KPMG

Encouraging 5G Investment

Lessons learnt from around the world

December 2019

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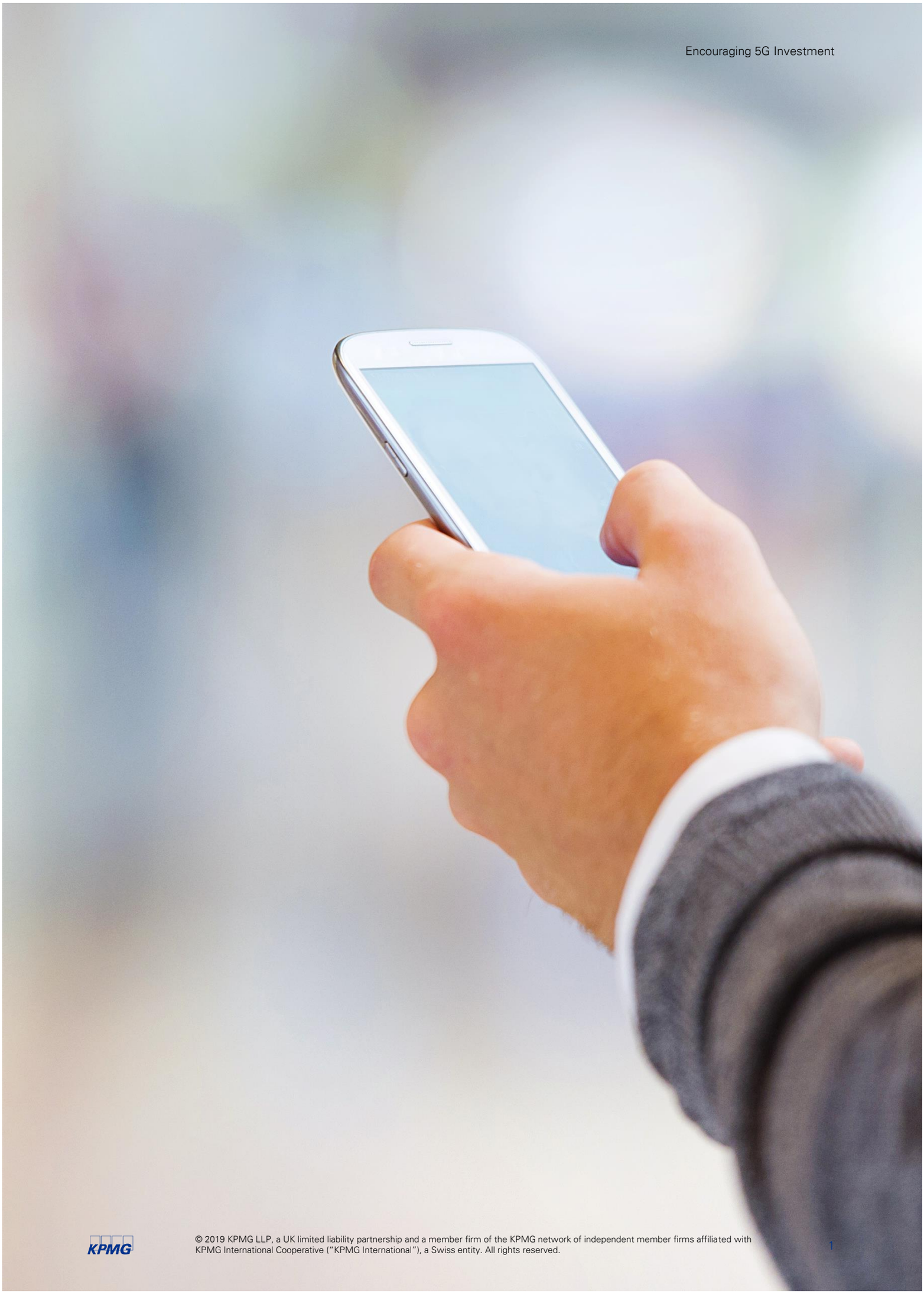


Contents

1. Executive summary

Scope of the report

5G is the next generation of mobile telecommunications and represents a step change in the future of technology and communications, given the wide range of innovative uses it can support when compared to previous generations. 5G offers much more than faster mobile internet speeds, and has the potential to support the creation of smart cities, agriculture and transport, and the automation of digital industrial ecosystems. Countries around the world are therefore looking to 5G to help spearhead future economic growth; getting national 5G policy right is front of mind for most major economies around the world.

GSMA (the trade body for mobile network operators) has carried out analysis on the future of 5G adoption and has predicted that by 2025, the top five regions for 5G adoption will be:[1]

1. South Korea;
2. The US;
3. Japan;
4. China; and
5. Europe.

In this report we consider how 5G deployments have been approached to date by the leading regions for 5G, as well as future plans. In most cases, 5G has built on 4G deployment. For the top five regions, we have considered:

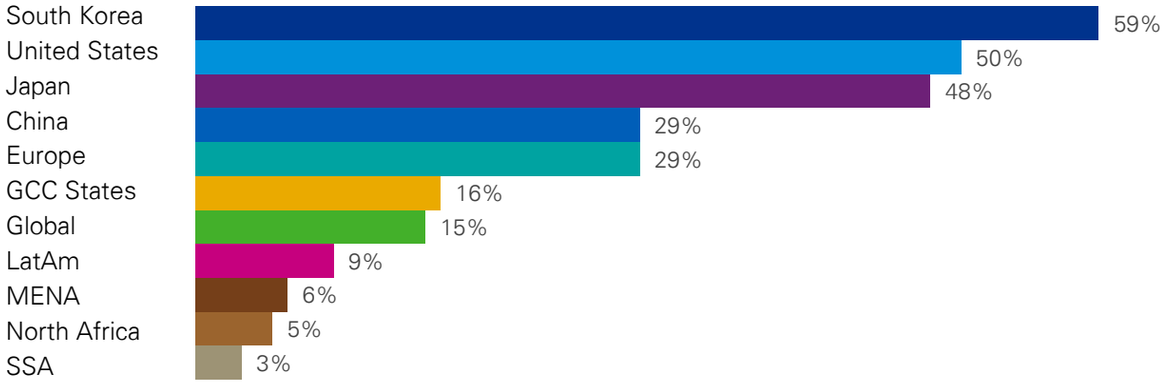
a) Policy-makers' strategy for encouraging 5G network rollout; and

b) The activities and plans of mobile operators.

Our analysis includes reviewing the progress made to date in relation to 5G deployment in the top five regions. In regards to Europe, we have included some of the larger, more connected economies: France, Germany, Portugal, Spain and the UK.

We have also included Singapore as an example of an early mover in high-speed communications infrastructure.

Figure 1: 5G connections as a share of total connections by 2025



Source: GSMA (2019)[2]

Key findings

Spectrum for multiple operators is crucial

In the most advanced countries for 5G, policy makers have allocated (or are planning to allocate) a mix of spectrum bands to multiple mobile network operators (MNOs), **allowing for competition between MNOs**.

Mid-band spectrum has been the most frequently allocated around the world for 5G, complemented by high-band spectrum in the US and East Asian countries, and by low-band spectrum for coverage in Europe.

Network sharing lowers cost of deployment

The deployment of 5G networks is likely to be a costly exercise. As such, **a number of policy makers have advocated commercially-driven network sharing agreements** as a means to substantially cut network build costs. Numerous mobile operators have also followed this route.

Removal of administrative barriers

5G network deployment will require coordination with numerous local authorities to install infrastructure. In all the countries considered**, policy makers have taken steps to remove administrative barriers to network deployment.**

Government support can help accelerate 5G

5G has the potential to power growth across a number of industries and **numerous governments have provided funding for R&D for 5G use cases.** Support has also been given to incentivise 5G network build.

