpost.com/business/1936268/nbtc-defers-700mhz-usage-to-january

84 https://www.nbtc.go.th/getattachment/8e39f8ac-cd32-482a-85d0-c7eb386da843/T_0014.PDF.aspx?lang=th-TH&ext=.pdf

85 5G Preparation in Thailand, NBTC-5GMF Joint Workshop on 5G, June 2019

4.1.3 Step 4: Spectrum valuation

Spectrum valuation is an important component of a spectrum release programme. Spectrum fees or auction reserve prices that are too high can lead to spectrum being left unsold and a potential delay in the roll-out of 5G. In Thailand, the award of 5G bands through an auction in 2020, including the 700 MHz, 2600 MHz and 26GHz bands, saw operators bid for all available 5G spectrum. The 1800 MHz, which is primarily used for LTE, was also included in the auction but was not sold. This suggests that importance of technology currency in spectrum valuation. Spectrum bands that are better suited to a strategic deployment of 5G to support a variety of use cases will be valued more highly by potential licensees. Any spectrum valuation will therefore need to take this into account.

Future spectrum valuation will also need to consider industrial use cases for 5G. The NBTC views this as an important engine for a connected society and established a programme called Regulatory Sandbox in 2019 to foster R&D of new uses for new 5G spectrum. Under the programme, a temporary licence with a maximum duration of 2 years may be granted to allow a potential service provider to carry out research and development, experimentation, or testing of a new system, test for interference or shared use of a spectrum between different technologies, or test the network system prior to commercial deployment.[88] Future spectrum valuation should also take account of the outcomes from this programme, in particular results pertaining to new commercial use cases and factors that can limit the spectrum usability due to potential interference.

It should also be noted that one likely reason why the 1800 MHz spectrum failed to attract a buyer in the last auction is its high reserve price. The value of spectrum changes over time based on market demand, which, in turn, is driven by its usefulness for future applications and technologies, as mentioned. This means a band that has been the cornerstone of LTE may not be as attractive as the transition to 5G gathers pace. A valuation used to set the reserve price should therefore be based on an economic assessment of spectrum use. Previously, it has been observed that the reserve price of spectrum in Thailand was closely linked to the historical selling price in an earlier auction, which could be well in excess of the current market-clearing price. Spectrum valuation should therefore be conducted with a realistic demand assumption, so that spectrum can be awarded and its usage improved.

4.1.4 Step 5: Award design

By law, spectrum for commercial use must be awarded through an auction in Thailand.[89] It is nevertheless imperative that the auction format adopted facilitate a well-functioning bidding process and a competitive outcome. A sequential SMRA (Simultaneous Multi-Round Auction) format with specific lots in 2015 led to excessive competition, a very long run time. The format that was used in the latest multi-band auction in 2020 was a simultaneous but independent clock auction with monotonic activity rule. A simultaneous clock auction was chosen for its speed, simple design and the fact that it works well where there is weak substitution across spectrum bands.[90] Future 5G auction designs will also have to take into account the merits of the different formats, spectrum substitutability as well as the overall objectives of the award.

One key consideration for a future award design for 5G spectrum auction is the potential for substitutability with spectrum bands that are expected to become available in the near future. In particular, a multi-band 5G auction to be held in 2022 would be influenced by spectrum that could be released up to 5 years later. This includes the spectrum in the 850 MHz, 2100 MHz and 2300 MHz bands currently held by NT. The rights to these bands will expire in 2025. This will likely affect the bidding behaviours as well as the perceived value of the spectrum in an auction that may be held in 2022.

86 https://www.gsma.com/spectrum/resources/releasing-cband-asean/

87 This is one of the primary objectives of the national regulators in most countries, including Ofcom in the UK and BNetzA in Germany.

88 https://www.bakermckenzie.com/en/insight/publications/2019/09/thailands-nbtc-introduces-regulatory-sandbox

89 The Fundamental Acts Relating to Telecommunications and Broadcasting Services (UNOFFICIAL TRANSLATION), NBTC 2015

90 https://www.itsworld.org/wp-content/uploads/2019/11/Spectrum-Auctions-in-Thailand,-Challenges-Before-and-Ahead.pdf

4.2 Roadmap for Indonesia

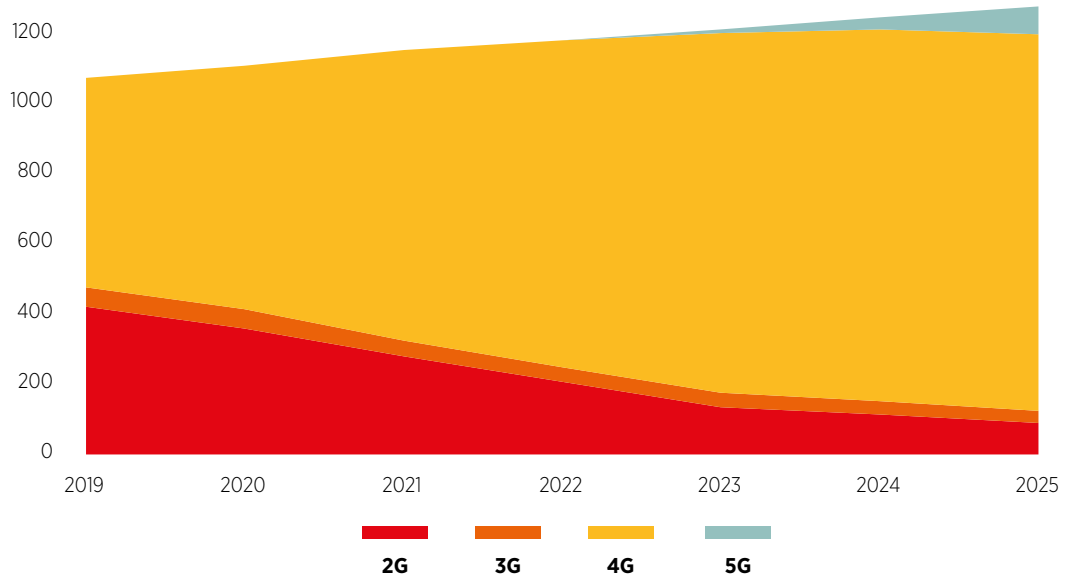
To improve the country's digital competitiveness ranking, and to support the vision of Indonesia Gold 2045, the Indonesian Government has drafted a Digital Indonesia Roadmap for 2021-2024[91] that clarifies the direction of policies to be implemented in four strategic sectors. These are digital infrastructure, digital administration, digital economy, and digital community.

The Indonesian market is characterised by a large number of operators, each holding very different portfolios of spectrum. The market has been complicated by several mergers and acquisitions, with some spectrum now held by an infrastructure and utility company as well as small holdings in the 2300 MHz band used by niche LTE operators. While the 1800 MHz and 2100 MHz bands are well utilised, there is some uncertainty over the future of the configuration of the 850 MHz and 900 MHz bands.

Against this, there is a slow but steady growth in demand, both in terms of the number of connections and total data traffic. The majority of subscriptions are already using LTE technologies, with 2G connections predicted to decline rapidly to near zero over the next few years.

FIGURE 4.3

MOBILE SUBSCRIPTIONS IN INDONESIA BY TECHNOLOGY (MILLIONS)[92]



Mobile operators are required to undergo an Operational Feasibility Test (ULO) prior to deployment of 5G networks, and as at October 2021 three operators had been granted licences following successful tests: Telkomsel, Indosat, and Axiata XL. While each of these operators have launched 5G services, these are running on a very limited geographic basis, covering a few of the major cities only; further, the services are run either over limited new allocations of 2300 MHz spectrum or, in the case of Axiata, refarming part of the 1800 MHz band. This limited spectrum availability will significantly impact on the potential of 5G services.

91 https://en.antaranews.com/news/167151/ministry-drafts-roadmap-for-indonesia-digital-2021-2024

92 Source: GSMAi

4.2.1 Steps 1 and 2: identification of spectrum and clearance

The current spectrum holdings in Indonesia do not include any of the key 5G bands, meaning that operators have been forced to utilise less supported bands (with low bandwidths) to launch 5G services: some limited spectrum in the 2300 MHz band was auctioned at the end of 2020, and at least one operator is refarming part of its 1800 MHz holdings. This has resulted in a comparatively low-speed service, with higher operating costs and lower consumer choice. When combined with the need for operators to trial the technology and apply for specific technology licences, this presents a significant roadblock to the rollout of 5G technologies.

Nevertheless, three operators have so far launched 5G networks in a few of the major cities in Indonesia, and further growth is predicted. In order to accommodate this demand, it is crucial that additional spectrum is released.

