Mobile Networks for Industry Verticals: Spectrum Best Practice

GSMA Public Policy Position

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Executive Summary

The development of new mobile technologies alongside the cloud, big data and machine learning are transforming how vertical industries can operate. These range from creating smart utility grids and automating manufacturing, to delivering goods by drones and supporting advanced public safety and transport networks. Policymakers play a vital role by managing the spectrum which underpins these developments. However, great care needs to be taken to ensure verticals are fully supported without harming other wireless users – especially the consumers and businesses who rely on 4G and 5G.

Verticals' are defined here as companies, industries and public sector organisations operating in a specific sector. They have traditionally deployed private networks to support their connectivity needs. However, this is changing as the requirements of verticals evolve to include more advanced capabilities - ranging from IoT to high-speed broadband. As a result, they are increasingly looking to partner with telecom providers - including public mobile operators, using licensed spectrum. This allows them to benefit from telecom operators' more extensive networks, more substantial spectrum assets, expertise and, typically, the operators' lower cost base.

However, some verticals may continue to operate their private networks and thus may desire access to additional spectrum to support advanced broadband capabilities. This represents a challenge for policymakers as widespread demands for additional spectrum outweigh supply. It is also difficult given some verticals may want direct access to spectrum in priority 4G and 5G mobile bands (e.g. 700 MHz and 3.5 GHz) so they can benefit from the mobile equipment ecosystem and thus lower deployment costs.

It is vital that policy makers support the needs of verticals by ensuring they can get the connectivity they need to support their use cases. This paper outlines the mobile industry's positions on effectively meeting the needs of verticals without undermining other spectrum users and upholding fair and efficient assignment of mobile bands. A core concern is the use of dedicated set-asides for verticals as this poses significant risks to wider mobile services, most notably slower 5G networks and reduced coverage. The GSMA proposes alternative options to support verticals - including other ways to provide access to spectrum for these networks.

1. **Commercial mobile operators support the needs of a wide variety of vertical sectors and will have added capabilities with 5G**
2. **Spectrum leasing or, when carefully planned, other types of spectrum sharing can be viable options for supporting verticals who want to build private networks**
3. **Spectrum that is set-aside exclusively for verticals in core mobile bands risks being underused and can undermine fair spectrum awards**
4. **Spectrum that is set-aside for verticals in core mobile bands can also threaten the wider success of 5G – including slower rollouts, worse performance and reduced coverage**
5. **Policymakers should consider the coexistence challenges when different use cases need to be supported in the same mobile band**
6. **Unlicensed spectrum is likely to play an important role for numerous verticals**
7. **Policymakers should carefully consider their options and consult stakeholders to ensure they most efficiently support the needs of verticals without undermining other spectrum users**

Background

Vertical industries have long relied on various wireless technologies and spectrum bands to support their connectivity needs. For example, Private Mobile Radio (PMR) networks using specific spectrum have been used to support voice communications on construction sites, to connect taxis and for private security. Public safety networks[1] used by the emergency services often have dedicated wireless technologies (e.g. TETRA) in their own spectrum band. Public transport often relies on private mobile networks which also operate in different frequency bands[2].

Evolving vertical requirements

However, the requirements of vertical networks are evolving – most notably from voice to high-speed data. Some verticals want networks that support low power wide area IoT for connecting smart meters and sensors, while others want networks that support very low latencies for advanced manufacturing including robotics. The importance of connectivity has created pressures for wide area coverage (e.g. utilities) and/or highly localised connectivity (e.g. manufacturing plants) as well as high levels of reliability including for safety of life applications (e.g. emergency services, hospitals, etc).

Given the needs of different verticals often overlap, there have been efforts to categorise complementary scenarios. This makes it possible to assess the verticals' network and spectrum requirements. At the most simplistic level, there are two scenarios:

Scenario	Select sample use cases	Spectrum
Local area connectivity	Broadband PMR to serve hotspot locations like factories, offices and shopping malls as well as slightly wider areas such as parts of cities and whole towns for some public transport applications like buses and radios for taxis	Capacity bands (>1 GHz) - especially for high-speeds
Wide area connectivity	Public safety networks, utilities and railway connectivity that require very wide area, even nationwide, coverage	Coverage bands (<1 GHz)

These can be further sub-divided into more specific network requirements – several of which may apply to any single vertical. Most notably, services requiring very low latencies, broadband uploads and broadband downloads might have to be placed in different bands as their radio resource requirements can be incompatible.