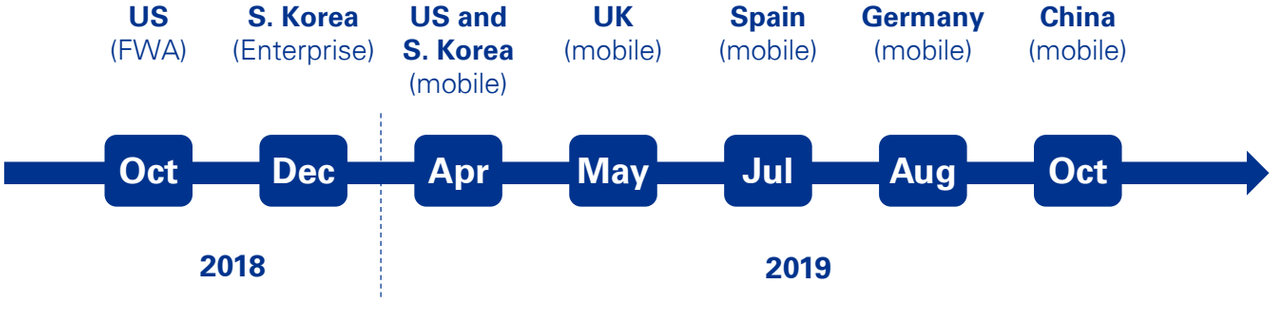
Table 1: Summary of 5G policies and activities

	Spectrum allocated/planned				Infrastructure		Public funding	5G launch
	Low	Mid	High	Auction	Reduction of deployment barriers	Promotion of network sharing*		
S. Korea	✗	✓	✓	✓	✓	✓	✓	✓
US	✗	✓	✓	✓	✓	✗	✓	✓
China	✗	✓	✓	✗	✓	✓	✓	✓
UK	✓	✓	✗	✓	✓	✓	✓	✓
France	✓	✓	✗	✓	✓	✗	✓	✗
Germany	✓	✓	✗	✓	✓	✓	✓	✓
Portugal	✓	✓	✗	✓	✓	✓	✓	✗
Spain	✓	✓	✗	✓	✓	✓	✓	✓
Singapore	✗	✓	✓	✗	✓	✓	✓	✗
Japan	✗	✓	✓	✗	✓	✗	✗	✗

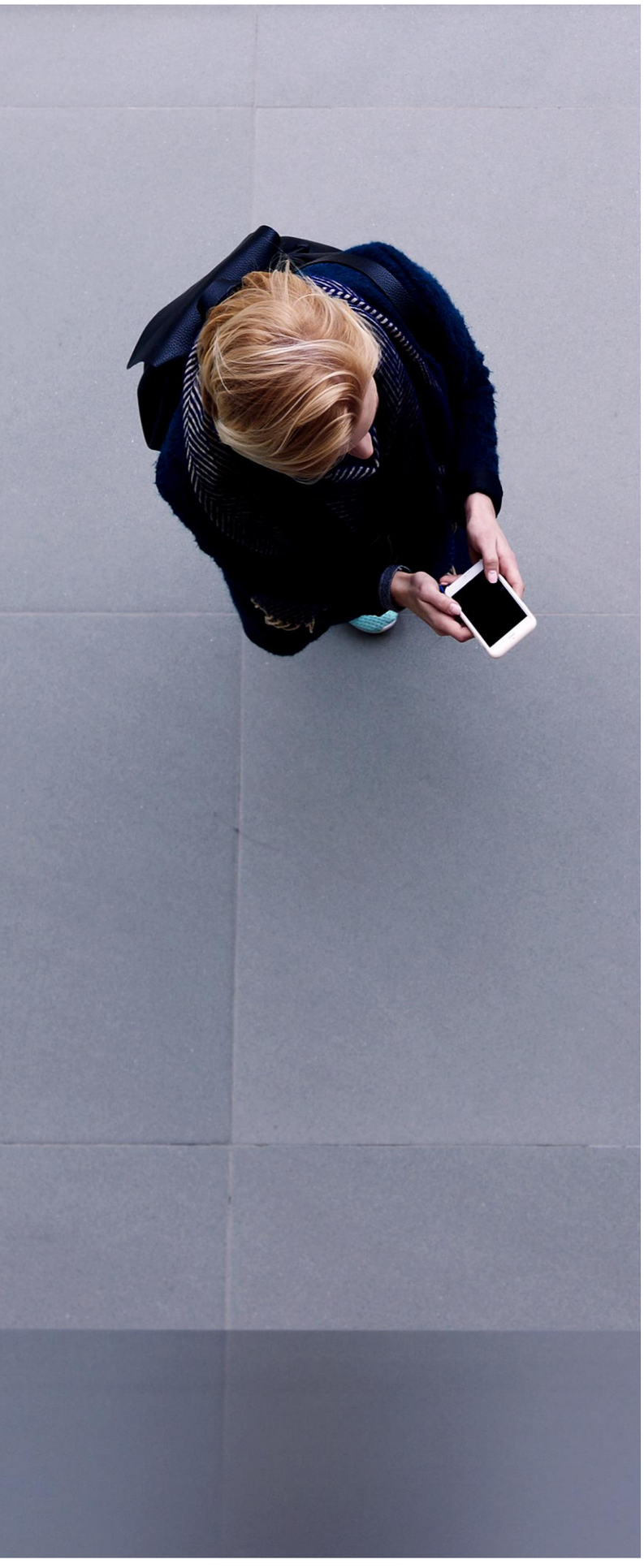
* Active and/or passive network sharing

Source: KPMG analysis of industry and regulatory reports

Figure 2: Timeline of commercial 5G launches to date in our universe



Source: KPMG analysis of industry and regulatory reports



Findings

5G policy

Regulatory certainty is an important factor for private investors when considering large-scale infrastructure investments, such as 5G investment by mobile operators. For example, within the UK's Department of Culture, Media and Sport (DCMS) Future of Telecoms Infrastructure Review (FTIR), the following is noted:[3]

> [t]here is…a broad consensus that more regulatory certainty and predictability and measures to stimulate demand are generally positive for investment.

Without full knowledge of the government/regulator's intentions, mobile operators may be reluctant to make the significant investments required for 5G (estimates from the European Parliament puts the cost of 5G deployment at up to three times that of previous mobile generations).[4]

Policy makers around the world have therefore set out plans for how they intend to support the rollout of 5G. In our review of national policies, we have grouped policy into four key themes: spectrum, tackling administrative barriers, network sharing agreements and public funding.

Spectrum

Spectrum for multiple operators

As an essential requirement for providing 5G services, policy decisions over spectrum (i.e. radio frequencies used for mobile technology amongst other things) are crucial for 5G rollout. These include which spectrum bands to free up and then award, the allocation method used, and as part of this, whether to allow multiple mobile operators to hold spectrum (and hence facilitate network competition). We observe the following:

— **Choice of spectrum band:** Figure 3 below summarises the 5G spectrum bands which have been allocated to date, and where plans have been put in place for allocations. All countries considered have either allocated, or plan to allocate mid-band spectrum, and most operators to date have launched on this spectrum. With regards to the German 5G auctions, the GSMA has stated that *"C-Band is the most vital frequency band for 5G….Germany is demonstrating 5G leadership in the timely release of this vital spectrum"*.[5]

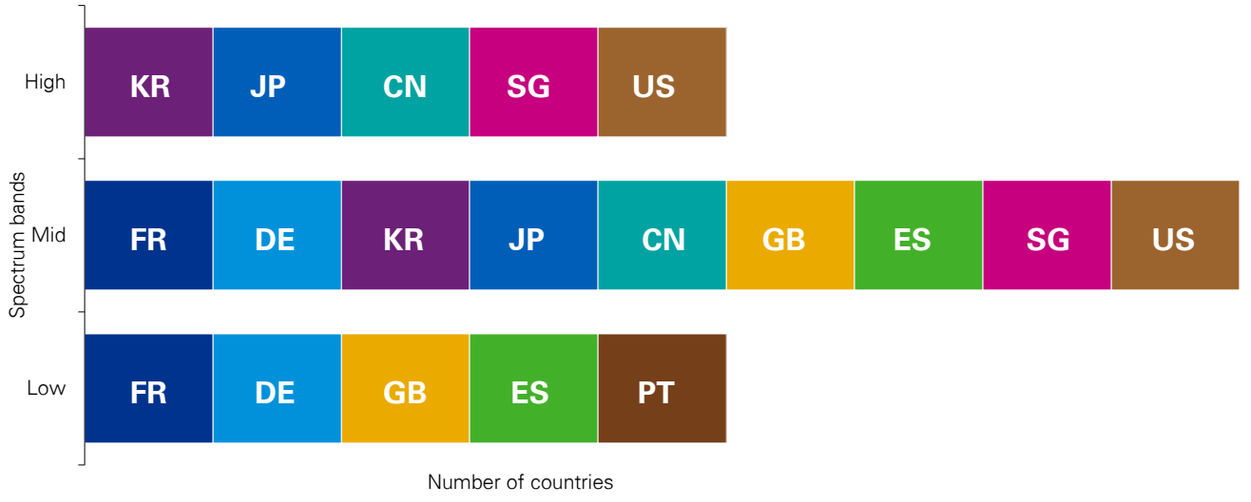
— In relation to other bands, European countries have considered using low-band spectrum to assist coverage for 5G, whilst the US and the East Asian countries have favoured high-band spectrum.

— **Allocation method:** The majority of countries have opted for an auction mechanism to allocate spectrum. However, we note that a number of mobile operators have voiced concern over the high costs of spectrum as a result of auction mechanisms, especially given the costs of 5G deployment. An alternative to the auction mechanism is what is called a 'beauty contest', whereby MNOs outline their business cases to the regulator, setting out how they can best meet national objectives. This approach has been taken by Japan and Singapore.