700 MHz

The 700 MHz spectrum band is currently used in Indonesia for analogue television broadcasting. The Ministry of Communication and Information (Kominfo) has stated that it intends for analogue switch-off to be completed by the end of 2022, which will then clear this band for mobile services; indeed, this deadline has been codified within the Omnibus Telecommunications Law[93]. However, this process has been ongoing since 2018, and there have been no commitments made how the spectrum will be released following clearance.

The GSMA has estimated that releasing the entire 700 MHz band to mobile would lead to an increase in productivity of 1% of GDP[94]. This band is particularly important in Indonesia due to population dispersion and the climate in which networks must operate. The regulator will need to make some careful decisions on how the band is awarded, however, due to the number of operators in the market. If they attempt to divide the 700 MHz band across all operators equally, then no operator will be left with a sufficient holding to run a full 5G experience. On the other hand, awarding larger blocks will cause some operators to have no spectrum at all.

In either case, it is clear that for 5G demand to be met it is imperative for the entirety of the 700 MHz band to be awarded to IMT. If analogue switch-off is due to complete by the end of 2022, the regulator should consult with operators to identify the appropriate band plan in the coming months.

93 See https://www.lexology.com/library/detail.aspx?g=90ba9495-029e-4f91-a7f6-923f8a0e2cfe

94 See https://www.gsma.com/spectrum/resources/indonesia-assigning-700-mhz-ushers-new-era-of-connectivity/

Mid-band spectrum

The capacity constraints are worsened by the current unavailability of spectrum in 2600 MHz and 3500 MHz bands. Both these bands, which are used to provide significant 5G capacity around the world, are currently occupied by broadcast satellite (2600 MHz) and fixed satellite (including TVROs) (3500 MHz) systems, which themselves are an important part of the Indonesian national broadband strategy. An initial spectrum plan[95] has revealed that these bands will not be made available until 2023, although this is under further policy review.

The 5G Task Force within the regulator has been considering whether it is possible for the 3500 MHz band to coexist between IMT and satellite, including TVROs (and a number of trials have already taken place), with a geographic split between rural and urban locations, as well as via filters and the consideration of a guard band. Kominfo has noted that 3.5 GHz spectrum is likely to be mainly used in urban areas, where satellite broadband is less useful due to a number of alternatives. While this would provide urban 5G users with a significantly better quality service, it would risk rural users from being provided with 5G if the remaining of the areas are not made available via a clear roadmap later..

Given this, Kominfo must carefully examine likely 5G demand in different regions so as to understand how mid-band spectrum should be allocated. Any consolidation of satellite broadcasting holdings, clearing other bands for IMT, may result in much better quality of coverage in rural areas.

4.2.2 Step 3: Technology definitions

Currently spectrum in Indonesia is awarded on a technology-neutral basis, but operators must demonstrate through use of trials that its use for 5G will not have an adverse impact on other spectrum users. When combined with a lack of spectrum availability, where operators will need to be flexible with refarming and spectrum configuration, this may present significant barriers to meeting consumer demand. A more dynamic licencing regime would allow operators to run appropriate 5G networks as needed.

95 See the presentation discussed at https://gadget.jagatreview.com/2020/12/roadmap-5g-dan-transformasi-digital-indonesia-kembali-dipaparkan/?__cf_chl_managed_tk__=FvsgU31rxvlXQnK4hM-1rljOuI7ytw_hjWbLMotKeyb4-1636045428-0-gaNycGzNCCU

4.3 Roadmap for India

The Government of India (GoI) launched the Digital India programme in 2015. The vision of the programme is to transform India into a digitally empowered society and a knowledge economy. The key vision areas of the programme are enhancing digital infrastructure, e-governance, and digital empowerment of citizens[96]. In order to achieve these, it is clear that there must be a significant focus on ensuring all citizens are connected, and this leads to a number of infrastructure policies.

This focus on digital infrastructure underpins the GoI's National Broadband Mission which was launched in December 2019 and is based on the three principles (universality of broadband services to bridge the digital divide, affordability of broadband services and high-quality broadband access for all). To achieve these, the Government has set the following main outcomes for a five-year period since the launch of the mission[97].

- All villages to have access to broadband by 2022.
- Availability of high-speed broadband (up to 50 Mbps).
- Increase fibre deployment from 22,000,000 to 50,000,000 kilometres, with a focus on deloying fibre to existing towers.
- To increase tower density from 0.42 towers per thousand population to 1 per thousand population, in order to improve quality of service and better connectivity.
- To increase the rate of fibre connection between the towers from current 30% to 70%.
- To create a Geographic Information System (GIS) for assisting in the planned deployment and monitoring of fibre networks.
- Roll out of 5G network and further strengthening the existing 4G network.
- Promoting domestic manufacturing of telecommunications equipment (Make in India).

This broadly aligns with the National Digital Communications Policy (NDCP)[98] which was determined in 2018. The NDCP aims to achieve the following strategic objectives by 2022:

- Provisioning of Broadband for All.
- Creating 4 million additional jobs in the Digital Communications sector.
- Enhancing the contribution of the Digital Communications sector to 8% of India's GDP from ~ 6% in 2017.
- Propelling India to the Top 50 Nations in the ICT Development Index of ITU from 134 in 2017.
- Enhancing India's contribution to Global Value Chains.
- Ensuring Digital Sovereignty.

Furthermore, the Department of Telecommunications (Dot) has reportedly[99] been looking into updating the telecommunications legal framework by replacing the 1885 Telegraph Act and the 1933 Indian Wireless Telegraphy Act before the launch of 5G. This initiative aims at addressing gaps in the legislation that could hold back the development of 5G in the country. We understand that the DoT is working with the National Law University in Delhi which has been tasked with the study of the current acts and the elaboration of potential amendments.

Overall, the government of India has a clear strategic vision to improve connectivity for its population, including the availability of 5G and making efficient use of existing LTE networks. There have been defined moves to ensure that fibre networks are in place to support 5G connections, although further work should be done to ensure access to spectrum for microwave links – including E-band spectrum – for areas where fibre backhaul is not available or needs support.

However, to date there have been a number of delays in allowing operators to enact these policies. In particular, and most relevant for this study, there have been significant delays in awarding new spectrum for 5G, against concerns of overly high spectrum fees, and licencing issues have prevented large-scale 5G deployment in existing bands.

In addition, while LTE adoption has been strong in India, there are still a very large number of subscribers continuing to use 2G connections, likely due to the cost of handsets and connection charges. This further highlights the importance of ensuring that spectrum fees for new technologies do not act as a barrier to uptake.

96 Government of India, 2021, Digital India, Available at: https://www.digitalindia.gov.in/content/vision-and-vision-areas

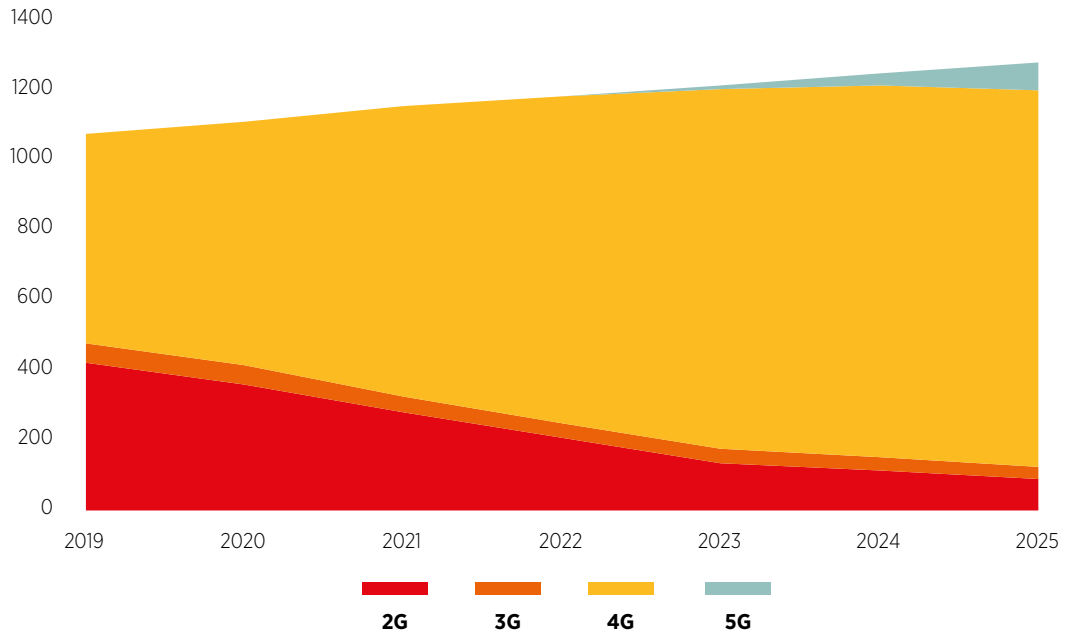
97 Department of Telecommunications, Government of India, December 2019, National Broadband Mission. Available at: https://dot.gov.in/sites/default/files/National%20Broadband%20Mission%20-%20Booklet_0.pdf?download=1

98 https://dot.gov.in/sites/default/files/EnglishPolicy-NDCP.pdf

99 https://www.commsupdate.com/articles/2021/03/08/dot-mulls-legislative-overhaul-before-5g-launch/

FIGURE 4.4

MOBILE SUBSCRIPTIONS IN INDIA BY TECHNOLOGY (MILLIONS)[100]



4.3.1 Steps 1 and 2: Identification of spectrum and clearance

India has, to date, awarded spectrum in the 850, 900, 1800, 2100, 2300 and 2600 MHz bands, for a variety of technologies. Details of the awards of these holdings are shown in Figure 4.5. However, it must be noted that India's spectrum awards are typically carried out on a regional basis, and so this does not represent an operator's ability to deploy nationwide networks.