Vertical need	Sample use cases	Spectrum/network requirements
High-speed broadband	Heavy data use potentially including security video	Wide channel sizes, potentially dense small cell networks, appropriate frame structure Upload intensive applications like security video typically need a different frame structure to high speed download applications
Low power wide area (LPWA)	Connected meters and sensors used by utilities	Wide coverage (i.e. <1GHz) and specialist LPWA technology (e.g. NB-IoT, LoRa, etc)
Ultra-low latency	Remote-controlled robotics in manufacturing	Low latency friendly TDD band frame structure and/or an FDD band
High resiliency	Public safety networks which need to be highly reliable	Wide coverage (i.e. <1GHz), resilience to disasters and prioritised traffic
High security	Financial and identity industries	Advanced encryption and/ or isolated network (i.e. not shared with others)

1. Often known as Public Protection and Disaster Relief (PPDR) systems
2. GSM-R is used by the railways in many countries

Meeting evolving vertical requirements

These evolving requirements have made it challenging for verticals to continue building and maintaining their own dedicated private networks. The move from voice to high speed data means much wider channel bandwidths are needed[3], which are difficult to secure - and the need to support diverse use cases can require access to spectrum in multiple bands. New dedicated network equipment and devices can be difficult to afford, rollout, maintain and regularly upgrade. As a result, many verticals that previously used dedicated private networks have started to outsource their network building and operation to third party providers.

Public mobile operators have long supported some of the needs of vertical sectors in their licensed spectrum and this has increased with more modern technologies. Small cells can provide targeted and hotspot coverage while LPWA cellular IoT can support vast numbers of smart meters and sensors. Virtual 'network slices' can provide tailored connections for verticals – rather than one general-purpose connection (see appendix A). For example, one slice can support low latency connections, another for highly secure connections, another for extremely fast connections, etc.

Other network providers are also supporting vertical industries using unlicensed spectrum. Some industry verticals are employing Unlicensed Low Power IoT technologies and providers (e.g. SigFox and LoRa) for applications such as smart metering communications. Private local 4G networks operating exclusively in the unlicensed spectrum are being used to support localised indoor connectivity (e.g. in warehouses). Given the radio environment inside warehouses and factories is controllable, the interference risks from using the shared band can be minimised. Therefore, between public mobile operators and these other providers, there is a vibrant competitive marketplace supporting vertical sectors.

Historically, there were opinions that verticals must have their own dedicated, isolated private networks to meet the highest standards – especially mission-critical networks for the emergency services, utilities and public transport. However, studies carried out for bodies like the European Commission show commercial networks can fulfil this role when designed to meet vertical needs[4]. Today, several countries have started outsourcing these networks to third party providers[5]. Research shows most verticals do not need dedicated, isolated networks and can make use of appropriately designed public networks[6]. Furthermore, mobile operators are also able to build fully isolated private networks using small cells.

Some verticals may want to continue to operate their private networks using dedicated spectrum or to build private networks for the first time. Given the broadband requirements of many of these networks, they will need larger amounts of spectrum than has traditionally been available to them. In some circumstances, they will choose to make use of the growing amount of unlicensed spectrum. However, some verticals are asking governments and policymakers to set-aside licensed spectrum to meet their needs.

The regulatory options

The central challenge is that policymakers are already struggling to make the limited supply of radio spectrum meet rising demand. There are a large number of verticals and giving them all new dedicated spectrum is simply not feasible. Some verticals are requesting special access to spectrum in widely harmonised mobile bands[7] so they can benefit from the mobile industry's economies of scale and equipment choice. This includes proposals to set aside a portion of spectrum in core 5G bands (e.g. 3.5 GHz) which would thus be removed from use for commercial public 5G services. This is unusual as policymakers typically avoid such special dispensations in mobile bands unless there is clear evidence of a market failure.