— **Allocation to MNOs:** In all countries where allocations have been made, multiple MNOs have received spectrum holdings as a result. Indeed, some regulators have explicitly stated the need to allocate spectrum to multiple operators to allow for competition, and as a result, differentiation and innovation. This has been recognised by Ofcom, the UK telecoms regulator; also Anacom, the Portuguese regulator has stated that market conditions should be created to *"enable the emergence of operations with different dimensions"* and as such, interested parties will be able to "acquire *the amount of spectrum they really need and value*".[7]

> Ofcom has a duty to ensure spectrum is used efficiently. We also ensure companies can compete fairly and customers have a good choice of mobile networks. So, to promote competition, we are still proposing a 37% cap on the overall spectrum that any one mobile company can hold following the auction. Promoting strong competition between mobile companies is important because it leads to better services for customers.[6]
>
> – Ofcom

Figure 3: 5G advanced countries that have allocated or propose to allocate different types of 5G spectrum



Source: KPMG analysis and European 5G Observatory[8]

Removing barriers

Removal of administrative barriers

The deployment of 5G networks is expected to be a costly exercise due to infrastructure requirements,[9] and the desire to achieve wider coverage. Policy makers and mobile operators have therefore considered how best to tackle the deployment of 5G networks.

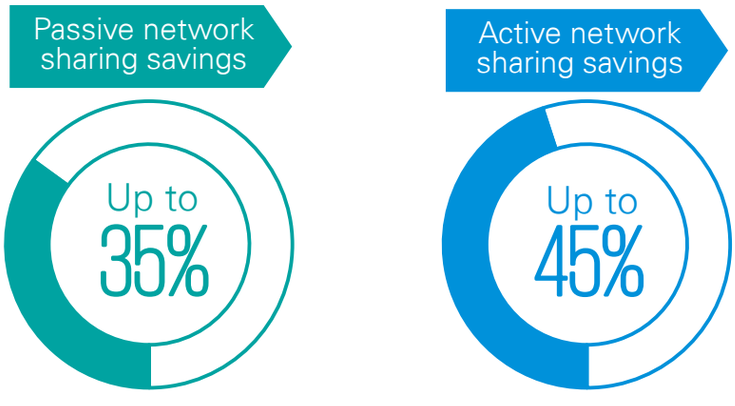
A common theme in the policies reviewed of leading 5G countries is simplifying regulations and administrative hurdles to allow for smoother and quicker deployment of mobile cells and fibre backhaul (for example, addressing local access requirements and access to passive infrastructure, such as ducts and poles); the need to review regulations has been highlighted in all the countries considered.

Network sharing

Network sharing lowers cost of deployment

A number of administrations have promoted network sharing agreements between operators as a means to substantially reduce the costs of infrastructure. BEREC (Body of European Regulators for Electronic Communications), the body for European telecoms regulators, has considered the cost savings of both passive and active network sharing agreements. It estimated passive agreements can generate savings for MNOs of 16%-35% on both capex and opex, and active agreements even more, saving between 33%-45% on capex, and 25%-33% on opex.[10] These cost savings could help accelerate the deployment of 5G technology. While passive network sharing has been commonplace for 3G and 4G deployments, we are seeing more active network sharing being deployed for 5G, particularly amongst the major European MNOs.

Figure 4: Estimated savings from networking sharing agreements



Source: BEREC (2018)[11]

Government support

Government support can accelerate 5G

Governments around the world have been keen to promote new use cases for 5G across industries and as such, have set aside generous amount of public funding to promote R&D. Public funding has also been used to help cover the costs of 5G network deployment in rural areas. For example, the US Government has created a $20.4 billion Rural Digital Opportunity Fund to extend high speed broadband to rural areas and to support the future of 5G. The UK Government has also created a £500 million fund to facilitate network sharing in rural areas as a means to achieve wider coverage.[12] Public funding has also been used to ease the burden of 5G deployment more generally, for example, some regions in China have promised rebates for each base station installed and have offered subsidised electricity to help support MNOs.[13]

Market characteristics

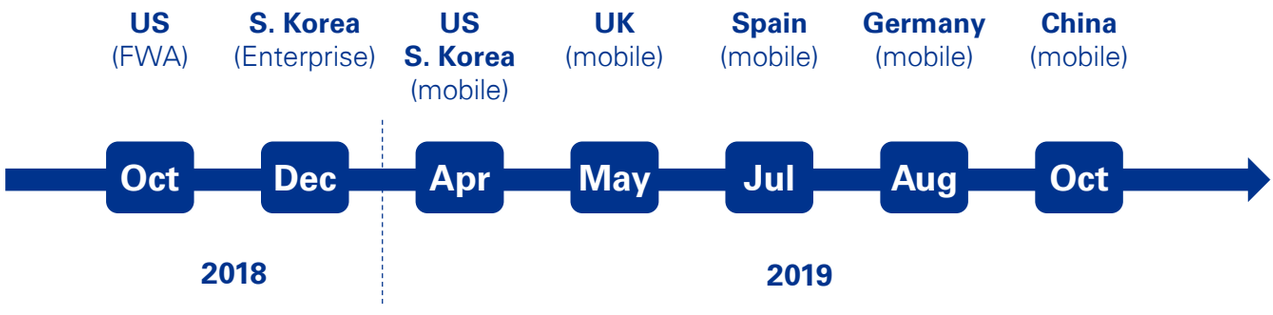
In the countries reviewed, we have found that the MNO market is typically characterised by the presence of three or four network owners. We also note in our review of national policies that the US has explicitly called for a lesser role for government and for the deployment of 5G to be market driven. Other countries, however, have provided some support for 5G, for example, through government subsidies and encouraging network sharing.

5G progress

The US claimed to be the first in the world to launch commercial 5G services in October 2018, followed by South Korea later in the year. Elsewhere, China has launched what it says will be the biggest 5G network by the end of 2019, and Europe has seen the rollout of 5G in selected cities. A timeline of the commercial 5G launches is shown in Figure 5.

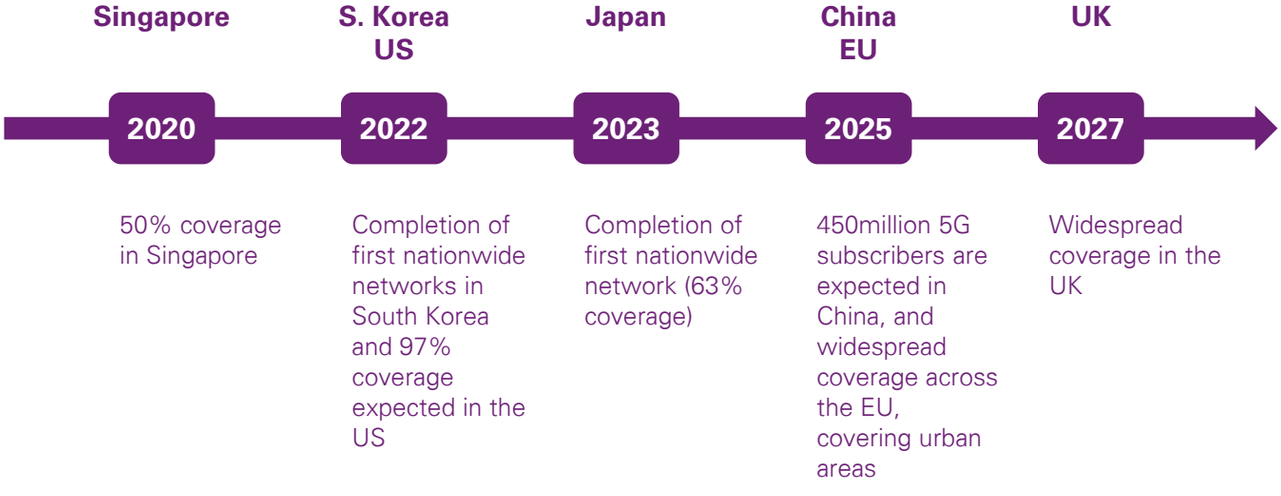
In terms of wider 5G coverage, again the US and South Korea are expected to be early leaders alongside Singapore which aims to achieve 50% coverage by 2020. A timeline of expectations for wider coverage across the countries considered has been presented in Figure 6.

Figure 5: Timeline of commercial 5G launches to date



Source: KPMG analysis of industry and regulatory reports

Figure 6: Expected timeline for wider coverage



Source: KPMG analysis of industry and regulatory reports

02 5G: An introduction

2.1 The evolution of mobile generations

Mobile technology has consistently improved since the 1980s, when the first mobile phones were introduced using 1G technology. The uses supported by each generation of mobile communications is illustrated in Figure 7.

The different generations of mobile technology utilise different ranges of spectrum (radio frequency). 5G will utilise a range of spectrum, as it develops and expands on the current 4G mobile technology to support new use cases which can be grouped into three categories.