FIGURE 4.5

SPECTRUM AWARDS IN INDIA[101]

Technologies	Bands	Generation	Airtel (Bharti airtel)	Vi	BSNL	MTNL	Reliance jio	Reliance
GSM	900, 1800	2G	Oct-95	Sep-96	Jan-01	Feb-01		
WCDMA HSDPA	2100	3G			Feb-09	Jul-09		
WCDMA HSPA+	900, 2100	3G	Jan-11	Mar-11				
WCDMA DC-HSPA+	900, 2100	3G	Mar-15					
CDMA2000 1X	850	3G			Mar-15			
CDMA2000 1xEV-DO Rev. A	850	3G			Jun-09			
LTE	850, 900, 1800, 2100, 2300, 2600	4G	Aug-15	Dec-15	Jan-19		Sep-16	Jun-16
TD-LTE	2300	4G	Apr-12				Sep-16	
VoLTE	-	4G	Sep-17	Feb-18	Mar-19		Sep-16	
LTE Advanced	1800, 2300	4G	Feb-16	Mar-21			Mar-21	

100 Source: GSMAi

101 Source: GSMAi. Note that while thise data shows the awards of spectrum, it does not reflect current holdings since BSNL and MTNL merged during 2019 and 2020, and Reliance and transferred all telecommunications operations to Jio Platforms in 2019. These columns should be considered together. Also, these awards do not represent nationwide allocations, and operators wining spectrum only indicates that they hold licences in one region of the country.

The March 2021 spectrum auction in the 800, 1800 and 2300 MHz bands increased the spectrum holdings of Jio, Airtel and Vodafone, which positively affected the speeds available for customers. Median download speeds increased from 8.52 Mbps in (Q1 2021) to 10.44 Mbps in Q2 2021. However, more spectrum, specific for 5G use will be instrumental in further growth of the sector and enhancement of consumer experience. As described in Step 4 below, while further spectrum was made available in the March 2021 auction, it did not sell due to overly high reserve prices.

The regulator, TRAI, has identified spectrum for 5G services in its White Paper[102].

- The 700 MHz band is available and an auction has already taken place, although this spectrum did not sell at the time.
- The 3500 MHz band is currently used in part by the Indian Regional Navigation Satellite System (IRNSS). However, this use is limited to a few geographic locations, and so the TRAI proposes to award the entire band from 3300 MHz to 3600 MHz with small geographic restrictions around satellite use. The whole band will be awarded on a TDD basis.

There will therefore be limited need for clearance of this initial spectrum. However, care will need to be taken over existing C-band use of fixed satellite services. All other incumbent users of the 3500 MHz range were required to vacate this band before 2019.

However, as noted, a previous auction for 700 MHz spectrum resulted in no sale, and an auction for spectrum in the 3500 MHz band has been postponed (from an initial date in 2017) due to a lack of ecosystem readiness and maturity. In both cases, high reserve prices have been cited as a barrier to efficient allocation of spectrum. This will be discussed further below.

102 TRAI (2019), Enabling 5G in India, available at https://trai.gov.in/sites/default/files/White_Paper_22022019.pdf

4.3.2 Step 3: Technology definitions and restrictions

While the 5G spectrum has not yet been auctioned in India, the operators in the Indian market have been carrying out preparatory work to support the 5G commercialisation after the spectrum is assigned.

The Department of Telecommunications gave a green light for operators to commence 5G trials in India in May 2021. Non-commercial 5G trials were to be conducted over a period of 6 months with allocated spectrum in the mid-band (3.2 GHz-3.67 GHz), mmWave band (24.25 GHz-28.5 GHz) and the sub-1 GHz band (700 MHz), as well as in the operators' existing spectrum. The focus was on developing India-specific use cases.[103] Participants in these trials were required[104] to conduct trials in rural, semi-urban and urban areas and encouraged to use locally developed 5G technology. Three operators are conducting 5G trials and have reportedly achieved very high 5G speeds. Airtel is rolling out 5G-ready network equipment and Jio is testing its own 5G open RAN solutions in multiple Indian cities.[105]

For the trials, both Airtel and Vodafone Idea are trialling the 5G Non-Standalone (NSA) solution and Jio is testing the 5G Standalone (SA) option. Airtel has also conducted a 5G trial in the 1800 MHz band. Reportedly, it has also tied up with Tata Consultancy Services (TCS) to develop an indigenous 5G solution.[106]

One of the important aspects of the 5G deployment in India is the 5Gi standard developed by the Indian Institute of Technology (IITs) with support from the Telecommunications Standards Development Society of India (TSDSI). The main feature of 5Gi is the Low Mobility Large cell (LMLC) which can enhance the signal transmission range of a base station. This would enable the operators to increase their coverage which could help in cost-effectively expanding 5G coverage, especially in rural areas and assist in decreasing the digital divide. [107] 5Gi will operate on the same bands and spectrum as the regular 5G network.[108]

The Indian government has expressed support for the 5Gi standard, but the industry opinion on 5Gi in India is mixed. Vodafone Idea and Airtel have expressed concerns around the interoperability and increase in network cost, while Jio is open to the idea of deploying 5Gi. The vendors have also shown some concerns regarding developing 5Gi specific equipment because of the lack of wider acceptability and potentially low return on investment. Other challenges noted with 5Gi are lack of global harmonisation and scale benefits. [109]

The international industry has also shown some reservations related to the 5Gi standard from the perspective of its impact on the supply chain security.[110] While the developers of the standard claim that it would only require for the operators to make small changes in the RAN software to deploy 5Gi and it would not affect the cost of the operators[111], operators themselves argue against this, with some equipment manufacturers stating that 5Gi demands major hardware change. In addition, the millions of 5G-enabled devices already in the market will only recognise the 3GPP-mandated global 5G standard – and this is additionally important when considering roaming. While there are disadvantages to the use of 5Gi, there are also advantages – including an enhanced rural deployment and experience. It is important therefore that operators are able to choose whether to utilise this technology, based on the needs of their consumers, rather than it being mandated.

In December 2021, a plan of action was agreed between 3GPP and TSDSI to allow the merger of 5Gi into 5G as part of Release 17, paving the way for a single common 5G specification going forward. [112]

103 The Hindu BusinessLine, June 2021, India's 5G network will have a desi soul. Available at: https://www.thehindubusinessline.com/info-tech/indias-5g-network-will-have-a-desi-soul/article35007094.ece

104 https://www.commsupdate.com/articles/2021/05/05/indian-operators-given-go-ahead-for-5g-trials/

105 Ibid (Ookla Speed Test, 11 August 2021, Recent Spectrum Gains Point to Improved 5G Outlook for Indian Consumers.)

106 Fierce Wireless, August 2021, Indian Government causes 5G delays. Available at: https://www.fiercewireless.com/operators/indian-government-causes-5g-delays-wants-5gi

107 ETTelecom.com, 2021, In-depth: What lies ahead for India's 5Gi? Available at: https://telecom.economictimes.indiatimes.com/news/in-depth-what-lies-ahead-for-indias-5gi/83942467

108 91 Mobiles, June 2021, 5Gi explained: What does it mean, how is it different from 5G, what Jio, Airtel and Vi say about 5Gi. Available at: https://bit.ly/39o2FOi

109 Ibid (ETTelecom.com, 2021, In-depth: What lies ahead for India's 5Gi?)

110 The Economic Times, August 2021, Tech bodies from US and UK oppose mandatory use of Indian 5G standard. Available at: https://economictimes.indiatimes.com/industry/telecom/telecom-news/tech-bodies-from-us-and-uk-oppose-mandatory-use-of-indian-5g-standard/articleshow/85221202.cms?from=mdr

111 Ibid (ETTelecom.com, 2021, In-depth: What lies ahead for India's 5Gi?)

112 3GPP, December 2021, Merging 5Gi and 3GPP specifications, available at https://www.3gpp.org/news-events/2243-3gpp_5gi

4.3.3 Steps 4 and 5: Spectrum valuation and award design

The 5G auction is expected in 2022. In November 2021 the Telecom Regulatory Authority of India (TRAI) published a consultation on the auction of spectrum for 5G.[113] The consultation covers a series of frequency bands including 700, 800, 900, 1800, 2100, 2300, 2500, 3500 MHz and 26/28 GHz bands, and the details of the auction are expected to be finalised in March 2022.