There are several approaches being considered by policymakers. These include:

1. **Continue to make spectrum available for verticals outside of core mobile bands[8]**
2. **Assign mobile spectrum as usual and, where needed, create licence terms and conditions that facilitate meeting the needs of verticals (e.g. to allow and encourage sub-leasing spectrum to verticals)[9]**
3. **Set-aside dedicated spectrum for verticals in core mobile bands[10]**
4. **Use local licensing and/or spectrum sharing to support the needs of all sorts of users including verticals[11]**

3. PMR channels were traditionally used for voice so often used paired 12.5 KHz channels. The need to support broadband data necessitates significantly wider channels (see - https://cept.org/ecc/topics/private-professional-land-mobile-radio)
4. See 'Is Commercial Cellular Suitable for Mission Critical Broadband?'
5. Public safety networks in the UK and the US are switching to using customised commercial mobile networks
6. See GSMA report 'Network Slicing Use Case Requirements' (April 2018)
7. Specifically so called "IMT" bands
8. Core mobile bands may be regarded as widely harmonised bands that have been fully cleared for mobile use without special usage restrictions (e.g. without reduced power emission levels or indoor-only restrictions). These can vary around the world. Some regulators are choosing to use the duplex gap in core mobile bands for verticals (e.g. in 700 MHz for public safety networks) to minimise the negative impact on commercial mobile services.
9. Finland adopted this approach in the 3.5 GHz band after initially considering set-asides
10. This approach was adopted in Germany in the 3.5 GHz band
11. This approach was adopted in the United States in the 3.5 GHz band through CBRS

Positions

1. **Commercial mobile operators support the needs of a wide variety of vertical sectors and have added capabilities with 5G**
   Mobile operators have the experience and the right mixture of technologies and spectrum assets to support a growing number of industry verticals (see annex B). They already serve various sectors ranging from utilities and construction to public safety services and localised public and private networks for retailers, manufacturers, venues and public facilities like hospitals, etc.

   Operators have diverse spectrum and network assets which allow them to provide very wide area coverage as well as significant data capacity to support high-speed mobile broadband. They deploy small cells and Distributed Antenna Systems to support targeted, localised connectivity - including indoor and outdoor private networks - for enterprise and vertical premises. New technologies like NB-IoT and LTE-M mean they can efficiently connect millions of lower power IoT devices (e.g. smart meters and sensors for utility companies) that are distributed nationwide, including deep inside buildings where coverage has traditionally been hard to deliver.

   The 5G era is heralding the arrival of new technologies and spectrum bands that allow mobile operators to significantly extend their capabilities. New 5G spectrum bands – including millimetre waves and mid-bands such as 3.5 GHz - can support larger channel sizes to enable considerably faster speeds. 5G is also able to support significantly lower latencies for delay-sensitive applications like remote-controlled robotics and connected cars. Existing mobile bands will also support 5G services, giving the public mobile operators a tool kit of bands to address multiple different use cases.

   Mobile operators' 5G networks will also support end-to-end network slicing and mobile edge computing, allowing them to tailor services specifically for the needs of different industry vertical sectors. The customisable network capabilities include data throughput, latency, reliability, security, power-efficiency and service optimisation (see appendix A). In this way. network slices can be tailored for verticals which need low latencies (e.g. for remote-controlled robotics in manufacturing) while another is tailored for power-efficiency (e.g. for smart meters and sensors with long-life batteries).

   In practice, each vertical sector will generally have multiple different requirements (e.g. low latency, high throughput, long-battery life, localised coverage, wide area coverage, etc). However, these differing requirements need different spectrum and network resources. Ultra-low latency services and high-speed broadband services need different spectrum bands as their radio resource requirements are incompatible. Similarly, high-capacity, localised services better suit capacity bands (i.e. above 1 GHz) whereas nationwide services benefit from coverage bands (i.e. sub-1 GHz). Commercial mobile operators are well placed to support such diverse requirements due to their generally wider spectrum assets.

2. **Spectrum leasing or, when carefully planned, other types of spectrum sharing can be viable options for supporting verticals who want to build private networks**
   There are ranges of alternatives to spectrum set-asides that can provide verticals with access to spectrum while avoiding harmful side effects (see positions 3 & 4). These include permitting operators to lease spectrum to verticals, as well as alternative assignment approaches such as spectrum sharing. There is no one size fits all markets as the best option will depend on local conditions. These include how much mobile spectrum has been brought to the mobile market so far to support advanced mobile technologies (e.g. 4G and 5G), as well as incumbency issues that make a band complex or impossible to clear and may therefore better lend themselves to sharing.

