5G Spectrum

GSMA Public Policy Position

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Executive Summary

5G supports significantly faster mobile broadband speeds and lower latencies than previous generations while also enabling the full potential of the Internet of Things. From connecting vehicles and transforming healthcare to building smart cities and providing fibre-over-the-air, 5G is at the heart of the future of communications. 5G is also essential for preserving the future of the most popular applications – like streaming video – by ensuring that growing usage can be sustained.

5G goes beyond meeting evolving consumer mobile demands by also delivering carefully designed capabilities that will transform industry vertical sectors. It introduces a new level of flexibility and agility so the network can deliver customisable services to meet the needs of a huge variety of users and connection types.

However, the success of the services is heavily reliant on national governments and regulators. The speed, reach and quality of 5G services depends on governments and regulators supporting timely access to the right amount and type of affordable spectrum, under the right conditions. There is already a significant variation in the amount of spectrum assigned, and the prices paid at auctions, which means the potential of 5G services will vary between countries. This, in turn, directly impacts the socio-economic benefits of 5G and the competitiveness of national economies.

This paper outlines the GSMA's key 5G spectrum positions, which focus on the areas where governments, regulators, and the mobile industry must cooperate to make 5G a success.

1. **5G needs significant new harmonised spectrum so clearing prime bands should be prioritised to meet market demand. Regulators should aim to:**
- **Award at least 80-100 MHz of contiguous spectrum per operator in initial 5G mid-bands (e.g. 3.5 GHz) and 800 MHz per operator in initial millimetre wave (mmWave) bands (e.g. 26/28 GHz).**
- **Plan timely significant further allocations and significant subsequent awards in both ranges to help 5G scale as needed. This should include more spectrum in the 3.5 GHz range (3.3-4.2 GHz), as well as 6 GHz and 40 GHz.**

2. **5G needs spectrum across low, mid and high spectrum bands to deliver widespread coverage and support a wide range of use cases. All three ranges have important roles to play:**
- **Low-bands (e.g. sub-1 GHz) support widespread coverage, including indoors, across urban, suburban and rural areas. Increased low-band capacity is required to create greater equality between urban and rural broadband connectivity and address the digital divide.**
- **Mid-bands typically offer a good mixture of coverage and capacity benefits. The majority of commercial 5G networks are relying on spectrum within the 3.3-3.8 GHz range. Other bands which may be assigned to, or refarmed by, operators for 5G include 1500 MHz, 1800 MHz, 2.1 GHz, 2.3 GHz and 2.6 GHz. More spectrum will be needed to maintain 5G quality of service and meet growing demand in the longer term (e.g. 3.3-4.2 GHz, 4.8 GHz and 6 GHz).**
- **High-bands support the ultra-high broadband speeds envisioned for 5G (e.g. 26/28/40/66-71 GHz).**

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 5G 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.).**

Background

What is 5G and how will it be deployed?

5G is defined in a set of standardised specifications that are agreed on by international bodies – most notably the 3GPP and the ITU. The ITU has defined criteria for IMT-2020 – commonly regarded as 5G – and selected a set of compatible technologies which will support the following use cases:

1. **Enhanced mobile broadband:** Including peak download speeds of at least 20 Gbps and a reliable 100 Mbps user experience data rate in dense urban areas.
2. **Ultra-reliable and low latency communications:** Including 1ms latency and very high availability, reliability and security to support services such as VR and connected vehicles.
3. **Massive machine-type communications:** Including the ability to support at least one million IoT connections per square km with long battery life and extensive wide-area coverage.
4. **Fixed Wireless Access (FWA):** Including the ability to offer fibre type speeds to homes and businesses in rural and urban areas in developed and developing markets.[1]

5G offers a far greater range of capabilities from the outset than any previous mobile technology generation. As a result, 5G not only meets the evolving requirements of consumers, but can also have a transformative impact on businesses to the extent that it is being hailed as vital to the so-called "fourth industrial revolution".[2] 5G is expected to underpin and enable many of the components of this revolution including the Internet of Things, cloud computing, cyber-physical systems and cognitive computing. From automated industrial manufacturing and autonomous cars to a vast array of connected machines and sensors, 5G enables smarter and more efficient businesses and industry vertical sectors (e.g. utilities, manufacturing, transport etc).

Advanced 5G features such as end-to-end network slicing and mobile edge computing help support the needs of industry vertical sectors. Network slicing allows services to be precisely tailored to the needs of an organisation in terms of required quality of service, speed, security, latency etc. Edge computing brings compute capabilities closer to consumers and enterprise end users which can enable very low latencies and customised local services.