One key concern over the award of spectrum in India is the regulator's current tendency to set high reserve prices. Previously, TRAI had recommended a reserve price of Rs 4.92 billion (approximately USD 67 million) per MHz for the 3500 MHz band, which the industry protested was very high. Similarly, the 700 MHz spectrum band has remained unsold after two attempts, despite the reserve price being reduced by 43% between the two auctions.

The government has been urged to revise its spectrum valuation methods, following the clear evidence that it has overestimated the price that operators are willing or able to pay. A standing committee report[114] from February 2021, has noted that the TRAI's recommended reserve price for the 3.5 GHz range in the upcoming 5G auction is 3-70 times the market determined price in other countries in absolute terms and 16 times in relative terms (after adjusting for factors like population, GDP per capita and ARPU). The report emphasised that there was a need to strike a balance between the Government's expectation to generate revenue (especially in the backdrop of the pandemic) and growth of the telecoms sector.

However, to date there has been no announced change in the TRAI's approach to reserve prices, although in its November 2021 consultation paper the TRAI sought comments from industry on the appropriate valuation approaches for the different bands to be auctioned and how the reserve price should be set. Some consideration has been shown over extending licence durations, but this will only partially mitigate the impact of high prices due to the inherent uncertainty of spectrum use in the long-term.

The TRAI and government have, however, announced a number of financial support measures for operators. In the second week of September 2021, the government approved a set of financial relief measures for the telecom sector. In 2019, the Supreme Court had ordered telecom companies to pay dues worth over Rs 1.4 trillion (approximately USD 19 billion) to the government[115]. This put intense financial stress on the operators which were already struggling due to an intense price war. Following this, the government set out a relief package for operators: the telecom companies have been given a four-year moratorium on spectrum and AGR dues, and they can now opt to pay these duties and interest accumulated at the end of the four- year period. If the company is unable to pay the dues at the end of this period, it will be able to negotiate with the Government to pay it an equity stake in lieu of the accumulated dues.

More recently India has adopted a major relief package for MNOs with spectrum-related reforms[116]. Adopted measures include the following: annual spectrum usage charges are revoked for future auction winners; licence durations are to be increased from 20 to 30 years; and there will be no more bank guarantee required.

These reforms are likely to ease some financial pressures and restrictions on operators, but they do not address the key issue of the TRAI's valuation exercises giving overly high estimates. Plum has previously examined the econometric and other methods used to estimate spectrum value[117] and noted a number of issues with the methodology; a number of other exercises have drawn similar conclusions. It is crucial that a full study of spectrum value and reserve prices is carried out before future awards, and the industry has already asked the TRAI to do this[118].

113 TRAI, November 2021, Consultation Paper on Auction of Spectrum in frequency bands identified for IMT/5G, available from https://www.trai.gov.in/sites/default/files/CP_30112021_0.pdf

114 DoT, 2020-2021, Ministry of Telecommunications, India's preparedness for 5G. Available at: https://eparlib.nic.in/bitstream/123456789/799780/1/17_Information_Technology_21.pdf

115 Traditionally the telecom companies had paid a fixed fee to the Government, but since 1999, they had been obliged to pay a portion of their Adjusted Gross Revenue (AGR) as well. In the past the Government and the operators have disagreed on what constitutes the AGR. The companies claimed that non-telecom revenue cannot be asked for as AGR, however the Government disagreed. The dispute ended up in the Indian apex court and the court ruled in the favour of the Government, resulting in large fees due from operators.

116 https://www.policytracker.com/india-adopts-wide-ranging-measures-to-rescue-mobile-sector/

117 See https://plumconsulting.co.uk/value-1800mhz-spectrum-india/

4.3.4 Future developments

The delay in the 5G auction has a high socio-economic cost for the country and any further delay could significantly harm the sector's growth, consumer welfare and development, and recovery of the economy from the Covid-19 pandemic. It is imperative that certainty can be given to operators over 5G spectrum awards as soon as possible.

However, this delay might have some inadvertent benefits. These are the reduction in the network equipment costs as the 5G ecosystem matures, and wider availability of the 5G devices resulting in affordable devices. These factors could both drive down the costs of operators in launching 5G services, supported by potential high demand for 5G underpinned by high penetration of 5G devices[119]. It is unclear whether these benefits will outweigh the costs from delayed deployment, however, particularly given the increasing energy costs caused by rising coal costs which form a significant part in India's electricity generation, which are in turn increasing the cost of rolling out new networks.

Comparing 5G non-standalone and 5G standalone options, the local industry specialists note that the operators in the Indian market might prefer to go with the non-standalone option to begin with before transitioning to standalone. In particular, there is currently no evidence of significant business demand for use cases which are facilitated by standalone networks. It is expected that the initial 5G uses case in India are likely to be (eMBB) and fixed wireless access (FWA) before the move to vertical based use cases[120]. Given this, it is important that there is sufficient spectrum maintained for LTE use, and spectrum should be made technology-neutral.

The Indian government's focus is on including Indian players providing the software and hardware for the 5G deployment or international players to be manufacturing equipment locally in India. It is reported that Ericsson, Nokia, Samsung, and Qualcomm are producing hardware in India[121]. Airtel and Tata have reportedly developed an indigenous 5G solution using Open-Radio Access Network, and Jio has announced an indigenous 5G solution by partnering with Qualcomm to produce 5G equipment. Other, domestic players like Tech Mahindra, Sterlite Technologies Ltd, state-run ITI Ltd and might be entering the 5G equipment market as well. Recently Tata has announced that its subsidiary Panatone Finvest has offered to acquire a controlling stake in Tejas Networks (a telecommunications equipment maker); this could further increase competition[122].

118 See https://www.financialexpress.com/industry/spectrum-auction-trai-may-look-at-new-pricing-model-to-fix-reserve-price-for-5g-auctions/2338333/

119 Ibid (Ookla Speed Test, 11 August 2021, Recent Spectrum Gains Point to Improved 5G Outlook for Indian Consumers.)

120 Ibid (Fierce Wireless, August 2021, Indian Government causes 5G delays.)

121 Ibid (The Hindu BusinessLine, June 2021, India's 5G network will have a desi soul.

122 See https://www.business-standard.com/article/companies/tata-sons-arm-panatone-finvest-acquires-8-stake-in-tejas-networks-121080201420_1.html

4.4 Roadmap for Pakistan

In 2020, almost half of all mobile connections in Pakistan were still carried over 2G technologies, following a relatively late and slow introduction of LTE to the market (starting in 2014, with some operators only launching LTE services in 2019). The coverage and capacity of LTE technologies still varies significantly by operator, with Zong (owned by China Mobile) having the most comprehensive LTE-A network and Ufone reporting many areas in which basic LTE is not available. In February 2022 the regulator PTA completed the rationalisation plan for the 1800 MHz band which involved consolidating previously fragmented holdings to enable contiguous holdings and efficient spectrum utilisation.[123] Against this background, an early adoption of 5G is not expected, but operators have started to request that the PTA, sets out an early and defined plan for 5G spectrum release.