   In some markets, regulators already actively permit, and indeed encourage, mobile operators to lease their spectrum assets so that verticals can build private networks. The Finnish regulator adopted this approach in the 3.5 GHz band instead of a vertical set-aside, and in Sweden, a sharing agreement is in place between Hutchison and a micro-operator that is solely focused on vertical industries. In the UK, Vodafone has sublicensed spectrum to an operator planning a rural broadband service. Licence obligations can be used to ensure the requirements of verticals can be met. For example, in Finland the 3.5 GHz licensees are obliged to either participate in tenders for vertical contracts in localised areas or else sub-license their spectrum to the vertical so they can build their own network. This preserves the benefits of market-based awards while also supporting a secondary market where verticals can sub-license spectrum from operators. However, for this to be possible, it is vital that regulators permit operators to share their spectrum – this is currently not permitted in most countries.

There are also other types of spectrum sharing that may lend themselves to supporting the needs of verticals. Some mobile bands have incumbency issues which can be impossible to clear in the near-term and have usage restrictions which can prevent high power use for macro base stations in significant areas[12]. These bands can lend themselves to localised low-power use by verticals wishing to build their own networks as well as mobile operators and other types of internet service providers (e.g. those targeting rural areas). There are a variety of ways this could be implemented including complex three tier-models (e.g. CBRS in the US), which supports users with different access rights, to a single-tier model with coordinated usage to avoid interference[13].

The key considerations when weighing up such sharing approaches is that that the approach is investment-friendly and supports high-quality mobile services – including 5G – and access is fair and equal.[14] Public mobile operators need access to a significant amount of spectrum – especially to support advanced 4G and 5G – so approaches which reduce the amount available create scarcity which risks more expensive, slower services and can inflate spectrum prices. The licence terms and conditions should also encourage long-term investment in the band and not constrain deployments to the detriment of consumers and businesses. This means it is important there are long-term guarantees or access with an expectation of renewal and clear access rights including protection from interference. If the conditions (e.g. power emission levels) overly restrict how the band can be used – then it will adversely affect some critical use cases.

It is also possible that hybrid spectrum management approaches may emerge where exclusive spectrum licences are assigned at auction in busy areas (e.g. cities) but then is made available on a shared basis elsewhere. This can ensure that mobile spectrum is made available to meet very high –level demand from consumers and businesses in city centres while also supporting the needs of verticals and regional internet service providers outside of these areas. This kind of sharing approach preserves the most efficient use of spectrum while also addressing the needs of multiple different users.

3. **Spectrum that is set-aside exclusively for verticals in core mobile bands risks being underused and can undermine fair spectrum awards**

Assigning spectrum to the highest value user has been central to the success of mobile spectrum management in recent decades. This has proven a reliable means of ensuring spectrum is used efficiently and significant value is created for society. Set-asides for vertical industries in core mobile bands circumvent this process and raise concerns about efficient spectrum use. Set-asides can also undermine other spectrum users who create more value for society[15]. Set-asides are only generally used where there is evidence of market failure and where other regulatory remedies are not viable – and even then, caution must be taken to minimise adverse effects on the mobile market.

Since the 1950s, economists have warned of the perils of policymakers deciding, in the face of different alternative uses, which spectrum user creates more value for society. The risk is that other more valuable users would not gain access to the spectrum and the chosen licensees may not use the spectrum very efficiently. There are indications this is likely to be the case with set-asides for verticals that are being proposed in core 5G bands like 3.5 GHz, and thus, the band may be underused and fragmented, which in turn will be difficult to resolve in an efficient way.[16]

For example, those vertical industries which choose to use a dedicated set-aside in the 3.5 GHz band are only likely to operate in a relatively small number of fixed locations so the spectrum is likely to go unused in parts of metropolitan areas and almost all suburban and rural areas. Furthermore, it is unclear whether a critical mass of verticals will wish to take on building their networks, and thus rely on the set-aside, given that other solutions providers may be able to better meet their needs. Surveys show most verticals do not need dedicated, fully isolated private networks[17]. In general, only operational isolation is required which can be fulfilled by public 5G networks in which verticals are able to independently monitor and even fully control a network slice or slices.