5G will be delivered over wide areas through the public macro mobile network as well as via localised public and private small cells. Public and localised private 4G and 5G networks are already provided today by mobile operators but others can build such networks using unlicensed spectrum or by gaining access to licensed spectrum. However, the capabilities of all these services are dependent on the type and amount of the spectrum used. Some features like super-fast broadband and very low latencies cannot be provided in a single 5G band as their radio resource requirements are incompatible so can require multiple bands.

How much spectrum does 5G need?

The 3GPP's 5G New Radio (NR) specification includes traditional mobile bands as well as newer, wider bands designed for 5G. It supports channel bandwidths ranging from 5 MHz to 100 MHz for bands below 6 GHz, and channel sizes from 50 MHz to 400 MHz in bands above 24 GHz. The full capabilities are best realised through the widest channel sizes in new 5G bands. 5G supports carrier aggregation to enable very high speeds, however, making spectrum available in the largest contiguous blocks possible supports faster, lower latency and greener 5G services.[3] The ITU's minimum technical requirements to meet the IMT-2020 criteria1 – and thus the fastest speeds – specify at least 100 MHz of bandwidth per operator. They also specify support for up to 1 GHz per operator in bands above 6 GHz such as mmWave bands.[4]

Recent research shows significantly more spectrum will be needed to help 5G services scale in the 2025-2030 timeframe. For example, it has been estimated that an additional 1-2 GHz of mid-band 5G spectrum could be needed to help ensure mobile networks are capable of delivering the IMT-2020 target of 100 Mbps per user in densely populated urban areas and to support FWA more widely.[5] This is in addition to initial 5G mid-bands (e.g. 400 MHz in 3.3-3.8 GHz) and assumes other mid-bands formerly used for 2G, 3G and 4G services are upgraded to 5G.

1. Source: GSMA report: 'Fixed Wireless Access: Economic Potential and Best Practices' (2018)
2. The first industrial revolution is associated with the impact of steam power; the second is linked with science and mass production; and the third was driven by the emergence of digital technology and computing
3. These benefits accrue from large single contiguous blocks as opposed to the same total amount of spectrum that is aggregated using several separate channels. See vendor's input (entitled 'Need for contiguous 100 MHz per operator in the 3400-3800 MHz band') into ECC PT1 meeting #59. Available here: https://cept.org/Documents/ecc-pt1/45083/ecc-pt1-18-168_huawei_nokia-100mhz-contiguous-in-3400-3800-mhz
4. Millimetre wave 5G bands are generally regarded as being 24 GHz and upwards (e.g. 26/28/40 GHz)
5. See Coleago Consultings' 'IMT spectrum demand model in the 2025-2030 timeframe'. Available here: http://www.coleago.com/wp-content/uploads/2020/12/Demand-for-IMT-spectrum-Coleago-14-Dec-2020.pdf

What spectrum are regulators making available for 5G and how?
Regulators have assigned 5G spectrum in three broad ranges: high bands (e.g. mmWave) which support the fastest 5G speeds; mid bands (e.g. 1-10 GHz) which offer a good mixture of coverage and capacity; and low bands (e.g. below 1 GHz) which help provide strong wide area and in-building coverage. Most focus has been on the 3.5 GHz range (i.e. 3.3-3.8 GHz) to support initial 5G launches, followed by mmWave awards in the 26 GHz and 28 GHz bands. Europe has prioritised the 700 MHz band for wide area 5G and a growing number of countries globally are supporting the 600 MHz band[6] (including the US which already uses it for 5G).

Most regulators have continued to make spectrum available for 5G in conventional ways (i.e. by auctioning nationwide, exclusive 5G licences). However, some regulators have set-aside[7] a portion of spectrum in priority 5G bands (for example, a portion of the 3.5 GHz range) for local users (e.g. businesses) so they can build their own private 5G networks. The United States adopted a spectrum sharing framework in the 3.5 GHz range, known as the Citizens Broadband Radio Service (CBRS), to meet the needs of various different users including the military, service providers (e.g. mobile operators) and businesses.