Guidelines for 5G trial licences were set in July 2019 following a public consultation. The "Framework for Test and Development of Future Technologies Particularly for Fifth Generation (5G) Wireless Networks in Pakistan"[124] established the rules for the allocation and use of radio spectrum on a trial basis for non-commercial purposes. At the time there were no specific spectrum bands offered, although operators were advised to consider mid-band and high-band allocations:

> **Applicants can propose spectrum for trial purpose which could inter alia, include but [is] not limited to the requisite spectrum blocks in 2600 MHz, 3600 MHz and other relevant bands amenable to millimetre wave propagation**

123 PTA. Rationalization plan for 1800 MHz spectrum completed, 18 February 2022. https://www.pta.gov.pk/en/media-center/single-media/rationalization-plan-for-1800-mhz-spectrum-completed-220222

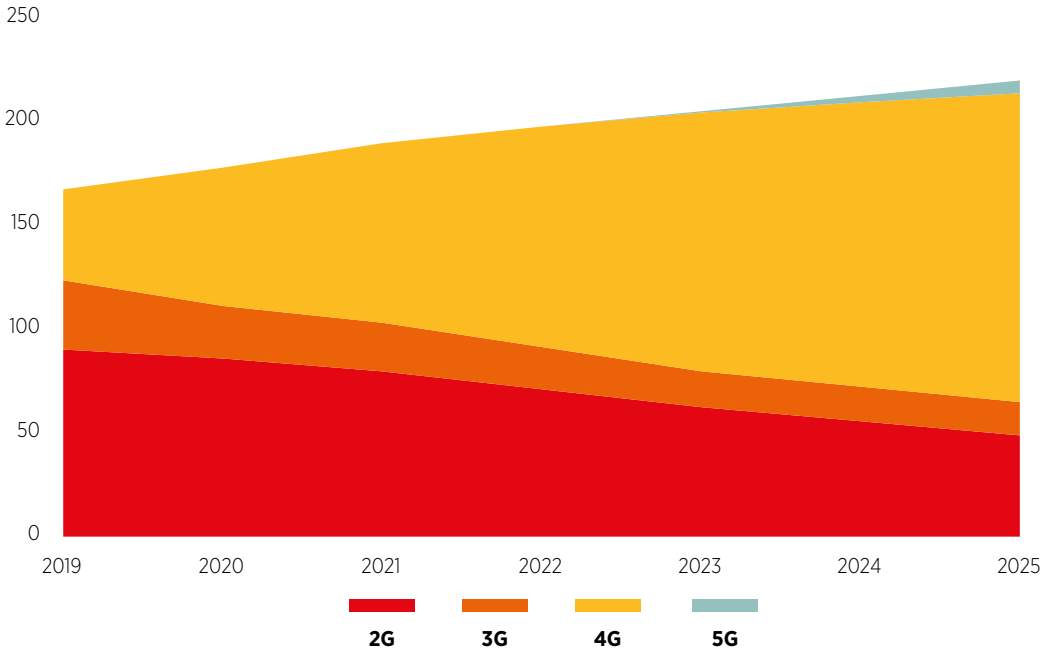
124 Available at https://www.pta.gov.pk/assets/media/final_framework_5g_test_trials_260619.pdf

4.4.1 Identifying demand for 5G

As described above, the majority of mobile connections in Pakistan are currently using 2G or 3G technologies, although the GSMA reports that LTE connections are growing (and are predicted to continue to grow) quickly. Even with this rapid growth, however, there is unlikely to be a constraint on capacity in the next couple of years.

FIGURE 4.6

MOBILE SUBSCRIPTIONS IN PAKISTAN BY TECHNOLOGY (MILLIONS)[125]



Jazz, the largest operator by number of subscribers, has confirmed that its focus in the short term is on growing the number of LTE connections. Jazz's CEO has stated:

> **We have to ensure the at least 60 per cent among all consumers are on 4G before going to 5G. We need to accept that the lack of good mobile phone sets is one of the key barriers to the Internet growth in the country**

To encourage LTE growth, operators have expanded coverage and have started to upgrade the network to LTE-A technologies – although this has not happened nationally. The operators believe they are constrained by policies from the PTA, in particular recent policies over the manufacturing of mobile devices[126]. To encourage local manufacture, the government has passed a mobile device manufacturing policy which increases taxes and introduces quotas on devices imported from overseas. However, the vast majority of mobile devices currently produced in Pakistan are compatible only with 2G networks, meaning that it is more difficult to encourage take-up of other, more efficient and capable, technologies.

125 Source: GSMAi

126 See, for example, https://tribune.com.pk/story/2303615/why-5g-is-still-out-of-pakistans-grasp

It is crucial, therefore, that the Pakistani market be given access to lower cost LTE-capable devices, whether produced locally or through reductions in import tax, so as to establish demand for LTE – and therefore future 5G – traffic.

Availability and affordability of devices is not the only barrier to LTE and 5G adoption: such measures need to be taken alongside general technology literacy programmes. The GSMA reports[127] that just over 40% of mobile users in Pakistan cite a lack of literacy and digital skills as the primary barrier to mobile Internet use.

4.4.2 Steps 1 and 2: Identification of spectrum and clearance

In November 2020, the government approved the 2020-2023 Rolling Spectrum Strategy[128], a roadmap for spectrum management. This national strategy provides a tentative timeline for spectrum policy reviews and frequency allocations planned for the period. Plans regarding policy and allocations include the publication of a spectrum sharing and trading framework; the refarming of spectrum in the 1950 MHz-1980 MHz & 2140 MHz-2170 MHz range which was previously used for wireless local loop and fixed links (2020-2021); the reassignment and renewal of licences for 900 MHz and 1800 MHz spectrum (2020-2021); and the allocation of unused 1800 MHz spectrum (2020-2021). In the longer term, the roadmap includes a need for award of the 2300 MHz and 2500 MHz spectrum bands.

In terms of spectrum specifically for 5G networks, the government has identified that the 700 MHz and 3500 MHz bands are being globally accepted as key locations, and in its spectrum strategy document it makes specific recommendations on these bands. However the Rolling Spectrum Strategy is not clear on when this spectrum will be available.

- The 700 MHz band is currently being used by government systems, and it is accepted that these existing users must be moved to enable full use of the band by mobile services. "There is a high chance that devices will hit critical mass before 2020 and it is recommended that MoIT&T/PTA/FAB aim to allocate the band for auction. This band is also crucial for Pakistan operators to extend the coverage to rural areas since it has better propagation characteristics".
- The 3500 MHz band is being used by fixed wireless broadband services, but it has also been offered to operators for 5G trials on a non-exclusive basis. The PTA has been instructed to stop issuing new FWA licences in these bands. The spectrum strategy also recommends: "PTA/FAB to auction the full band when all the licences expire in 2024. In the longer term, there should be a plan for WLL systems to be eventually phased out – for example with the view that legacy WLL will eventually be replaced by mobile services and other relevant 5G use cases. In the meantime, PTA/FAB should make arrangements to hold 5G trials in this band as per 2017 GoP policy."

Given current usage of the 3500 MHz range, the regulator's priorities for 5G spectrum award are the 3300-3400 MHz band, alongside the 700 MHz and 2300 MHz band. Some operators believe this spectrum could be awarded during 2022, but the award of spectrum will not necessarily mean it is immediately available to use. The award of the 2300 MHz band is perhaps the most important, as this is already cleared for use.

Although these are identified as key 5G bands, the spectrum strategy document also notes that spectrum should be awarded on a technology-neutral basis, and most recent awards have followed this rule, enabling operators to use some existing bands for 5G deployment where there is capacity.

4.4.3 Steps 4 and 5: Spectrum valuation and award design

However, while the government has a clear strategy for releasing new spectrum, the logistics of doing so may be more difficult. The country has recently held its first spectrum auction in four years and it only attracted one bidder[129], Ufone, which secured 2×9 MHz in the 1800 MHz band. The other MNOs, Jazz, Telenor Pakistan and Zong, withdrew from the process while criticising the award process for an overly complicated auction design, as well as the high spectrum fees that would be due, overly onerous licence conditions, and concerns over a lack of clarity regrading renewal terms. Spectrum in the 2100 MHz band went unsold, again largely due to the high prices required.

The PTA has stated in its 2020 annual report that it is aiming to auction spectrum for 5G services in the 2023 fiscal year. Recognising that this is some way off, the PTA is encouraging operators to trial advanced 5G technologies in the hope that when 5G networks are launched, they are more capable (with higher speeds, lower latency and better reliability). However, with uncertainty over the demand for 5G, as well as concerns over the cost of spectrum, onerous coverage and quality of service obligations, and the timing of the auctions, it is unlikely that operators will feel able to invest significant sums in this research.

127 GSMA (2021): "The State of Mobile Internet Connectivity 2021"

128 Available at https://www.moitt.gov.pk/SiteImage/Misc/files/PakistanRollingSpectrumStrategyFinal23Nov2020.pdf

129 https://www.commsupdate.com/articles/2021/09/13/pta-awards-additional-airwaves-to-sole-bidder-ufone/

4.5 Roadmap for Cambodia

As of October 2021, operators in Cambodia are waiting for the government to release its 5G policy and roadmap, along with the allocation of spectrum.

This is not to say, however, that the government or regulator in Cambodia has been silent on the rollout of 5G, or that operators have not been working on deployment. In November 2019, the Telecommunications Regulator of Cambodia (TRC) organised a roundtable[130] discussion on how to "pave the way to 5G in Cambodia" with the relevant ministries, telecommunication operators and equipment suppliers. This roundtable was the fourth forum organized by the regulator to gather inputs from stakeholders and to help the Ministry of Post & Telecommunication (MPTC) develop the national policy on 5G. A number of policy options were explored, including the possibility of joint ventures rolling out a reduced number of networks – it is understood that the Ministry has asked the regulator to explore the possibility of small telecom operators jointly running as providers[131].