12. For example, the 2.3 GHz and 3.8-4.2 GHz band in Europe
13. Private Mobile Radio (PMR) licences are managed in this way
14. The GSMA's position paper on spectrum sharing explores these issues in more detail
15. Regulators assess the socioeconomic benefits users create when deciding how to assign spectrum. Mobile assignments are often prioritised because of the large number of mobile subscribers and economic value created (e.g. there were 5.1bn unique subscribers and the mobile industry contributed $3.9tn to global GDP in 2018)
16. Ironically, the 3.5 GHz band, where vertical set-asides are being considered, is still in the difficult process of being defragmented in many countries following use by other services, so there is a risk of history repeating itself
17. See GSMA report 'Network Slicing Use Case Requirements' (April 2018)

Even where verticals do need a fully isolated network and dedicated spectrum, this can still be met without a set-aside in a core mobile band (e.g. by outsourcing to another provider or using another regulatory approach as discussed in position 2). These other options should be considered given the risks such set-asides pose to commercial mobile services and the consumers, businesses and verticals who will rely on them (see position 4). However, where policymakers believe a set-aside is required, then a cost-benefit analysis should be conducted to demonstrate that the benefits to verticals outweigh the costs imposed on other spectrum users. This analysis should also address why other approaches to making local 5G services or spectrum available to verticals are not suitable (e.g. a failure of the market to provide a solution). The GSMA would also highlight that where set-asides are used, there are some ways that the additional costs to mobile services can be minimised:

- Consider shared mobile bands as they can better suit lower-power local vertical usage rather than core mobile bands which have higher value alternative uses including wide-area 5G[18]
- Define set aside spectrum as service neutral so others can make use of it where verticals choose not to (e.g. public mobile services)
- Regulation should not prohibit mobile operators from using the set-aside to provide services to verticals
- Establish goals for set-asides and regularly review usage to ensure these goals are being met and, if not, a sunset clause can be implemented (e.g. so unused spectrum can be made available to others after a certain amount of time has elapsed)
- Minimise the size of the set-aside to what is strictly necessary when there are other potentially higher-value alternative users.[19] This should involve carefully assessing demand in the market for spectrum from verticals and their precise requrements
- Increase spectrum efficiency by exploring synergies between vertical networks so the same spectrum and technologies can be put to multiple uses (e.g. PPDR, utilities and railway)
- Set a reasonable price for the spectrum to encourage efficient use and minimise the risk of hoarding
- Consider the impact on fair competition if licensing is done on a “first come first served” basis and take measures to avoid spectrum hoarding such as with “use it or lose it” rules

4. Spectrum that is set-aside for verticals in core mobile bands can also threaten the wider success of 5G – including slower rollouts, worse performance and reduced coverage

The success of 5G is heavily reliant on policymakers supporting timely access to the right amount and type of affordable spectrum, and under the right conditions. 5G spectrum awards have already begun and the variation in the amount of spectrum assigned, and the prices paid, means the potential of 5G services will vary significantly between countries. Set-asides for verticals in priority 5G bands (e.g. 3.5 GHz & 26/28 GHz) limit the spectrum available for commercial public 5G services while also creating artificial scarcity which drives up the cost of spectrum sold at auction. Collectively, these factors lead to reduced 5G performance and potentially slower rollouts and worse coverage.

5G needs a significant amount of new, harmonised mobile spectrum so defragmenting and clearing prime bands are critical. The GSMA recommends at least 80-100 MHz of contiguous spectrum is awarded 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). Regulators are also advosed to plan timely significant further allocations and significant subsequent awards in both these frequency ranges to help 5G scale as needed[20]. Set-asides for verticals that make these targets difficult or impossible to meet therefore undermine the wider success of 5G. They can also drive up network deployment costs as the capacity shortfall from a lack of spectrum may need to be made-up in more expensive ways (e.g. further network densification). Set-asides also introduce deployment complexity which can restrict the use cases that can be supported (see position 5).

When policymakers choose to set-aside portions of core 5G bands for verticals, they also artificially limit how much spectrum can be awarded at auction. By limiting the supply of 5G spectrum, operators are likely to overpay for spectrum to secure the large amounts needed for the best services. High spectrum prices have been shown to lead to slower services and worse coverage as operators are less able to invest as much in their networks[21] and could lead to higher consumer prices. More widely there is also a risk that operators will start to limit long-term network investment in markets where there are signs mobile spectrum will be withheld from market-based awards and assigned directly to others as this introduces uncertainty.