Figure 7: Evolution of mobile technology

1G	Analogue calls
2G	Digital voice and text
3G	Mobile broadband, allowing for the emergence of 'smart phones'
4G	Faster mobile broadband with greater capacity, allowing for richer content (e.g. for better video streaming)

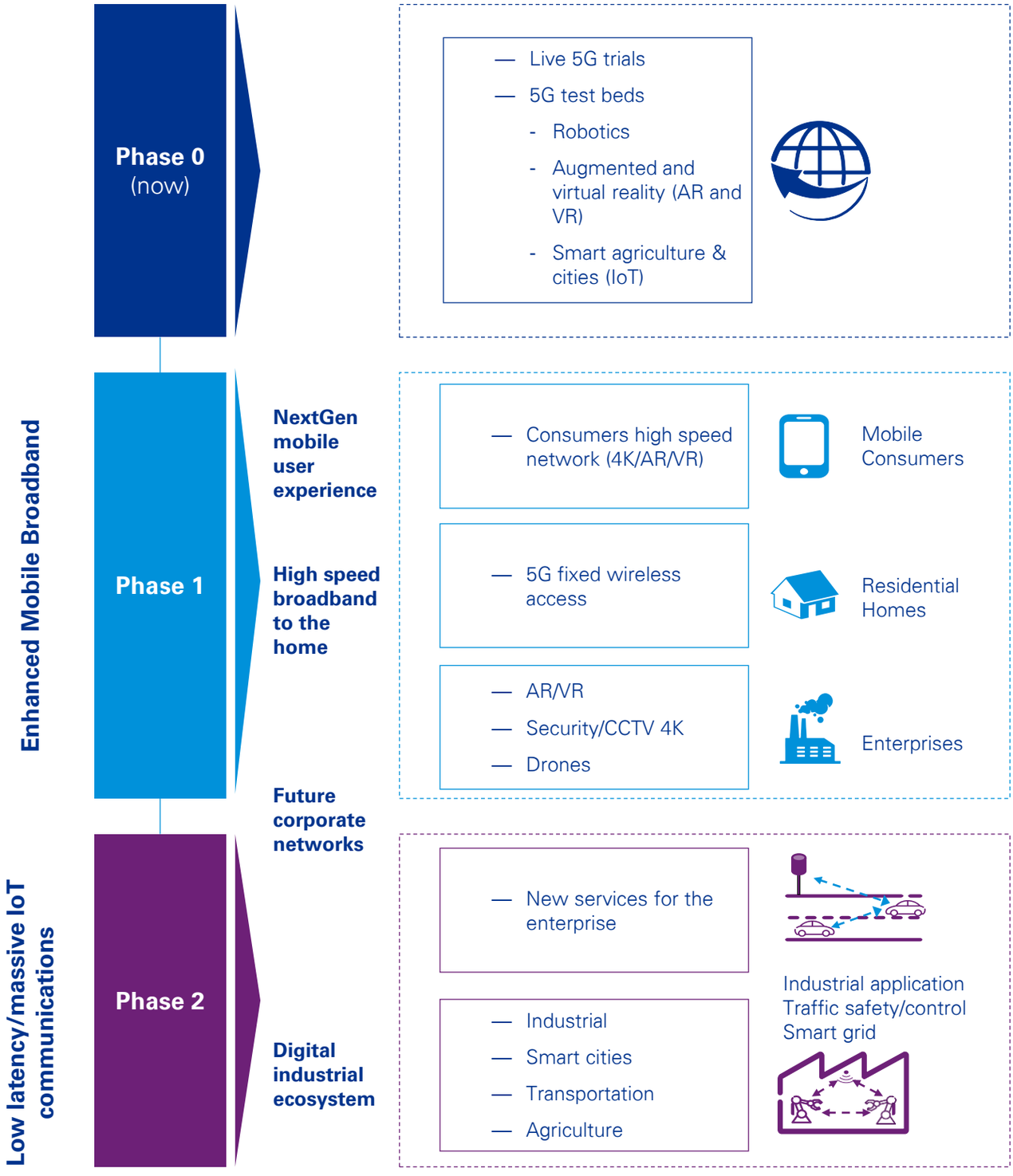
Source: Qualcomm (2014)[14]

The new use cases are:

1. **Enhanced mobile broadband (eMBB);**
2. **Ultra-reliable and low latency wireless communications (URLLC); and**
3. **Massive machine type communications (MMTC).**

Further detail on the above is given in Figure 8.

Figure 8: 5G uses cases



Source: KPMG/ITU[15]

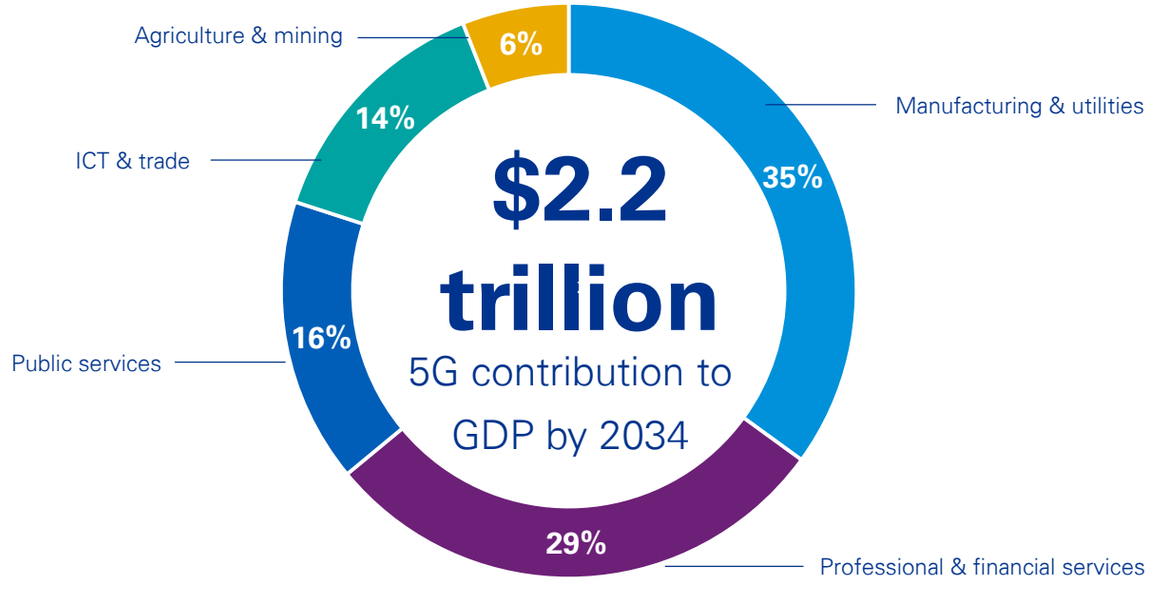
2.2 5G: The fourth industrial revolution?

5G is anticipated to bring many new services and applications in the future as a more diverse range of suppliers and industries begin to use it. This in turn is expected to drive global economic growth. As forecast by GSMA, 5G is expected to contribute over $2.2 trillion to the global economy by 2034,[16] which will be driven by growth across a number of sectors (Figure 9).

Examples of how 5G is expected to be used in the future across various sectors is set out below in Figure 10.

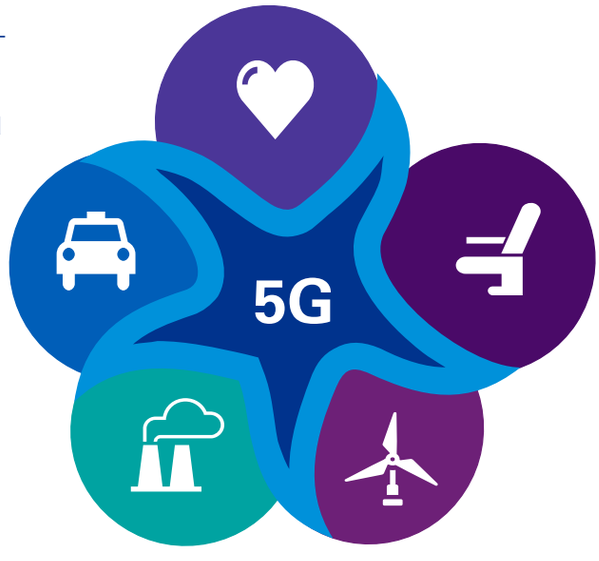
Given the potential of 5G, some commentators have hailed 5G as the driver of the next industrial revolution.[17]

Figure 9: Expected economic impact of 5G



Source: GSMA (2019)[18]

Figure 10: 5G vertical use cases



Automotive

- Exchange of information between vehicles in real-time
- Provision of information to drivers about the road ahead
- Improve safety and efficiency

Health

- Use of robotics for surgery/remote surgery

Media and Entertainment

- On-site live experiences, immersive media and collaborative
- Virtual reality based gaming
- Viewing of sports in 3D from home

Manufacturing

- Use for time-critical tasks
- Automation of processes
- Remote control of machines

Energy

- Grid access management for backhaul and grid backbone
- Balancing of energy supply and demand

Source: EC (2015)[19]

03 5G around the world

3.1 Introduction

As the evolution from 4G to 5G gains traction around the world, one of the key considerations for governments, telecoms national regulatory authorities (NRAs) and mobile operators is how to approach the deployment of 5G networks. The approach to 5G is not a straightforward task and there are a number of factors to consider from the perspective of policy makers and mobile operators. Factors include how to approach the allocation of spectrum, the infrastructure build and the approach to market competition.