5G set-asides have been controversial as there is a concern that the spectrum may go unused in many areas and means less spectrum is available for public 5G services. There is a striking variation in the amount of spectrum assigned to mobile operators for 5G around the world as a result of set-asides and the difficulty some regulators have had clearing bands for 5G. Many countries have struggled to assign the aforementioned targets in the first 5G mid-bands (e.g. awards range from 20-150 MHz per operator) and in the first mmWave bands (e.g. awards range from 200-800 MHz per operator). Reduced spectrum availability is also associated with higher prices being paid at auctions which is linked to worse coverage and slower rollouts and broadband speeds.

What is the impact of using TDD bands?
5G is also the first major rollout of Time Division Duplex (TDD) cellular networks in most countries. All 5G bands above 3 GHz – including the vital 3.5 GHz range and mmWave bands – will adopt TDD. This means 5G base stations and end-user devices transmit using the same channel at different times. This can create interference issues within and between different 5G networks. For example, higher power transmissions from base stations on one network can interfere with the ability of base stations on other networks to receive signals from lower power end-user devices.

Effective interference measures typically require that TDD networks operating in the same frequency range and within the same area are synchronised. Base stations using the same TDD band will need to transmit at the same fixed time periods, and all 4G and 5G devices need to transmit at different time periods. The chosen approach to synchronisation impacts the use cases that can be addressed in the band. For example, ultra low latency or uplink centric 5G applications can't be supported in the same band and area as very fast mobile broadband 5G applications. Mobile operators should be able to overcome this issue by making use of a variety of bands for 5G. Regulators need to consider this when deciding how to make spectrum available in 5G TDD bands and technical conditions for use.

What about spectrum for 5G backhaul?
The significantly improved performance of 5G also has a major impact on spectrum for mobile backhaul - the connection between 5G base stations and the mobile core. While fibre backhaul is ideal, wireless terrestrial backhaul still plays a vital role as fibre is not accessible or affordable at all sites. Terrestrial microwave backhaul is expected to account for at least 60 per cent of global mobile backhaul from 2021-2027.[8] However, 5G backhaul requires new wider spectrum bands from the outset, such as the 'E-band' (i.e. 70/80 GHz), and is likely to need additional new bands after 2025 (e.g. 92-114 GHz and 130-175 GHz). Traditional microwave bands (e.g. 6-42 GHz) will continue to play an important role as they can support longer distance backhaul links, however they have relatively narrow channel sizes so would better support 5G if they were made wider.

6. It should be noted that Asia Pacific may use a different 600 MHz band plan to the United States
7. The term 'set-aside' refers to a portion of spectrum that is held back from market-based awards (e.g. auctions) and assigned via other means (e.g. first come first served) and specific users are often prioritised
8. See ABI Research report 'Wireless Backhaul Evolution' (2021)

Positions

1. **5G needs significant new harmonised mobile spectrum so clearing prime bands should be prioritised to meet market demand. Regulators should aim to:**
   - Award at least 80-100 MHz of contiguous spectrum per operator in prime 5G mid-bands (e.g. 3.5 GHz) and 800 MHz per operator in initial mmW bands (e.g. 26/28 GHz) for 5G launches.
   - Plan timely significant further allocations and subsequent awards in both ranges to help 5G scale as needed. This should include more spectrum in the 3.5 GHz range (3.3-4.2 GHz), as well as 6 GHz and 40 GHz.

   A central component in the evolution of all mobile technology generations has been the use of increasingly wide frequency bands to support higher speeds and larger amounts of traffic. 5G is no different. Regulators should aim to get as close as possible to assigning at least 100 MHz per operator in the first 5G mid-bands and 800 MHz per operator in the first mmWave bands to support optimum 5G services. These targets have been met with Finland awarding 130 MHz to each operator in the 3.5 GHz range and 800 MHz per operator in the 26 GHz band.

   Regulators should also start planning additional spectrum assignments to help 5G services scale following initial launches. It is vital that operators have the capability to deliver on the potential of 5G - including the ambitious targets of user experienced data rates of 100 Mbps and area traffic capacity of 10Mbit/s/m^2 (for machines) as well as peak data rates of 20 Gbps. Such capabilities will require significant amounts of spectrum over the 5G era, especially as adoption scales, so regulators should plan additional allocations and awards in new mid-bands (e.g. 3.3-4.2 GHz, 4.9 GHz and 6 GHz), mmWave bands (e.g. 40 GHz) as well as low bands for wide area coverage, including indoors, and for IoT (e.g. 600 MHz).