There are two driving factors behind this debate.

- First, there are concerns that the cost of rolling out separate networks for each operator may be prohibitive, and the government does not have funds to subsidise this. Tram Iv Tek, the former telecommunications minister, stated that "The government does not have a large budget to invest in its 5G system, so we are looking into the possibility of allowing multiple private investors to create partnerships and provide the capital required to run this major project".
- Second, the regulator recognises that large contiguous bandwidths are required to run effective 5G services. "Since there is a frequency limit on the current 5G network, we are considering setting the number of operators between four or five. This is because we need the network to run smoothly. We have to manage the frequency in order to comply with current international standards. "If we allow too many operators to run on the network at once, the frequency will be too low and not provide the quality speeds needed to provide the benefit of a 5G network".

The TRC has stated that it is considering 400 MHz of spectrum in mid-band ranges for 5G deployment, but in the absence of a final and clear policy, operators cannot commit to investment. In addition, the current draft of the spectrum sub-decree contains certain restrictive terms on technology neutrality which may reduce incentives to invest in 5G.

In the meantime, five operators have conducted 5G tests in the country, including Smart Axiata, Cam GSM (Cellard), Metfone, the South East Asia Telecom Group Pte Ltd (SEATEL Group) and Kingtel. It is reported that the government has assigned spectrum licences to the operators to conduct these trials, before retraction of trial licences, "citing concerns about wastage and inefficiency occurring if each operator built a separate 5G infrastructure"[132].

130 https://www.trc.gov.kh/en/?s=5G

131 https://www.khmertimeskh.com/50700681/5g-ministry-proposes-joint-partnerships-to-maximise-investment

4.6 Roadmaps for Bangladesh, Malaysia, Sri Lanka and Vietnam

Governments in Bangladesh, Malaysia and Sri Lanka have all identified at least some spectrum that will be released for 5G networks, and have taken steps to clear this. In each country a number of operators have undertaken trials to demonstrate the capabilities of networks.

However, each country has faltered in spectrum award processes, defining the market, or taking decisive action on developing a roadmap.

In **Malaysia** the Ministry of Finance announced in February 2021 during the launch of the Prime Minister's Malaysia Digital Economy Blueprint (MyDIGITAL) that a government-owned Special Purpose Vehicle (SPV) would be responsible to rolling out a nationwide single wholesale network (SWN) to deliver 5G. This has led to the establishment of Digital National Berhad (DNB)[133] which would be responsible for rolling out the 5G network and providing wholesale services to operators on an open, fair and non-discriminatory basis over the next 10 years.

There are several reasons cited by the government for this decision, namely to:

- reduce capital expenditure;
- enable communications to work as a utility;
- enable current MNOs to focus on improving their 4G networks;
- pass cost savings to consumers and encourage 5G adoption; and
- allow fair and non-discriminatory access to the 5G network.[134]

132 https://developingtelecoms.com/telecom-business/market-reports-with-buddecom/11812-cambodia-waits-on-the-government-to-release-5g-policy.html

133 https://www.mcmc.gov.my/skmmgovmy/media/General/pdf/CMA-2021-3.pdf

134 https://www.gsma.com/asia-pacific/wp-content/uploads/2021/09/DT-Economics-Safeguarding-the-road-to-5G-in-Malaysia-Final-report-August-2021.pdf

It is understood there were also concerns over whether insufficient spectrum in the 700 MHz and 3500 MHz bands could lead to sub-optimal assignments with each player left with not enough bandwidth to provide reasonable 5G service. The decision surprised industry players who had been making their own 5G plans[135] and also raised significant concerns over how the SWN model will work; other wholesale networks in Rwanda, Kenya and Mexico have not been as successful as hoped. There was a further concern that deployment via a single wholesale network may cause significant delay in the availability of 5G services.

The MCMC subsequently confirmed[136] that DNB would be licensed and regulated under the Communications and Multimedia Act 1998. In August 2021 the MCMC published a public inquiry paper on its Access List which sets out the proposed access terms and conditions for regulated network infrastructure and services. including for the DNB's 5G wholesale service.[137]

DNB will be assigned spectrum in the 700 MHz (2×40 MHz), 3.5 GHz (200 MHz at 3.4-3.6 GHz) and the 26/28 GHz (1600 MHz at 26.5-28.1 GHz) bands. The price to paid for this spectrum has not been identified. As part the government's decision to appoint DNB as the SWN operator, MNOs are prohibited from using their existing spectrum holdings to provide 5G services, which will prevent them from refarming spectrum for 5G or any future network technologies. The duration of this prohibition is not clear, but it is a significant step away from the previous technology neutrality within spectrum licences. These changes to spectrum policy have led to significant uncertainty in the regulatory environment, which may discourage large-scale investment from operators. At the time of publication, none of Malaysia's major operators have agreed to use the government's 5G network due to transparency and pricing issues.

DNB has signed a 10-year deal with Ericsson to deploy the 5G network, and intends to adopt a phased deployment starting in December 2021. The target to achieve approximately 36% coverage in populated areas (Kuala Lumpur, Putrajaya, Cyberjaya and state capitals of Johor, Penang, Sabah, Sarawak. Selangor) within two years, approximately 77% coverage by 2024 and 90% coverage by 2027.

Alongside the 5G SWN model, the Malaysian Government also adopted a digital infrastructure plan (Jalinan Digital Negara or Jendela) which is aimed at addressing the arising needs and demand for better quality for fixed and mobile broadband coverage.[138] Jendela is a five-year plan (2021-2025) and the objectives for the first phase (up to 2022) include increasing 4G coverage from 91.8% to 96.9% in 2022, mobile broadband speed from 25 Mbps to 35 Mbps and switch-off 3G networks by the end of 2021.

Separately, in May 2021, the Minister of Communications and Multimedia issued an order to award 2×5 MHz of 900 MHz to Altel,[139] a MVNO which also holds some 2600 MHz spectrum. Spectrum in the 2600 MHz band is held by eight licensees was also renewed.[140] With the main 5G bands assigned to DNB, it is not clear at present if additional spectrum in other bands would be made available for MNOs to support their existing networks.

135 For example, Celcom claims that it had already upgraded its core network to be compatible with 5G capacities and had partnered with SIAE Microelettronica to upgrade wireless backhaul for both 4G and 5G; Maxis announced an agreement in October 2019 with Huawei which covered 5G network upgrades; Digi had already announced its partnership with ZTE in October 2020 to upgrade its radio network to be 5G ready.

136 https://www.mcmc.gov.my/en/media/press-releases/mcmc-s-oversight-of-digital-nasional-berhad-the-go

137 https://www.mcmc.gov.my/en/media/press-clippings/mcmc-holds-public-inquiry-to-review-access-list

138 For more information, see https://myjendela.my/

139 https://www.mcmc.gov.my/skmmgovmy/media/General/pdf/CMA-2021-1.pdf

140 https://www.mcmc.gov.my/skmmgovmy/media/General/pdf/CMA-2021-2.pdf

In **Bangladesh**, the regulator BTRC previously committed to 5G spectrum release by the end of 2021, with an aim for 5G services to be launched by 2023 and coverage in every region by 2026. The primary band for 5G is intended to be at 3500 MHz.

However the most recent focus of the regulator has been elsewhere; earlier this year, BTRC has completed an auction of left over spectrum in the 1800 MHz and 2100 MHz bands.[141] The regulator is looking to conduct the next round of auctions (in the 2300 MHz and 2600 MHz bands) in the second quarter of 2022; these will be awarded on a technology-neutral basis. We understand that operators are seeking to delay the timing of these auctions until there is greater clarity over demand for different mobile services, and until the bands can be cleared (and awarded on a contiguous lot basis). Only once these awards have been made is the regulator going to consider the 3500 MHz band.

The first 5G trial in Bangladesh was conducted[142] in July 2018 in Dhaka by local operator Robi Axiata. Following this trial, the BTRC required MNOs to provide presentations regarding 5G technology and in January 2019 the regulator announced[143] that it has started preparations for awarding 5G licences to operators in 2020. We understand that Teletalk has already been granted 60 MHz of spectrum to use for trials[144] on the condition that a 5G service is eventually launched; however this does not match the 100 MHz requested. These trials are due to commence in January 2022.