The GSMA has carried out analysis on the future of 5G adoption and has predicted that by 2025, the top five regions for 5G adoption will be:[20]

1. South Korea;
2. The US;
3. Japan;
4. China; and
5. Europe.

In this report we consider how 5G deployments have been approached to date by the leading regions for 5G, as well as future plans. In most cases, 5G has built on 4G deployment, these are known as non-standalone networks. For the above regions, we have considered:

a) The strategy of policy makers in relation to building 5G networks; and

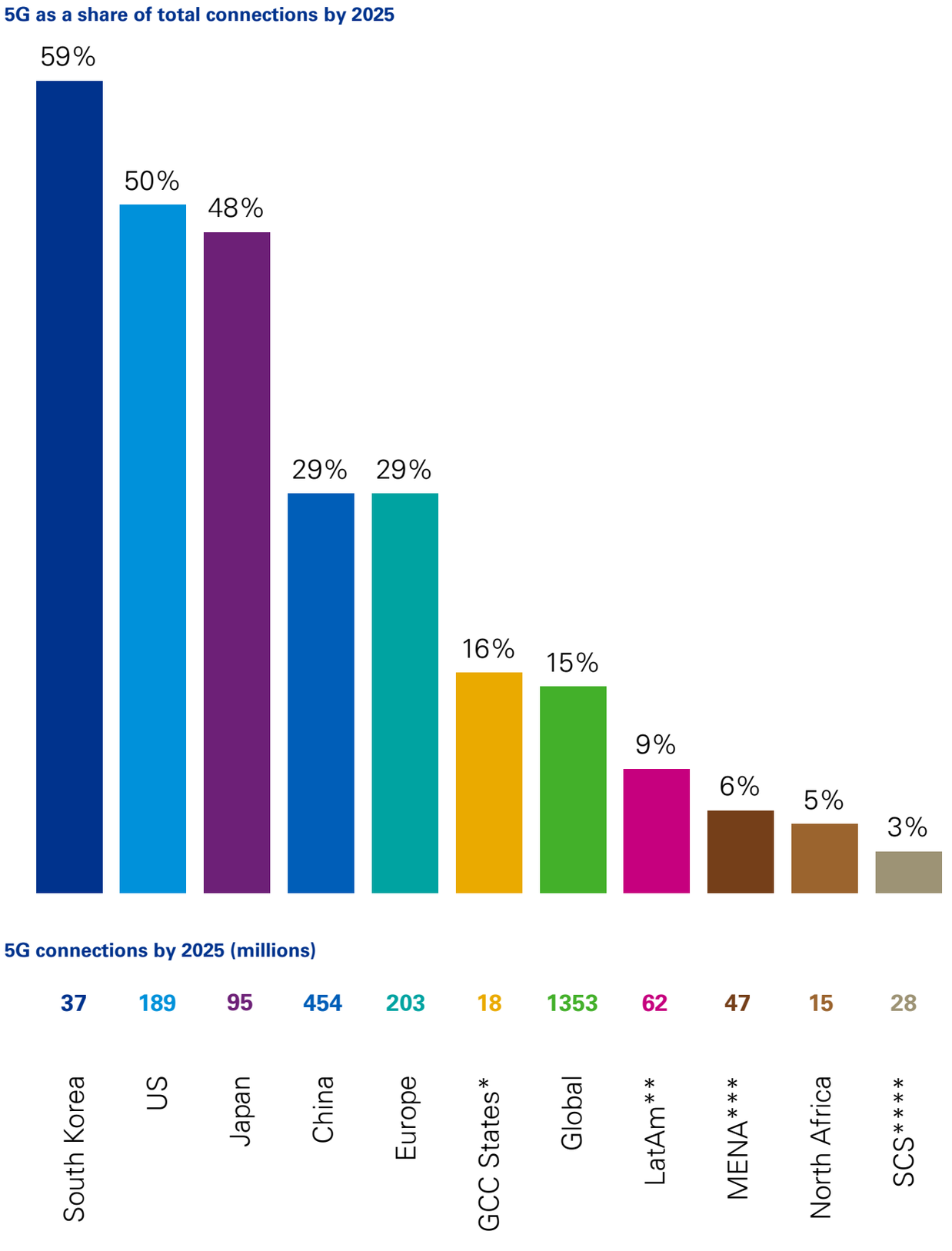
b) The activities and plans of mobile operators.

Our analysis includes reviewing the progress made to date in 5G deployment in these regions. With regards to Europe, we have considered some of the larger, more connected economies: France, Germany, Portugal, Spain and the UK.

We have also included Singapore as an example of an early mover in high-speed communications infrastructure.

5G future leaders: China, the US and South Korea set to lead the race

Figure 11: 5G connections as a share of total connections and number of 5G connections by 2025



*Gulf Cooperation Council States, **Latin America, ***Middle East and North Africa, **** Sun-Saharan Africa

Source: GSMA (2019)[21]

3.1 Common policy themes

We have grouped our review of national 5G policies into four themes:

1. Spectrum for multiple operators

Spectrum is a scarce resource and an essential input for 5G services. As such, policy makers have to decide how best to allocate spectrum, for example, through an auction mechanism, or based on the assessment of business cases (also known as a 'beauty contest'). Policy makers also need to consider which spectrum bands to allocate, and when these should be allocated, to meet policy objectives. There are also competing users of spectrum to be considered, including different forms of media, the military, and satellite providers, etc.

A summary table of the spectrum positions taken around the world is provided in the annex.

2. Removal of administrative barriers

The deployment of 5G networks are expected to be a costly exercise, given the potential for 5G to require more base stations, and the desire to achieve wider coverage. Policy makers and mobile operators have therefore considered how best to tackle the deployment of 5G networks, through the removal of planning restrictions and other administration barriers.

3. Network sharing lowers cost of deployment

A number of regulators have encouraged network sharing agreements between operators as a means to substantially reduce the costs of infrastructure. BEREC, the European telecoms regulator, has considered the cost savings of both passive and active network sharing agreements. It estimated passive agreements to generate savings for MNOs of 16%-35% on both capex and opex, and active agreements to save between 33%-45% on capex, and 25%-33% on opex.[22] These cost savings could help accelerate the deployment of 5G technology. Network sharing has also been a popular choice amongst the major European mobile network operators, partly driven by declining levels of profitability, creating greater incentives to reduce costs.

4. Government support can help accelerate 5G

Governments around the world have been keen to promote new use cases for 5G across industry verticals and have set aside public funding to promote R&D. Other uses for public funding have been to help cover the costs of network deployment in 5G in rural areas.

National 5G policy decisions in the selected countries and the 5G activities of the major MNOs are considered in the following sections.

Over 2 million
5G subscribers

2022

Target date for completion of nationwide network

High and mid-band spectrum

3.2 South Korea

South Korea was an early mover in the adoption of 5G and was the second country (after the US) to deploy 5G services. 5G services were showcased during the Winter Olympics in February 2018 where 5G technology was used for live streaming of sports and to operate drones. Since then, all three South Korean MNOs have rolled out commercial 5G services.

3.2.1 Market characteristics

There are three main mobile operators in South Korea: SK Telecom, KT and LG Uplus, with SK Telecom being the largest of three. Average revenue per user (ARPU) for mobile services have been in decline for all three operators with the fall in ARPU ranging from 6.5% to 10% in Q3 2018.[23]

3.2.2 National policy

South Korea's Ministry of Science and ICT (MSIT) has implemented a series of initiatives to foster the optimal environment for MNOs to deploy 5G networks through a competitive market. The actions taken by the MSIT include:[24]

— **Encouraging MNOs to launch 5G services simultaneously and to share the costs of deployment**

The South Korean Government has taken steps to encourage network sharing between MNOs and has promised tax benefits and security maintenance services as a means to incentivise MNOs to cooperate. As a result, the three MNOs initially launched a limited 5G service simultaneously, sharing existing network assets, and jointly building new 5G facilities, before commercial launches by each MNO based on upgrades to existing 4G sites.

— **Provision of funds for 5G launches**

A series of public funding initiatives have been launched including a $1.5 billion investment program in 2014 to develop 5G standards and a range of R&D funding programmes in 2018 covering areas such as software computing and security.

— **Reforming legislation to facilitate 5G infrastructure deployment**

Following the revision of legislation, MNOs have better access to local and government-owned areas (for example, street lamps and traffic facilities) to install mobile equipment for 5G services. As a result the number of 5G-installed base stations has increased from around 8,500 at the end of 2018 to 85,000 by April 2019.