18. Core mobile bands may be regarded as widely harmonised bands that have been fully cleared for mobile use, without special usage restrictions, and are suited to a competitive award process due to high demand. Other mobile bands, such as shared mobile bands, have lower opportunity costs due to geographic or power restrictions (e.g. due to incumbency issues) or they lie outside the main portion of core mobile bands (e.g. the duplex gap). For example, the UK is considering low power shared licensing, that suits local vertical use, in 3.8-4.2 GHz as it’s difficult to clear and protect incumbents. Some countries plan to support public safety networks in the 700 MHz duplex gap.

19. The amount of spectrum needed for higher value alternative users such as 5G commercial mobile services should also be considered (see position 4)

20. Source: ITU report ‘Minimum requirements related to technical performance for IMT-2020 radio interface)

21. See GSMA Intelligence research study on ‘The impact of spectrum prices on consumers’

5. **Policymakers should consider the coexistence challenges when different use cases need to be supported in the same band**

   Authorising both commercial mobile networks and independent vertical networks in a single mobile band can create coexistence issues. This can result in harmful interference, limit the use cases that mobile operators and verticals can support in the band, and create additional burdens on equipment design that can impact efficiency and affordability.

   For example, all 5G networks operating in TDD bands (e.g. 3.5 GHz) will typically need to be synchronised[22] to ensure they do not interfere with each other. This synchronisation creates limitations on what use cases can be supported. For example, very high-speed broadband networks could not co-exist with separate, very low latency industrial networks in the same area. In practice, policymakers and industry stakeholders will need to agree a synchronisation framework[23] and put in place procedures to ensure it can be enforced to avoid harmful interference. This framework will determine the download speed, upload speed and latency of networks in the band and may undermine the ability to deliver a 5G experience that is a significant improvement over 4G technology.

   Public mobile operators can overcome the limitations imposed by synchronisation by using their wider spectrum assets. Verticals using set-aside spectrum in a single TDD band would either need to accept the limitations, work with public mobile operators on a hybrid solution or coordinate their deployments with their neighbours, which would introduce other constraints. For example, studies show that a separation distance of around 14km would be needed between unsynchronised 5G networks in the adjacent spectrum and 60km for co-channel networks.[24] If verticals choose to deploy non-standardised technologies, then the coordination distances could be greater. Naturally, this would create serious restrictions on where 5G deployments can happen and which use cases can be supported.

The coordination issues that policymakers need to consider are especially complicated in border areas. Currently, neighbouring countries take extensive efforts to control spectrum usage along borders to prevent interference and unwanted roaming. This involves careful control over the location, height, direction and power levels of transmitting networks. This process would be more cumbersome when the number of spectrum users changes from a small number of public mobile operators to a potentially much larger number of independent vertical networks. Crucially, it also means that policymakers would also need to agree an approach to synchronising all networks (e.g. vertical and public mobile operator) in the border areas with their neighbours within 30km of the border. There are similar problems if policymakers choose to adopt regional licensing for mobile bands as this creates "borders" within countries so that licence holders in different areas would need to coordinate their usage.

More generally, the differing nature of deployments in adjacent bands also creates challenges. Spectrum was set-aside widely around the world for use by railways (i.e. GSM-R) adjacent to the 900 MHz mobile band. Unfortunately, standardised GSM equipment did not provide sufficiently strong protections for the railway networks given the different density of the networks. The relatively small number of GSM-R base stations were outnumbered by the larger number of GSM base stations deployed by operators, leading to the railways receiving poor cell edge performance. This problem could be replicated with other verticals[25]. The remedy would be to create specialist radio equipment[26] for the railway, or other vertical, which drives up costs, thus undermining some of the benefits of using a mobile band or reducing the power or number of mobile operator base stations which would harm coverage. 5G has also been standardised based on the density/topology used by public mobile operators and deviating from that is likely to cause coexistence issues. This is very different from the more traditional Private Mobile Radio systems which use frequencies that are further apart from commercial public mobile networks and allow for overlapping coverage.