Where 5G spectrum is held back from the market (e.g. through set-asides) then commercial 5G services are likely to suffer and operators may overpay at auctions which risks limiting network investment thus harming consumers.[9] However, although maximising the amount of spectrum released in a 5G band is encouraged, individual lot sizes at auction should be small enough to maximise flexibility. In 5G mid-bands, equal lot sizes of around 10 MHz[10] each are sensible so bidders can aggregate them to meet their needs, while in the millimeter wave bands block sizes of around 100-200 MHz are suitable. Mismatched lot sizes can create artificial scarcity which risks inflating spectrum prices and operators failing to secure their desired amount of spectrum.

In many countries, there are incumbent users in priority 5G bands so meeting the aforementioned targets can be challenging. It is essential that regulators make every effort to make this spectrum available for 5G use – especially in the 3.5 GHz range (3.3-3.8 GHz). This can include:

- Providing incentives for incumbents to migrate ahead of awarding the spectrum;
- Moving incumbents to alternative bands or within a single portion of the range; and
- Allowing incumbents to trade their licences with mobile operators.

Countries that assign spectrum in one range using multiple phases need to take extra care. The reason for doing this can be to gradually migrate incumbents (e.g. assigning 3.4-3.6 GHz then 3.6-3.8 GHz), or when incumbent licensees are part of the band. To succeed, the process should involve re-planning the band afterwards to allow operators to create larger contiguous blocks. Long-term 5G roadmaps should be developed in consultation with stakeholders as soon as possible so operators understand how much spectrum will be made available by when, and what will happen to incumbents. The latter helps inform spectrum trading decisions.

9. See position 6
10. Much larger block sizes (e.g. 50-100 MHz) would generally only suit mmW bands (e.g. 26/28/40 GHz)

2. **5G needs spectrum across low, mid and high spectrum bands to deliver widespread coverage and support a wide range of use cases. All three have important roles to play:** Increased low-band (i.e. <1 GHz) capacity will be required to create greater equality between urban and rural broadband connectivity thus reducing the digital divide. It will also improve in-building 5G services everywhere and help support the growth of IoT. A portion of UHF television spectrum should be made available in the near-term for this purpose through the second digital dividend.[11] The European Commission supports the use of the 700 MHz band for 5G services[12] and in the United States T-Mobile is using the 600 MHz band for 5G across the country. There is also a longer term need to support additional lower frequency bands, and this is already being considered by governments in Europe, the Middle East and Africa at the World Radiocommunication Conference in 2023 (WRC-23).

   Mid-bands typically offer a good mixture of coverage and capacity for 5G services. It is vital that regulators assign as much contiguous spectrum as possible in the 3.5 GHz range (3.3 GHz-4.2 GHz). The 2.3 GHz and 2.6 GHz bands should also be licensed to operators for 5G use. All existing and new licences should be technology neutral to allow their evolution to 5G services. In the long term, more spectrum will be needed to maintain 5G quality of service and growing demand, in bands between 3 and 24 GHz. This includes more spectrum in the 3.5 GHz, 4.8 GHz, 6 GHz and 10 GHz ranges which will all be considered at WRC-23.

   High-bands are needed for 5G services such as ultra-high-speed mobile broadband. 5G will not be able to deliver the fastest data speeds without these bands. It is important that governments award spectrum that has been globally identified for IMT (e.g. 26 GHz and 40 GHz) and additionally make the 28 GHz band available where possible. The 26 GHz and 28 GHz bands have especially strong momentum and, as they are adjacent and well harmonised, can be supported quickly by a wide range of affordable devices and with reduced complexity. Spectrum roadmaps should also include plans to make the 66-71 GHz band available to encourage timely equipment support.

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.** It is vital that 5G services are able to scale as adoption grows following initial launches. Research has shown that this is likely to require significant additional spectrum in urban areas as well as more widely across countries to support use cases such as Fixed Wireless Access and IoT. A key focus will be on additional mid and low 5G bands which are a key part of the agenda at WRC-23. Numerous countries are already starting to make long term decisions around some of these bands (e.g. 6 GHz). Importantly, these decisions should be informed by the WRC-23 considerations and efforts to harmonise 5G bands internationally to support affordable equipment, enable roaming and minimize cross-border interference.