As less than 30% of registered devices in Bangladesh are LTE-enabled, there are concerns about the level of demand for 5G services. At first it is clear that operators will only look to launch 5G in dense urban areas; the recent auction for 1800 MHz and 2100 MHz spectrum is expected to increase capacity for LTE subscribers, and future awards of 2600 MHz spectrum may be used for 5G. Members of the industry have been quoted[145] as saying:

> **Currently, 4G is only available in the divisional cities, with fluctuating network quality and internet speed. Thinking about transitioning to 5G now would not be wise.**

141 https://www.commsupdate.com/articles/2021/03/15/btrc-auctions-additional-1800mhz-2100mhz-spectrum/
142 https://www.commsupdate.com/articles/2018/07/26/robi-huawei-demonstrate-speeds-of-4gbps-in-5g-trial/
143 https://www.commsupdate.com/articles/2019/01/17/btrc-starts-preparations-for-5g-licence-awards/
144 These trials are expected to commence in December 2021.
145 See https://www.dhakatribune.com/business/2021/01/21/mobile-operators-lukewarm-on-5g-after-btrc-s-guideline

This contrasts against data from GSMAi which suggested that LTE networks cover 95% of the country's population[146]; however, the lack of enabled devices will have a significant impact on take-up. The level of demand is not the only issue faced by operators considering their 5G strategies. Infrastructure costs could be significant, particularly since operators are not permitted to deploy certain infrastructure themselves – this is further hindered by a lack of a unified licencing framework.

Coupled with this high investment costs needed for 5G deployment, there is concern in the industry that the relatively high prices paid for spectrum in the March 2021 auctions will have left operators with little cashflow available for additional spectrum investment. This is particularly true when considering the multiple bands that may be auctioned over the next two years, and the potentially high spectrum fees that the regulator tends to impose. As well as the forthcoming 2300 MHz and 2600 MHz awards, spectrum in the 3500 MHz band, along with anything that is left unsold after the forthcoming auction, is expected to be auctioned in early 2023.

In **Sri Lanka,** 5G services are not yet commercially deployed, but all three operators have completed 5G demonstrations and trials in the past two years. In June 2019, Dialog Axiata completed trials[147] of 5G technology, using 3500 MHz spectrum allocated by the regulator for a pre-commercial trial of 5G services and it is reported that it had converted 20% of its LTE antennae for 5G by the end of 2019[148]. Mobitel completed trials in June 2019 achieving data speeds of 1.55 Gbps, and activated its first 5G base station at a retail outlet in March 2020 to demonstrate 5G capabilities to the public. Early this year, the CEO of SLT announced that the operator is preparing to launch a "pre-commercial" 5G service in mid-2021, ahead of the planned allocation of mobile spectrum. More recently, Hutchison Telecommunications Lanka (Hutch), has held its first 5G trial event, achieving a data transmission speed of 1.8 Gbps.

It is reported that during Hutch's demonstration event, the TRC Director General announced that 5G spectrum auction will be held by the end of the year – this was later delayed until the first half of 2022[149]. However, there are few other details available. It is widely expected that the spectrum that will be awarded will be in the 3500 MHz band, but no decisions appear to have been published regarding award mechanism, lot sizes, or fees, and operators have not been consulted on these.

The regulator, TRCSL, has taken steps to clear this spectrum but has not published progress updates. In addition, discussions are ongoing to release the 700 MHz spectrum to operators, but again no details have been published. The TRCSL did launch a consultation on its spectrum licensing framework in mid-2021 and submissions from industry members have been made.

There is certainly a desire within government to see connectivity improvements. In the November 2021 budget, the Minister of Finance stated that one of the government's aims was to "expand internet coverage and provide high-speed broadband with fibre optic, 5G, and other technologies"; the statement went on to state that spectrum for 5G would be awarded within the next year. However, this mention of spectrum awards was included when talking about taxation revenue generation, and the government and industry must be careful not to inefficiently allocate spectrum as a result of chasing higher auction revenues.

Vietnam was planning on launching commercial 5G services in 2020[150], despite the fact that 4G networks in the country only launched in early 2017. In June 2020, Vietnam's Prime Minister approved the National Digital Transformation Programme to 2025[151], with a vision towards 2030. The programme includes several tasks related to the development of digital technology networks, including 5G infrastructure.

Vietnam's Ministry of Information and Communications (MIC) announced in November 2020 the award of licences allowing the launch of pilot 5G networks to mobile operators including Viettel, MobiFone[152] and VNPT-Vinaphone[153]. All three operators were awarded non-commercial one-year 5G trial licences to test 5G with subscribers in Hanoi using spectrum in the 2600 MHz, 3500 MHz and 26 GHz bands. Plans were announced to fully award spectrum for 5G networks by the end of 2021, but so far these auctions have not been started. Since the release of spectrum for 5G trials means that the spectrum has had to be identified, cleared, and legislated for, the regulator now has only to define the final award mechanism, including prices and obligations.

Overall, it appears that the regulators in these countries have been working on awarding spectrum for 5G networks, particularly in the 3500 MHz bands. However, operators have not been given a clear indication of when or how this will be achieved – and, in the case of Malaysia – whether this will require a new structure for the industry. There is also a lack of clarity over the release of 700 MHz spectrum. Greater transparency and decisiveness is required.

146 See page 8 of https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2021/03/Achieving-mobile-enabled-digital-inclusion-in-Bangladesh.pdf
147 https://www.commsupdate.com/articles/2019/06/07/dialog-axiata-tests-5g-in-sri-lanka-achieves-speeds-of-1-4gbps/
148 https://www.globenewswire.com/news-release/2020/03/16/2001231/0/en/Sri-Lanka-The-market-is-now-preparing-to-move-from-4G-towards-5G-mobile-services.html
149 https://www.dailynews.lk/2021/03/18/business/244284/trc-commence-5g-spectrum-auction-year-end
150 https://www.commsupdate.com/articles/2018/11/21/vietnam-plans-to-test-5g-next-year/
151 https://english.mic.gov.vn/Pages/TinTuc/146875/5G-rules-to-assist-quality-control.html
152 https://www.commsupdate.com/articles/2020/11/03/viettel-mobifone-permitted-to-trial-5g-with-end-users/
153 https://www.commsupdate.com/articles/2020/11/19/vnpt-vinaphone-permitted-to-trial-5g-with-end-users/

4.7 Roadmap for Hong Kong

The regulator in **Hong Kong,** OFCA, has been proficient in awarding spectrum to mobile operators. It is one of the first regions to award spectrum in the mm-wave bands, with an award of 28 GHz spectrum in 2019 to three operators; it has previously awarded spectrum in almost all major bands as well as the 4800 MHz band. In September 2021 an auction for spectrum in 600 MHz (indoor-only), 700 MHz, 850 MHz, 2600 MHz and 4800 MHz bands was commenced, marking a large increase in sub-1 GHz spectrum availability. The certainty over spectrum availability has led to wide-scale 5G investment and availability.

In Hong Kong, a clear 5G spectrum roadmap has meant that operators are keen to invest and the availability of 5G is assured. Ongoing spectrum awards will provide a good platform for 5G growth. However, regulators need to continuously assess whether spectrum has been awarded in sufficient quantities and in the correct configuration.

5 Recommendations

In this section we identify a number of general recommendations based on the current status of spectrum award in the APAC countries and international best practice. In all cases, objectivity, transparency and accountability should be considered as key principles for spectrum allocation.