22. These bands use Time Division Duplexing which means that base stations and devices transmit in the same portion of spectrum but at different times to avoid interference. All networks operating in the same geographic area need to be synchronised to ensure interference free operation. For more information, see the GSMA's synchronisation whitepaper
23. This would involve agreeing a common frame structure for all spectrum users in the band. Vertical industries may be interested in 4G friendly frame structures (due to the lower equipment costs) which are not compatible with many 5G options and would not support very low latency use cases.
24. See ECC REP 296 which considers separation distances between unsynchronised 5G macro networks
25. For example, a set-aside for emergency service networks adjacent to mobile operator networks in the 700 MHz band is being considered in some regions.
26. For example, receiver equipment with improved selectivity

6. **Unlicensed spectrum is likely to play an important role for numerous verticals**

   Unlicensed spectrum plays a powerful role for vertical industries by allowing them to build their private networks with advanced capabilities – or outsource to third-party providers. Wi-Fi provides high-speed connectivity and the latest standard, Wi-Fi 6, alongside carefully designed enterprise-grade deployments, can support growing numbers of users and traffic growth. At the same time unlicensed IoT technologies also play a role for verticals such as low power wide area services for utilities (e.g. Lora and SigFox) or local connectivity for smart devices (e.g. Zigbee and ZWave).

   At the same time, cellular technologies have evolved to make use of unlicensed spectrum to allow verticals to build their own private networks. 4G-LTE networks, and in the near future, 5G as well, can be deployed entirely in unlicensed spectrum to support a wide variety of use cases ranging from high-speed broadband to low power IoT connectivity. For instance, private LTE networks in unlicensed spectrum are being used to successfully automate warehouses[27].

   All these approaches are being supported by careful ongoing regulatory support for unlicensed spectrum to ensure capacity issues can be managed. Given the fact that verticals often operate in controlled radio environments (e.g. they can control all transmissions in factories) unlicensed spectrum can be relied upon to deliver high-quality connectivity with minimal interference. As a result, unlicensed spectrum and evolving technologies help support a vibrant and competitive set of offerings for the vertical market. However, it should be noted that unlicensed spectrum will not be able to support all use cases, especially when the highest quality of service is needed and the radio environment is difficult to control (e.g. in public or semi-public areas like stations and ports).

7. **Policymakers should carefully consider their options and consult stakeholders to ensure they most efficiently support the needs of verticals without undermining other spectrum users**

   The success of mobile spectrum management has been built on providing reliable, affordable and fair access to support competition, long-term investment and enable technology evolution. It is vital that approaches to supporting the needs of verticals continue this trend. There is no one single approach to best meeting the needs of verticals using mobile spectrum in all markets. The state in the evolution of mobile networks, the number of mobile operators, evolving data traffic demands, the availability of core mobile bands, incumbency issues in bands and the level of demand from verticals will vary in different markets.

   It is important that vertical industries can benefit from fast-moving technological innovations – including 4G and 5G. Policymakers should carefully consider how best to satisfy those verticals that wish to directly access mobile spectrum to support their private networks while also considering the impact on other wireless users. However, there are some options (e.g. set-asides for verticals) that present clear risks to the vast number of consumers and businesses who rely on commercial mobile services. As such, the GSMA recommends that before proposing such set-asides, regulators should conduct and publish a comprehensive cost-benefit analysis to demonstrate how the benefits of a set-aside approach outweigh wider losses to other spectrum users - and their customers - and how it represents a superior approach to alternative options.