   WRC-23 is considering additional 5G spectrum in the 3.5 GHz range, 4.8 GHz, 6 GHz, and 10 GHz as well as within 470-960 MHz. Potential new 5G spectrum in these bands will have a central role to play in ensuring 5G reaches all users and can address key use cases. Additional spectrum below 1 GHz help support 5G in rural areas, deep inside buildings as well as accelerate IoT growth. New mid-bands (the 3.5 GHz range, 4.8 GHz, 6 GHz and 10 GHz) are already starting to be considered for 5G and in some cases decisions have already been made.[13]

   A key current focus in numerous developed telecom markets is the 6 GHz band (5925-7125 MHz) which is being considered for licensed 5G as well as a new unlicensed band (e.g. for Wi-Fi, unlicensed 5G etc.). A new licensed 5G band within 6 GHz will be important to help 5G networks scale as adoption rises. It is recommended that at least 6425-7125 GHz is made available for licensed 5G – some countries are already planning to make the whole 6 GHz band available (e.g. China). The unique benefits of this range – including a mixture of coverage and capacity - cannot be replaced with mmWave or coverage bands. Unlicensed spectrum plays an important role for Wi-Fi, including for mobile network offload, as well as for other services. However, this should be balanced against the need for additional licensed 5G spectrum. There should be scope to meet the needs of both.

11. The second digital dividend is the 700 MHz band in Europe, the Middle East and Africa and the 600 MHz band in the Americas and Asia-Pacific
12. 'European Commission stakes out 700 MHz band for 5G' – Telecom TV (2016)
13. For example, the US has decided to make the entire 6 GHz band (5925-7125 MHz) unlicensed while China has decided to license the entire band for 5G.

Additionally, regulators need to consider the needs of incumbents in the 6 GHz band and how coexistence should be managed. Fixed links within this range play an important role for mobile broadband backhaul in many countries and few other bands share its unique benefits, especially for addressing rural backhaul. Co-existence studies are needed – including at WRC-23 – and solutions must be found to avoid harmful interference and provide quality of service assurances to fixed-link services. Decisions should not be rushed, especially when creating a new unlicensed band, as it is very difficult to make future changes later. Also, the creation of a new unlicensed band needs enforcement procedures in place to prevent the sale and use of unlicensed devices which do not meet national regulations.

4. **Exclusively licensed spectrum over wide geographic areas is vital to the success of 5G.**
Licensed spectrum is essential to guarantee the necessary long-term heavy network investment needed for 5G and to deliver high quality of service. The risks surrounding network investment are significantly increased without the assurances of long-term, reliable, predictable, spectrum access. Licensed spectrum, which enables wider coverage areas and better quality of service guarantees, has been central to the major global success of mobile services.

5G services benefit from significant amounts of exclusively licensed spectrum that cover entire countries. Nationwide mobile spectrum licences[14] continue to be important, including in mid-bands and millimeter wave bands, to address a diverse set of use cases. These range from addressing high capacity needs in hotspots, fixed wireless access in cities, suburban areas and rural towns as well as other locations with high densities of usage which can be in a wide variety of areas (e.g. factories, business parks, train stations etc.). There is also scope for 5G access bands to be used for backhaul in various locations. Regulators can adopt licence conditions and obligations to incentivise operators either to use their spectrum or make it available to others where it will not be used or will not be used in a reasonable timeframe (see 'use it or lose/lease it' in position 8).

Based on national circumstances, other licensing approaches could be explored with the mobile industry in mmW frequency bands, including exclusive wide area licences in high demand areas (e.g. city centres) with local licensing used elsewhere, or even local licensing in all areas. However, it should be noted that such approaches are significantly more burdensome for regulators to manage, including ensuring the many potential assignments are fair, hoarding/under-use is monitored and avoided and interference issues managed.

Local licensing can also complicate operator deployments as access to sufficient amounts of spectrum is less predictable and the approach may present constraints on use (e.g. power limitations) to avoid interfering with neighbouring licensees.

5. **Spectrum sharing and unlicensed spectrum can play a complementary role.**
Spectrum sharing frameworks can play a complementary role but must be carefully designed to avoid undermining the potential of 5G.[15] Regulators should permit operators to voluntarily share spectrum with each other to help support ultra-fast 5G services, more efficient spectrum usage and to extend the benefits of network sharing arrangements. Club licensing can also offer these benefits and is especially attractive in situations when spectrum is scarce by allowing operators to access wider channels than would otherwise be possible. Club licences allow licensees in a band to access one another's spectrum where it is unused and/or pool spectrum in shared networks (e.g. in shopping centres etc.).

However, club licensing is a new model and therefore needs careful management to accurately establish accessibility and prevent interference (e.g. databases) etc. It also needs to be clear at the outset who has access to the licences, under what terms and how to manage disagreements. It should also be noted that although it can mitigate spectrum scarcity issues, it cannot overcome them. If there is insufficient total spectrum available to meet demand in an area then services are likely to suffer.