5.1 Existing spectrum

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

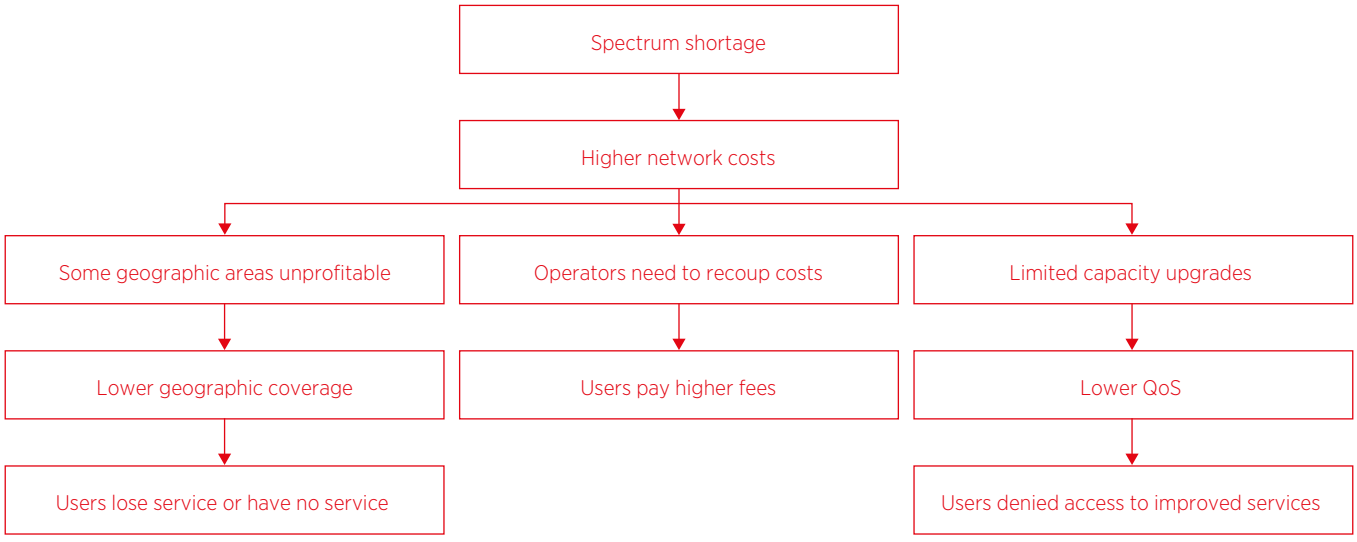
5.1.1 850, 900, 1800 and 2100 MHz

Depending on the configuration of the bands, there is generally up to 380 MHz of spectrum available in the 850 MHz, 900 MHz, 1800 MHz and 2100 MHz bands combined. 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 some countries in the APAC region. Some countries have a reasonable amount of legacy spectrum awarded, but many others, in particular in Cambodia, Bangladesh and Pakistan, have significantly less spectrum awarded. Given this, it is unsurprising that operators in these countries have asked for more spectrum for both new and legacy services. 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.

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



We recommend that those countries with limited spectrum already released should investigate the potential to release further spectrum in the existing frequency bands of 850, 900, 1800 and 2100 MHz, and the timescales for release and award. Depending on the configuration, there is potentially a total of 2×45 MHz available across the 850 MHz and 900 MHz bands[154], with 2×75 MHz at 1800 MHz and 2×70 MHz at 2100 MHz; a total of 380 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. Regulators must consider the demand for spectrum against its supply, to ensure that spectrum release is based on an efficient reflection of end user demand.

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 3500 MHz

The 700 MHz band and in particular the 3500 MHz range are the preferred frequencies for 5G and should be the main focus for award wherever feasible. The 3500 MHz range (3300 MHz – 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 3500 MHz varies by country. Many countries have focussed on an initial assignment of 3400 MHz to 3800 MHz, with some also awarding the 3300 MHz – 3400 MHz band, and others considering the wider band at 3800 MHz to 4200 MHz. 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, some of which have only recently been moved to these frequencies to clear the lower 3.5 GHz band. There may be a need for extensive refarming work to ensure that mobile operators have access to spectrum that does not suffer from interference, while maximising the bandwidth available – this may require narrow guard bands with improvements to VSAT equipment and filters, for example. Part of the regulator's work must be to ensure that legacy demands are balanced against the needs for 5G capacity in these key bands.

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154 Malaysia has achieved this with 2×10 MHz in the 850 MHz band, and 2×35 MHz in the 900 MHz band. However, this has led to a few synchronisation issues in border regions.

5.1.3 Configuration of 850 MHz alongside other sub-1 GHz spectrum

Within ITU Region 3, where APAC countries sit, there has traditionally been some use of the 850 MHz band for 2G services. As stated above, this has impacted in many cases on the way that the 900 MHz band could be configured; this also affects the availability of the 800 MHz band – and now the 700 MHz band.

The situation around 850 MHz in APAC is quite fragmented and progress has been slow due to incumbents and lack of consensus and harmonisation region-wide.

- CDMA: there are still a number of developing APAC countries which have CDMA800 technologies operating, although these should be declining and licences should be technology and service neutral to facilitate refarming, and so therefore this may not be a significant issue in the future.
- PPDR: the 800 MHz band has been identified for PPDR[155] and there are various technologies in use or being considered (TETRA, P25, LTE).
- Interference into 900 MHz: the use of this band plan means countries need a guard band of around 10 MHz, or allow interference to be self-managed (requiring the same operator in adjacent 850 MHz and 900 MHz frequencies).

This is not only a problem within a single country. Not all countries use 850 MHz spectrum (for example, Singapore has not awarded this band) but where neighbouring countries continue to run this band there will be interference into related spectrum in border areas. In addition, use of the 800 MHz band for PPDR (as described above) will have a further impact on the availability of spectrum.

In addition, a number of countries in the region have started to investigate use of the 600 MHz band for IMT services.

So that maximum use can be made of sub-1 GHz spectrum, it is crucial that countries liaise to configure all sub-1 GHz spectrum bands in a way that minimises interference and maximises efficiency. This will be particularly important as legacy networks become less used, so spectrum is desired for use on 5G technologies.

5.1.4 Other IMT bands

A number of other IMT bands, which have previously been awarded for use by 3G or LTE services, have increasingly been refarmed by operators for 5G networks where dedicated spectrum has not been made available. In particular, a number of countries have launched 5G services in the 2300 MHz or 2600 MHz bands, which are either being refarmed from other mobile technologies, or in some cases have been newly awarded.

This refarming, while allowing 5G roll-out earlier than would otherwise be possible, has a number of disadvantages. First, bandwidth is taken away from LTE services, where there may already be capacity constraints. Second, there is unlikely to be sufficient bandwidth to provide a full 5G experience, which may lead to an erosion of consumer confidence in the technology. Third, deployment outside the standard 5G bands leads to less equipment compatibility, which may be more expensive or have lower consumer benefit.

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. Indeed, Hong Kong has already awarded some spectrum in the 4.8 GHz band. The GSMA estimates[156] that by 2030, total mid-band spectrum demand for 5G services in cities will be, on average, 2 GHz– this is likely not achievable in the 3500 MHz band alone. Regulators across APAC 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.

155 See https://www.apt.int/sites/default/files/Upload-files/AWG/APT-AWG-REP-73Rev.1_APT_Report_PPDR_Spectrum_Harmonization.docx

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

5.2 Technology neutral licences

For any country that wants to offer the best possible mobile networks for its citizens, 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.

In the APAC region there have been some examples of regulators moving away from technology-neutral licencing, particularly where fundamental changes in the market structure are being imposed. In Malaysia, a single wholesale network will be given exclusive rights to run 5G services, meaning that existing licensees will not be allowed to use their spectrum for 5G technologies. In Cambodia, the regulator now requires notification and approval before new technologies can be used in existing spectrum bands. This move away from technology freedom will have an adverse impact on the efficiency of spectrum use by operators.

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 (such as 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 (such as 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 3500 MHz 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[157], 3300-3800 MHz 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. It is also crucial that operators in each country are consulted over the appropriate timing of spectrum release, since the demand for services will depend on LTE adoption and 5G device availability – it is crucial that operators are able to target investment in LTE upgrades and deployment where this is in higher demand. This is helped through the use of technology-neutral licences, where operators can choose to transition from LTE to 5G networks when the market demands them.

Some countries, particularly those where there is extensive use of C-band satellite services, have faced difficulties in releasing the 3300-3800 MHz band.[158] Potential alternatives to mid-band spectrum include the 2300 MHz and 2600 MHz bands,[159] 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.[160]

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 particular administrative 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).

157 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.

158 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/

159 The 2300 MHz and 2600 MHz bands have been earmarked for 5G in countries as China, Saudi Arabia and Thailand.

160 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/

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. In addition, regulators must make sure there is an attractive environment for innovative investment, meaning that they should ensure:

- Technology neutrality;
- Affordable spectrum fees, balancing administrative fees against reserve prices imposed on auctions;
- Unified licencing – allowing users to deploy different types of telecommunications network; and
- Simplified rights of way legislation.

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, 3500 MHz, 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 (3500 MHz) and Singapore (3500 MHz 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 A.1

KEY FEATURES OF DIFFERENT TYPES OF AWARDS[161]

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 to 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.

161 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 (such as 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).

However, it must be recognised that placing obligations on operators can lead to market distortions, and may lead to some spectrum investments becoming unprofitable. Any requirement or obligation must be carefully studied to understand potential impacts.

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.[162] 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. This should not be carried out on a long-term basis, however, as it would effectively generate an artificial market for spectrum with excess profits for the operator.
- **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, 2300 MHz, 1800 MHz) to support innovative use.163 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.[164]
- **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.[165]

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.

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

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

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

165 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.[166]

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[167]. 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[168]. 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 licences (for example, with a term of 25 years) with the expectation of renewal[169].

166 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

167 Source CRA Qatar and Decision on radio spectrum fees.

168 https://www.soumu.go.jp/main_content/000613734.pdf

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

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