— **Securing mid and high-band spectrum frequencies**

The MSIT committed to securing a range of frequencies for 5G which encompasses a total of 1,300 MHz across the 3.5 GHz and 28 GHz bands by 2018, and a further allocation of 300 MHz in the 3.5 GHz band and 1000 MHz in the 28 GHz band. Further bands will be made available by 2026 to allow for autonomous devices to be used.

> The **government is a trigger for the private sector**. The private sector is doing very well on the R&D, and the government needs to encourage them to build advanced infrastructure.[25]
>
> – Lee Sang-Kug, Deputy Director of ICT Policy, Future Planning Ministry

3.2.3 5G progress and plans

Large investments have been made by SK Telecom, KT and LG Uplus in 5G as part of the nation's ambitions to become a 5G leader. As at April 2019, it was estimated that the three MNOs had spent around $2.6 billion on 5G technology, with further investments to be made as the deployment of 5G continues.[26] For example, KT stated plans to invest $19 billion between 2018 and 2023 on 5G and associated technologies,[27] and LG Uplus plans to invest over $3.5 billion on 5G deployment for its nationwide rollout.[28] As noted above, South Korean MNOs have benefitted from tax breaks and public funding for the deployment of 5G.

The three MNOs launched their 5G networks together in December 2018 for use by enterprise customers. A consumer rollout followed in April 2019; this service, however, was limited to Seoul and five other cities at launch. Since launching consumer services, over two million of South Koreans have subscribed to 5G services, accounting for 77% of the total 5G subscribers around the world.[29]

Table 2 below, summarises the MNOs 5G progress.

Table 2: South Korean commercial 5G progress

	SK Telecom	KT	LG Uplus
5G subscribers (as at Aug/Sept 2019)	c.1 million	c.1 million	540,000
Number of 5G base stations	38,000	30,000	50,000
Spectrum on which 5G launched	3.5 GHz	3.5 GHz	3.5 GHz
Initial target areas	Major cities, highly populated areas (for example, universities), high-speed trains, highways and metropolitan subways.	Aim to offer 5G in 85 major cities by the end of 2019 covering key transport routes, two major highways, six airports and the ground section of high-speed railways.	Seoul and surrounding areas, plus some metropolitan cities.
Further targets	2 million subscribers by the end of 2019 Expansion of coverage to nationwide subways, national parks and festival sites by the end of 2019	Expansion of coverage to subways, public offices and university hospitals. Rumours of rollout to large indoor areas.	Deployment of 80,000 base stations and 90% population coverage by 2019.

Source: Industry news[30]

Market-led approach to 5G network build

2022

Expected date to achieve 97% population coverage

High and mid-band spectrum

3.3 The United States

The US is one of the leading countries as regards the pace of 5G deployment, with the American MNO, Verizon, claiming to have been the first in the world to launch a 5G service. A market-led approach was taken for 4G deployment, and has again been promoted by the US Government and the Chairman of the Federal Communications Commission (FCC) in reaction to calls by some to pursue the creation of a national 5G operator.[31]

3.3.1 Market characteristics

The US mobile market is largely served by three nationwide mobile operators: Verizon, AT&T and T-Mobile (which is attempting to merge with Sprint, the fourth provider). American MNOs benefit from relatively high levels of ARPU when compared to other regions. For instance, the average mobile ARPU of the largest European MNOs (across Germany, France, Italy, UK and Spain) in 2018 was 65% less than the largest MNO in America and whilst mobile revenues have declined by 4.6% over the last ten years, American mobile revenues have increased by 3.6% over the same period.[32]

> **Free up airwaves** to accommodate the increase in wireless traffic. **Get rid of the red tape** that slows the deployment of wireless infrastructure. **Provide targeted investments** in a fiscally responsible way to extend coverage to areas where there isn't business case to build. And then **get government out of the way** as much as possible. **This has been a winning strategy in the past**.[33]
>
> – Ajit Pai,
> Chairman of the Federal Communications Commission

3.3.2 National policy

To foster a market-led approach, the national telecoms regulator, the FCC, has launched a 5G action plan: Facilitate America's Superiority in 5G Technology (the 5G FAST Plan) which is supported by three key pillars:[34]

1. Pushing more spectrum into the market place

The auction of high-band spectrum is a priority for the FCC; the first wave of high-band auctions have been initiated with further auctions planned in late 2019. More mid-band spectrum is to be made available and the FCC is looking to improve the use of low-band spectrum. An evaluation will be conducted in relation to opportunities for unlicensed spectrum.

2. Updating infrastructure policy

New rules at the federal level will be adopted to reduce regulatory impediments to deploy small cells. At the state and local levels, potential roadblocks to 5G deployment will be removed.

3. Modernising outdated regulations

This pillar encompasses several focus points:

— Restoring Internet Freedom – encouraging investment and innovation whilst protecting internet openness and freedom.

— One-Touch Make-Ready – updated rules governing the attachment of new network equipment to utility poles to reduce costs and speed up the 5G backhaul deployment.

— Speeding the IP Transition – revised rules to make it easier for companies to invest in next-generation networks and services.

— Business Data Services – updated rules for high-speed, dedicated services by lifting rate regulation where appropriate to incentivize investment in modern fibre networks.

— Supply Chain Integrity – rules over public spending on suppliers perceived to pose a national security threat to the integrity of American communications networks or the communications supply chain.

Regulations at the local level are to be reviewed to enable the smoother deployment of 5G infrastructure. Several states have already introduced 5G and small cell-related legislation. The legislation varies between states, but has the same basic principles of:

— a streamlined application processes to access public areas;

— caps on costs and fees; and

— streamlined timelines for consideration of cell site applications.

For example, San Jose, CA had previously charged MNOs an annual fee of $US3,500 per small cell but has recently announced an agreement with Verizon, AT&T and Mobilitie which reduces this cost to $750 (if the MNO has over 2,000 sites). Similarly, Indianapolis, IN is charging an annual fee of just $50 per small cell.[35]

In addition to the above principles, the FCC have announced the creation of a $20.4 billion Rural Digital Opportunity Fund to extend high speed broadband to rural areas and to support the future of 5G.[36]

3.3.3 5G progress and plans

Whilst 5G services and handsets are not yet widely available nationwide, the MNOs have laid out plans to gradually extend their coverage throughout the next few years.

A summary of American MNO's progress on 5G is provided in Table 3.

Table 3: US commercial 5G progress

	Verizon	AT&T	T-Mobile/Sprint
Initial target areas	Initial focus at launch was on fixed wireless 5G services followed by mobile 5G six months after. Verizon's mobile 5G service is available across 13 cities.	Focus on mobile 5G services. 5G services available in select areas across 21 cities.	Launched a 5G network in select areas across six cities and plans to launch a nationwide 5G by December 2019.
Further targets	5G mobile services to reach 30 cities by the end of 2019. Plans to bring 5G to sports stadiums.	Coverage to be expanded throughout 2019 and nationwide 5G mobile expected in the first half of 2020.	5G coverage for 97% of the population within 3 years and 99% by six years.
Investment made and planned	Capex spend in 2019 expected to reach $18 billion, with the majority to be spent on 5G.	$130+ billion spent between 2014 and 2019 including capital investment and acquisitions of spectrum and wireless operations for 5G.	Plans to invest $40 billion in the first three years of 5G network build.

Source: Industry news[37]

Government incentives for 5G build

3.4 China

5G deployment in China has benefited from a number of state-backed initiatives such as rebates and subsidies. 5G services were launched in October 2019, and it is expected that by the end of 2019, the Chinese 5G network will be the biggest in the world.[38]

3.4.1 Market characteristics

China's mobile market is primarily served the by three state-backed MNOs: China Telecom, China Unicom and China Mobile. With each having significant free-float listings in Hong Kong and elsewhere. ARPU for the MNOs has declined in recent years, with the decrease in ARPU ranging from 5% to 17% between FY16 and FY19.[39]

2025

450 million 5G subscribers expected

3.4.2 National policy

The Government is backing a range of policy initiatives designed to aid the deployment of 5G:[40]

— **Contributions to the development of a global 5G standard**

In 2013, the Ministry of Industry and Information Technology (MIIT) and the National Development and Reform Commission (NDRC) established the IMT-2020 (5G) Promotion Group, which includes nearly 60 industry experts. The group works to promote 5G research and has worked with governments and industry associations around the world including the US, South Korea, Japan, and the EU. Through taking a leading role in the development of global 5G standards, the Government hopes that Chinese technology will form a large part of the standards adopted – 30% of international patents related to 5G connectivity standards were from China as at May 2019.

High and mid-band spectrum

— **Making spectrum more accessible**

The standard spectrum fee for 5G licenses has been reduced: fees have been waived in their entirety for the first three years, and will not return to the full rate until seven years after licenses have been issued.