Sharing frameworks should include permitting operators to voluntarily sublease their spectrum to other types of operators, such as enterprises or wireless internet service providers, which want to build their own networks. This approach helps maximise the benefits of exclusively licensed spectrum while also ensuring it is efficiently used and available to meet the needs of other potential users.

However, other approaches which undermine mobile operators' certainty of access to spectrum, such as mandating that existing licensed spectrum is shared in ways that create an uncertain business environment, risk jeopardising planned long-term, wide area 5G network investment. Also, sharing may not always be possible due to several reasons including planned coverage improvements, including those required by licence obligations, or due to the risk of interference in nearby areas.

15. GSMAi (2018) 'Spectrum pricing in Developing Countries' & NERA (2017) 'Effective Spectrum Pricing'

Sharing can also play a role where clearing a band is not feasible by opening up access to new spectrum for 5G in areas where it is under-used by current incumbent users. Still, prospective bands for sharing must be harmonised and available in the right amounts, in the right areas and at the right times to support 5G. To justify widespread heavy network investments, mobile operators need certainty of access to significant amounts of licensed spectrum for a sufficient duration (e.g. 20-year licences).

More complex, three-tier sharing regimes with set-aside spectrum for General Authorised Access[16] may limit, or eliminate, the potential for 5G services in the band. For example, the CBRS approach in the United States is unlikely to support very high-speed 5G services, as there is only a limited amount of spectrum available to operators through Priority Access Licences (PALs). Sharing models can also make it difficult to coordinate 5G networks to avoid interference as synchronising many different 5G networks that are used for different purposes can be challenging as their configurations may be incompatible.

Unlicensed spectrum is also likely to play a complementary role in the delivery of 5G services and is available across a range of different spectrum bands.[17] Firstly, this allows any organisation to roll out 5G networks without needing to apply for a spectrum licence, especially for use locally indoors. Regulators should take this into consideration when considering the needs of local private 5G networks.[18] Secondly it can help operators to augment the 5G user experience by aggregating licensed and unlicensed bands to support faster services.

6. **Setting spectrum aside for local or vertical usage in priority 5G 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.**

Spectrum that is set-aside[19] for local usage including by vertical industries in priority 5G bands (i.e. 3.5/26/28 GHz) poses several threats to the wider success of 5G. Set-asides can limit the assignment of sufficiently large contiguous blocks to allow mobile operators to deliver the fastest 5G services. They can also undermine fair access to spectrum by providing certain users with privileged access instead of participating in competitive awards. Set-asides also create artificial scarcity which risks inflating spectrum prices which is linked to slower rollouts, worse coverage and slower speeds.

Regulators should especially avoid set-asides where it will mean they cannot meet the aim of making available 80-100 MHz per operator in priority mid-bands (e.g. 3.5 GHz) and 800 MHz in mmWaves (e.g. 26 or 28 GHz).[20] Even if regulators can meet these targets in the near-term, they should be mindful that further mid-band and millimeter wave spectrum is likely to be needed for public 5G services over a longer timeframe (e.g. 2025-2030) as usage scales.

More widely, set-asides for restricted use cases can lead to inefficient spectrum usage. For example, vertical industries are unlikely to use spectrum in priority 5G bands very widely across any country, so national set-asides are likely to go unused in many areas. Instead, mobile operators can provide customised 5G services for verticals that can then benefit from network slicing, small cells, and wider geographical coverage. Mobile operators' larger and more diverse spectrum assets and deployment experience also provides powerful benefits for verticals. Given the high risk that set-aside spectrum may go unused in many areas, it is sensible for regulators to enable it to be made available through market mechanisms after a reasonable period should this prove to be the case (e.g. a sunset clause).

A comprehensive cost-benefit analysis should be conducted to justify that a set-aside approach would deliver a better socioeconomic outcome for a country compared with a fully market based award. If a set-aside is chosen then regulators should take care to minimise the harms to public 5G services and the consumers and businesses who rely on them (please see the GSMA paper 'Mobile Networks for Industry Verticals: Spectrum Best Practice' for more information).