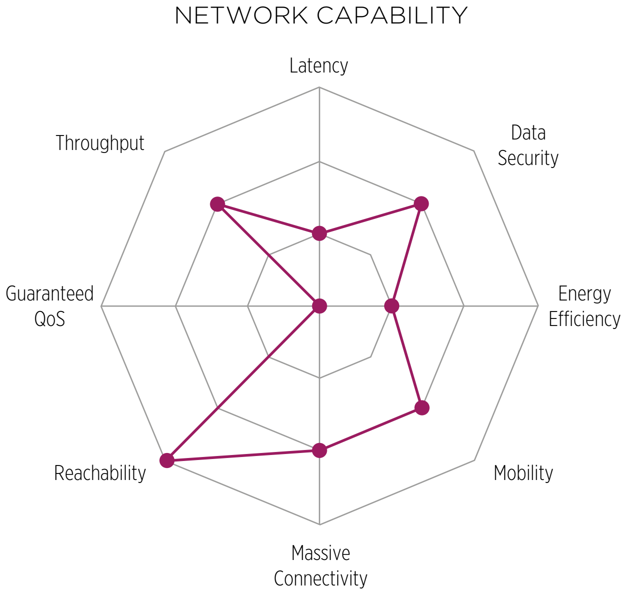
   It is also vital that policymakers ensure their rules and regulations create an environment that allows mobile operators to effectively support vertical sectors, including investing significantly in networks to meet their various needs. For example, mobile operators require long-term access to a sufficient amount of affordable spectrum and a clear renewal process in order to justify making necessary long-term network investments. Therefore, it is vital that policymakers have fair and predictable licence renewal policies and publish a spectrum roadmap to give assurances that future demand can be met. They should also ensure licences are technology and service neutral to support all vertical use cases. In numerous countries, there are technology-specific spectrum licences (e.g. only 2G technology may be used) which means operators are prevented from supporting vertical use cases that need mobile broadband or advanced cellular IoT technologies.

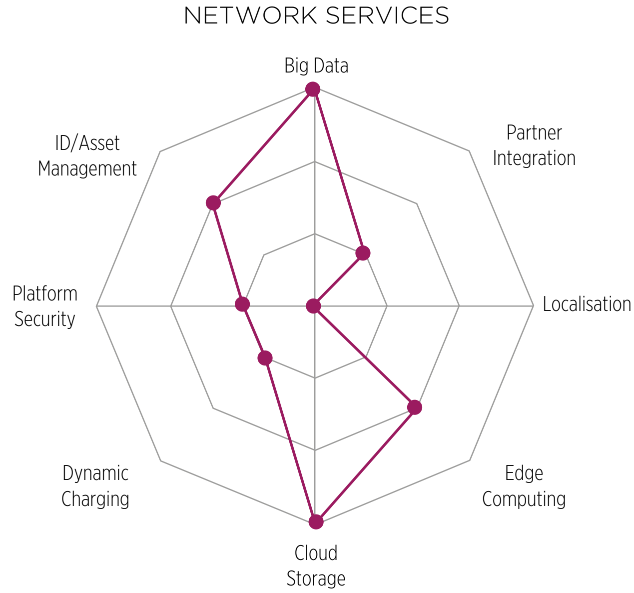
   More widely, policymakers should properly consult all stakeholders to ensure that their plans for addressing the needs of verticals are technically and commercially feasible and attractive. All proposals should be evidence-based, consider the evolution of technology and services and have comprehensive business cases. Clear objectives should be outlined at the outset to ensure the right band and approach are selected.

27. Ocado Automated Warehouse

Appendix A

Each network slice is customised to provide a tailored connection for a specific vertical requirement. One vertical is likely to require several different slice types, which can require several different spectrum bands to address (e.g. very low latencies and very high-speed broadband have different resource requirements). Sample network capabilities and slices are illustrated below:





For more information on network slicing, please refer to the GSMA deliverables:

1. **From Vertical Industry Requirements to Network Slice Characteristics** (https://www.gsma.com/futurenetworks/wp-content/uploads/2018/09/5G-Network-Slicing-Report-From-Vertical-Industry-Requirements-to-Network-Slice-Characteristics.pdf)
2. **An Introduction to Network Slicing** (https://www.gsma.com/futurenetworks/wp-content/uploads/2017/11/GSMA-An-Introduction-to-Network-Slicing.pdf)
3. **Smart 5G networks: enabled by network slicing and tailored to customers' needs** (https://www.gsma.com/futurenetworks/wp-content/uploads/2017/09/5G-Network-Slicing-Report.pdf)
4. **Network Slicing Use Case Requirements** (https://www.gsma.com/futurenetworks/wp-content/uploads/2018/07/Network-Slicing-Use-Case-Requirements-fixed.pdf)

GSMA HEAD OFFICE
Floor 2
The Walbrook Building
25 Walbrook
London EC4N 8AF
United Kingdom
Tel: +44 (0)20 7356 0600
Fax: +44 (0)20 7356 0601