— **Promoting 5G trials**

The MIIT issued 5G trial spectrum permits in December 2018 for low and mid-band spectrum to the three MNOs. The operators were then given the go-ahead for commercial deployment after being allocated commercial 5G licenses in June 2019.

The stated goal for China is to build a standalone 5G network (however, MNOs have initially focused on non-standalone 5G). Standalone 5G will require large upfront investments for base stations, backhauls links and core networks in order to construct a new mobile network. Chinese MNOs have been undertaking trials for standalone 5G and China Mobile has recently launched a standalone 5G site in a test facility.[41]

Mobile operators have also benefited from local schemes. For example, the city of Shenzhen has outlined a number of incentives for 5G deployment such as grants of CNY10,000 (approximately $1,400) for every unique 5G base station deployed, with each operator eligible for up to CNY150 million (approximately $21.4 million). In addition, the Shenzhen Government will provide subsidised electricity use and support for land use rights to aid 5G rollout. Other forms of support offered include subsidised loans and risk compensation schemes.[42]

China's approach to spectrum allocations has prioritised mid-band frequencies, with plans for the higher frequencies to be announced in December 2019.[43]

3.4.3 5G progress and plans

China's MNOs launched their 5G services at the end of October 2019, ahead of the expected launch date of 2020, covering 50 cities with more than 86,000 base stations. The Government has stated that by the end of 2019, the country will have achieved the deployment of the largest 5G network in the world, with more than 130,000 base stations to be activated.[44]

MNOs commenced activities to sign up customers for 5G services in September 2019 and within a month, 10 million users had subscribed.[45]

The operators have committed to investing further to achieve wider coverage. It is estimated that by 2025, mobile operators in China will spend a total of $150 billion on their 5G networks, representing a 50% increase in the total amount spent on 4G between 2013 and 2018. It is also expected that by 2030, there will be 4.9million base stations deployed across China.[46]

Network sharing

The three MNOs use a form of passive network sharing with telecom towers being jointly owned through the state company, China Tower.[47]

Whilst the Chinese Government has not explicitly called for 5G network sharing, this strategy has been identified by China Telecom and China Unicom as a means to accelerate 5G rollout and to cut capital expenditure costs. The two MNOs have agreed to "co-build" and "co-share" networks across 15 cities.[48] It has been estimated by China Unicom's chairman that sharing infrastructure could save it between €25-34 billion. China's largest telco China Mobile could also be included in the initiative to deploy shared 5G infrastructure in low population density areas.[49]

Network sharing promoted by BEREC

2025

Target date for widespread coverage

Low and mid-band spectrum

3.5 Europe

The rollout of 5G across Europe started in summer 2019, with a few countries seeing limited launches in larger cities. The EU has outlined plans to coordinate 5G deployment across the region and the respective national authorities have also laid out their plans to complement the EU agenda.

3.5.1 European market characteristics

European mobile markets are typically characterised by three large MNOs, and a fourth, smaller MNO. The ARPU of European MNOs are low relative to the likes of American MNOs: average ARPU levels of the largest European MNOs across France, Germany, Italy, Spain and the UK were around 65% lower than the largest American MNO in 2018.[50]

3.5.2 EU policy

The European Commission launched the 5G for Europe Action Plan (Action Plan) in 2016 as a means to accelerate the coordination of 5G deployment across the EU. The Action Plan sets out a number of targets which includes the alignment of 5G roadmaps throughout the EU, promoting early 5G deployment and encouraging industry-led innovation. In addition, the EU has set aside a budget of €700 million for research, development and innovation over a period of seven years.[51]

In a paper prepared for the European Parliament in 2019 by the Policy Department for Economic, Scientific and Quality of Life Policies, it is stated that the European Commission is targeting a 2025 date for the rollout of 5G coverage to all urban areas across Europe.[52]

To promote 5G across the EU, the European Parliament has called for the creation of an optimal environment for private investors:[53]

> The European Parliament … has asked the Commission to propose rules fit for the digital age which would **boost investment, competition and innovation** for over-the-top services and telecom operators, to the benefit of consumers.
>
> It also calls for an **investment-friendly regulatory environment for fair competition**, a coherent European spectrum strategy with improved coordination in the allocation of spectrum, and it demands the acceleration of the EU's 5G standardisation efforts.
>
> – European Parliament

Network sharing

Recommendations have also been made by BEREC in relation to the potential competitive benefits of network sharing:[54]

> [where] operators are confronted with such a scarcity of available sites, or limited space or other essential inputs … such that they cannot individually deploy their parallel networks in order to supply demand … infrastructure sharing could be objectively necessary for competition among MNOs.
>
> – BEREC

A number of MNOs have also recognised the advantages of network sharing agreements (including passive, active, backhaul, active indoor spectrum, and others) for efficiency and cost reduction.

As such, BEREC has noted that European NRAs have reported an increase in the number of network sharing agreements:[55]

"Many NRAs see an increase or an increased need of passive sharing (Bulgaria, Cyprus, Poland, Sweden, UK), active sharing (Bulgaria, Croatia, Poland, Turkey, UK), spectrum sharing (Belgium, Croatia), active indoor sharing (Finland, Malta, Slovenia), fronthaul (Malta), backhaul (Malta, Sweden, UK, Switzerland), dark fibre (Poland), ducts (Poland) and sharing through user authentification (UK). New types of sharing are also expected, including specific providers of connectivity cooperating with MNOs (Austria, Spain), municipalities or public services participating in sharing (Germany) or even verticals (Austria) may be involved in sharing".

A summary of recent national policy developments across four of the major EU economies, France, Germany, Spain and Portugal is provided in this section, alongside a more detailed discussion of the UK's 5G policy. Common themes across the policy decisions is to promote collaboration and infrastructure sharing between MNOs, using public funds to support innovation and to allow spectrum to be allocated on a competitive basis.

UK policy

As part of the review of the Government's industrial strategy, the Department of Culture, Media and Sport (DCMS) has carried out the Future Telecoms Infrastructure Review (FTIR) which explores the incentives for investment in new digital infrastructure - including 5G.

Under the current mobile market model, there are multiple vertically integrated national operators supported by a number of commercial infrastructure agreements and supplemented by independent infrastructure providers.

As part of the review, DCMS evaluated several market structures as possible means to deploy 5G. One of the key conclusions of the review is that a competitive market is the best means to drive investment and deliver innovation:[56]

> …supporting a competitive market of mobile network operators, which the Government believes is an important driver of investment in 5G, as well as promoting innovation by new providers that could deliver 'innovative solutions' to challenges such as rural coverage.
>
> – UK Government

DCMS has also outlined a number of key recommendations to support a competitive mobile market and investment and innovation for 5G.[57]

1 **Making it easier and cheaper to deploy mobile infrastructure**

Planning reforms will be considered and the Government will strive to improve access to public sites and power supplies. Local deployment barriers will also be addressed.

2 **Supporting infrastructure models that promote competition and investment in network densification and extension**

This can be achieved by providing support to industry initiatives to build on commercial MNO infrastructure sharing agreements.

3 **Stimulating demand and new use cases through the 5G Testbeds and Trials Programme**

A series of projects will be funded by the Government to explore different connectivity solutions and business models. An initial phase of projects have been launched which focuses on connected urban communities.

4 **Securing a diverse set of innovative 5G services through flexible and future spectrum policy**

The telecoms NRA, Ofcom, has been encouraged to appraise flexible licensing models for spectrum which includes spectrum sharing as a way to enable new players to access spectrum and invest in new business models.

Government funding

One of the recommendations of the UK Government is to stimulate demand via the 5G Testbeds and Trials programme. The UK Government has set up a £200million fund for this, which aims to improve UK businesses opportunities to develop 5G technology for domestic and global markets in a range of geographic and vertical market segments. In March 2018, six trials were announced with each receiving between £2-5 million in government grants. The trials are concluding in 2020. Additional funding has also been provided for trials of 5G in urban communities, on roads and rail, and for 5G security.[58]

Spectrum

The UK's approach to spectrum has seen Ofcom hold spectrum auctions for 2.3 GHz and the 3.4 – 3.6 GHz band in 2018, with initial 5G launches being in the 3.4 – 3.6 GHz band. It has also announced its intention to hold another auction for further spectrum in the 700 MHz and 3.6 – 3.8 GHz band in spring 2020. The amount of spectrum any one operator can win will be capped at 37% of the overall spectrum available to ensure effective competition:[59]

> Ofcom has a duty to ensure spectrum is used efficiently. We also ensure companies can compete fairly and customers have a good choice of mobile networks. So, to promote competition, we are still proposing a 37% cap on the overall spectrum that any one mobile company can hold following the auction. Promoting strong competition between mobile companies is important because it leads to better services for customers.
>
> – Ofcom

Network sharing

In addition, the UK Government has recently announced a 'Shared Rural Network' plan, in conjunction with MNOs, to provide high quality 4G coverage for rural communities. Under this deal, operators will invest £530 million and this will be supplemented by a further £500 million of public funding. These funds will be used by the four MNOs to come together to share existing masts and infrastructure, and government-owned infrastructure will be opened up for use by the MNOs.[60]

The UK Government aims to achieve widespread 5G coverage by 2027.[61]

National policy developments: France, Germany, Spain and Portugal

France

The French telecoms NRA, ARCEP, launched a public consultation in summer 2019 in relation to licenses for the 3.4-3.8 GHz band. This band has been described by ARCEP as the 'core' band as it strikes a balance between coverage and speed.