Voluntary spectrum sharing approaches are typically preferable to set-asides. They avoid limiting the availability of spectrum for public 5G services and can be used to support all potential 5G users, including verticals. For example, MNOs can be permitted to lease their spectrum assets so that verticals can build their own private 5G networks should they wish. In Finland, the regulator instead created an obligation on mobile operator licensees in the 3.5 GHz range to sub-lease their spectrum to verticals where they were not able to provide suitable services. Mobile operators are sharing their spectrum with other users in a growing number of countries, including in Sweden where spectrum has been sub-leased to a specialist vertical micro-operator.[21]

16. This refers to a portion of the CBRS band that is similar to licence-exempt spectrum but that may require registration on a spectrum access system database
17. This includes the existing 2.4 GHz and 5 GHz unlicensed bands. Regulators are also considering making significant additional other unlicensed spectrum available (e.g. parts of 6 GHz and 66-71 GHz).
18. Unlicensed spectrum is already used to support private 4G networks
19. A set aside is defined here as a portion of spectrum in a harmonised mobile band that is treated differently to the remainder of the band which is treated more conventionally by being awarded through a well-established competitive process such as an auction.
20. Finland is notable for having been able to assign 800 MHz for each of the three mobile operator in the 26 GHz band while also having a local set-aside. However this may not be possible in many countries as there may be four operators and they may struggle to clear as much of the band for 5G use
21. 'Three Sweden leases public spectrum for private usage' May 28, 2019

Mixing industrial and commercial networks in a band through set-asides also presents technical deployment challenges. If not addressed, they could result in harmful interference or limit the 5G services that can be supported. For example, all 5G networks in a band are likely to need to be synchronised which means very high-speed public broadband networks could not co-exist with very low-latency or uplink-centric industrial networks in the same area unless multiple bands are used. At the very least, the users of vertical set-asides need to coordinate with 5G commercial networks to mitigate interference. Existing studies show that a separation distance of 14km would be needed between unsynchronised 5G mid-band networks in adjacent spectrum, and 60km for networks in the same spectrum (i.e. co-channel).[22] In practice, this would create serious restrictions on where 5G deployments can happen and which use cases can be supported.

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.**
Governments and regulators should assign 5G spectrum to support their digital connectivity goals rather than as a means of maximising state revenues. Effective spectrum pricing policies are vital to support better quality and more affordable 5G services. High spectrum prices are linked to more expensive, slower mobile broadband services with worse coverage.[23] The causes of very high prices are typically policy decisions that appear to prioritise maximising short-term state revenues over long-term socio-economic benefits. To avoid this, governments and regulators should:
    - Set modest reserve prices and annual fees, and rely on the market to determine spectrum prices
    - Avoid limiting the supply of 5G spectrum as scarcity can lead to excessive prices. A particular concern is set-asides for local use/verticals or new entrants in core 5G bands (i.e. 3.5 GHz and 26/28 GHz)
    - Carefully consider the auction design[24] to avoid unnecessary risks for bidders (e.g. avoiding mismatched lot sizes, which create artificial scarcity, and first-price, sealed bid auctions)
    - Develop and publish a 5G spectrum roadmap with the input of stakeholders to help operators plan effectively around future availability
    - Consult stakeholders on the award rules and licence terms and conditions, and also take them into account when setting prices (i.e. onerous obligations reduce the value of spectrum)

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.**
The move to 5G requires significant increases in backhaul capacity so regulators should plan appropriately and consult industry.[25] While fibre has an important role to play, it is essential that regulators plan to make available newer higher frequency bands which can support wider channels and have a greater total amount of spectrum available. In the near-term, the E-band (70/80 GHz) will be most important, especially to support initial 5G growth, but the W-band (92-114 GHz) and D-band (130-175 GHz) will be vital to scale capacity in subsequent years.

    Traditional microwave backhaul bands continue to have an important role to play in the 5G era especially as they can cover longer distances with fewer hops than newer higher frequency bands (e.g. E-band). They are vital in many suburban and rural areas, where less capacity is typically needed, as well as to provide added resiliency for higher frequency backhaul bands. Regulators need to ensure they make significant amounts of spectrum available in these bands, and in sufficiently wide channel sizes (e.g. 56 MHz-250 MHz channels) to address various backhaul scenarios. They also need to carefully consider interest in these bands from alternative use cases – including 5G access and unlicensed Wi-Fi (see position 3).

    Regulators should also review their backhaul licensing approaches including whether the pricing methodology is suitable for the 5G era. There are a variety of licensing approaches for licensing backhaul bands, especially with the emergence of higher frequency bands and dense small cell networks. Regulators should carefully consider their options to ensure they are encouraging spectrum efficiency, facilitating rapid deployments and ensuring the process can be efficiently managed by all parties. For example, block licensing could play a greater role in new higher frequency backhaul bands. Supporting longer licence durations and encouraging spectrum trading can also encourage heavier backhaul network investment and more efficient spectrum use.

22. See ECC REP 296 which considers separation distances between unsynchronised 5G macro networks
23. See various GSMA studies here - https://www.gsma.com/spectrum/resources/effective-spectrum-pricing/
24. See the GSMA's 'Auction best practice' position paper (2019)
25. For more information on backhaul please see the GSMA's 'Spectrum for mobile backhaul' position paper

The price that operators pay for backhaul varies significantly around the world. A recent study found that the highest spectrum prices in some markets were are 22 times higher than the global median and 59 times higher than the lowest priced markets. This places a significant financial burden on operators making it more difficult to afford to quickly rollout 5G, especially outside urban centres. The formulas used to calculate prices are often designed for legacy narrow backhaul channel sizes, which means costs quickly become unsustainable for newer wider channels. It is essential that regulators ensure formulas contain components that mitigate such price jumps. Some pricing approaches also penalise operators for adopting newer and more spectrum efficient backhaul technologies. These too should be avoided, as they discourage network upgrades.

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**

The decisions regulators make around spectrum licensing – including geographic licence areas and terms, conditions and obligations – as well as the mechanism for awarding the licences will have a major impact on 5G services. It is essential that regulators carefully consider these decisions and consult the industry to ensure the best possible 5G services can be delivered.

5G has a wide variety of applications and benefits from very large bandwidths so there is expected to be significant spectrum demand from service providers. As a result, competitive spectrum awards – especially auctions – continue to have an important role to play in 5G spectrum awards including for mmW assignments.[26] Auctions remain the fairest way to assign spectrum where demand is high (e.g. national licences or local licences in high-demand areas). Auctions may not be suitable in situations where demand is lower such as local licences where there are fewer people/businesses or where there are unavoidable limitations on how the spectrum can be used (e.g. low power/indoor only). Auctions are also typically inappropriate when licences are due for renewal as the focus should be on providing predictability for licensees in order to encourage ongoing network investment,

Licence terms, conditions and obligations should be used very carefully to augment investment in rollouts, minimise the cost of covering non-profitable areas, and avoid distorting the award of spectrum. Coverage obligations are not suitable for most 5G bands (e.g. mmW and mid-bands) as they are designed for delivering high capacity rather than coverage. There are a variety of other, more innovative regulatory approaches to improving coverage that regulators are encouraged to adopt.[27] Similarly, rollout obligations should be used with caution as they can distort the most efficient and effective 5G rollout strategy. In general, market competition remains the best way to protect consumer interests. All obligations should be factored into the price of spectrum licences as they have a significant impact on their value and the costs associated with acquiring them.

Given the use of relatively high frequency bands for 5G (e.g. mmWave and mid-bands such as 3.5 GHz) there will be areas with low population densities where deployments are high risk, impractical or not economically viable. It will also take time for licensees to achieve their full 5G rollout plans. Regulators may therefore want to adopt obligations to prevent under-use or spectrum hoarding. For example, if a local licensee – such as a mobile operator or an enterprise vertical - does not use its spectrum in a reasonable period of time then the unused spectrum should be made available to others who do have immediate plans (e.g. "use it or lose it" obligations). Similarly, if a national licensee is not using its spectrum in a particular area in a reasonable period of time then it could be sub-leased to others (e.g. "use it or lease it" obligations). However, such obligations should not undermine realistic planned future usage which can take time to achieve. They should also enable the licensee to be compensated appropriately for reasonable costs they may have incurred (e.g. spectrum costs).

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.).**

5G network deployments require significant network investment. The speed of rollouts, quality of service and coverage levels will all be compromised without sufficient investment. Governments and regulators can encourage high levels of investment by adopting important spectrum policies including:

- Supporting exclusive, long-term, wide area 5G mobile licences with a predictable renewal process (e.g. nationwide licences with a duration of at least 20 years)
- Producing a national broadband plan including 5G which details activities and timeframes
- Publishing a 5G spectrum roadmap
- Ensuring all mobile licences are technology neutral to speed up wide area 5G rollouts and encourage improved spectrum efficiency

26. For more information see the GSMA's public position on auction best practice (available here https://www.gsma.com/spectrum/wp-content/uploads/2019/05/Auction-Best-Practice.pdf)
27. See GSMA position paper on improving mobile coverage (available here: https://cp.gsma.com/expanding-mobile-coverage/)

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