Under the draft plans, ARCEP is proposing to allocate blocks of spectrum to up to four MNOs in exchange for commitments relating to regional coverage under an initial allocation, followed by a second allocation for further spectrum. The amount of spectrum that can be obtained by any one operator will be capped.

In relation to geographical coverage commitments, ARCEP has proposed that each operator should launch 5G services in at least two cities by the end of 2020, to reach 3,000 sites by 2022 and 8,000 sites by 2024 and 12,000 sites by 2025.

Germany

The Federal Ministry of Transport and Digital Infrastructure has outlined 'Five Fields of Action' as part of its strategy to fully implement 5G by 2025:

1. stepping up network rollout;
2. making available frequencies based on demand;
3. promoting cooperation between telecoms operators and user industries;
4. supporting 5G research; and
5. initiating 5G for cities in municipalities.

A multi-band 5G spectrum auction concluded in June 2019 which saw spectrum allocated to four MNOs. The spectrum allocation included coverage commitments including speeds of 100Mbps at a minimum to at least 98% of households in each state by 2022. In addition, each operator must set up 1,000 5G base stations and 500 base stations in defined rural areas by the end of 2022.

The GSMA welcomed the auction, which included C-band spectrum. *"The C-Band is the most vital frequency band for 5G,"* said Mats Granryd, director general of the GSMA. *"Germany is demonstrating 5G leadership in the timely release of this vital spectrum."*

Spain

The Spanish Government has drawn up a 5G national plan which has a number of pillars to support the EU Action plan:

1. radio spectrum management and planning – securing the availability of necessary bands for 5G;
2. driving 5G technology – network and service pilot projects and R&D&I activities;
3. regulatory issues – providing an adequate and flexible legal framework to promote and enable investment; and
4. 5G Plan coordination and international cooperation – developing the necessary infrastructure for 5G.

Furthermore, the Government has also stated that it will continue to support and foster the sharing of infrastructure for mobile networks.

Auctions for the 3.6-3.8 GHz spectrum band were held in summer 2018 with three out of the four participating MNOs receiving a share of spectrum.

Portugal

Anacom, the Portuguese NRA, has outlined key success factors for 5G deployment surrounding the following areas:

1. infrastructure – regulating access and sharing of passive infrastructure, creating incentives for effective competition at the infrastructure level;
2. spectrum – theoretical identification of 700 MHz as a suitable band for achieving nationwide coverage and assessing the feasibility of 3.4 – 3.8 GHz and 26 GHz;
3. financing – facilitating the supply of industry-led risk capital to foster innovation, national support for R&D and promoting cooperation between traditional telecoms and future vertical markets; and
4. small cells – facilitating deployment.

Spectrum auctions will be held in summer 2020 for the allocation of 6 bands, including 700 MHz and 3.6 GHz. Anacom believes that market conditions should be created to *"enable the emergence of operations with different dimensions"*, and as such, interested parties will be able to *"acquire the amount of spectrum they really need and value"*.

Source: Industry news and regulatory updates[62]

3.5.3. European 5G progress and plans

Europe has seen limited 5G launches to date. With regards to the European countries considered, 5G services have not yet launched in Portugal and France. Details of launches in the other countries are as follows:

Germany

5G services were launched by Vodafone and Deutsche Telekom in late summer 2019, covering 20 and 5 cities respectively.

Spain

Vodafone is the first to launch 5G services in Spain. 5G from Vodafone is available across 15 cities in Spain in June 2019, with around 50% coverage in the available cities. No other 5G services are yet available at the time of writing.

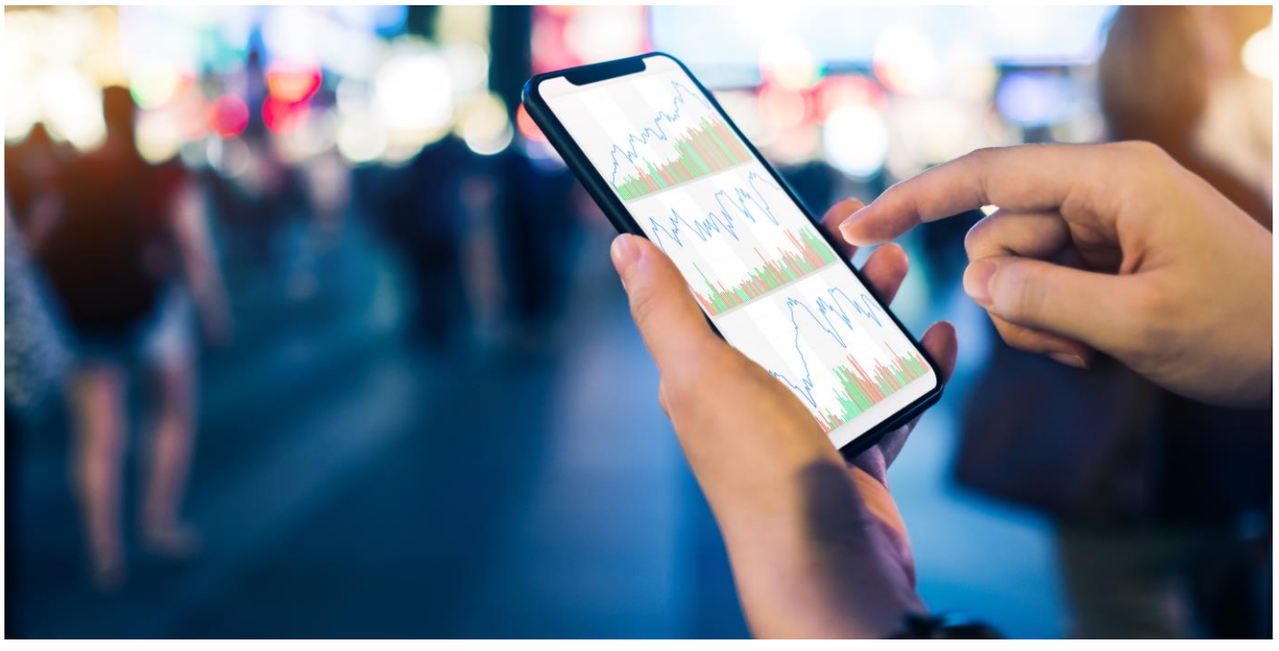
UK

The UK is the first country to have four 5G networks. EE was the first MNO to launch 5G mobile services in the UK in May 2019, covering 10 cities. This was then followed by Vodafone and O2 respectively in July and October 2019, with Vodafone covering 15 cities and O2 covering 6 cities. The fourth MNO, Three, has launched 5G broadband services in London. Further rollouts of 5G mobile services to more cities are expected over the remainder of 2019.

Spectrum costs

Concerns have been raised by a number of European MNOs over the high costs of spectrum due to the auction mechanisms used for allocation. These costs may then hinder MNOs ability to invest in 5G networks. For example, the German spectrum auctions have been controversial due to the sums paid by the participating MNOs: a total of €6.55 billion was paid by the four bidders, with the highest sums spent by Deutsche Telekom and Vodafone Germany (€2.17 billion and €1.88 billion, respectively). In response to the results of the auction, the CEO of Deutsche Telekom said:[63]

> The result [of high spectrum costs] is a dampener on our network buildout. Spectrum, again, is much more expensive in Germany than elsewhere. Network operators now lack the money to expand their networks.
>
> – Deutsche Telekom



Network sharing

European MNOs have relatively low levels of ARPU relative to their counterparts in the US.[64] Given the high costs of 5G deployment and lower revenues, a number of European MNOs are looking to the use of network sharing agreements. The use of network sharing agreements has also been encouraged by policy makers across Europe.

The largest pan-European MNOs, Vodafone, Telefónica, Deutsche Telekom, and Orange have all outlined the benefits of network sharing, and have entered into commercial agreements with each other and other MNOs. Some examples of network sharing are:

UK

Vodafone has entered into a network sharing deal with O2 which includes both active and passive elements. There will be active 5G sharing including radio antennas on new joint network sites. Vodafone and O2 have also agreed to extend existing passive network sharing on approximately 2,700 existing sites in 23 of the UK's larger cities. At these sites, each party will install its own 5G radio equipment, fibre backhaul connection and power supply, whilst continuing to share the physical elements such as the mast.[65]

Spain

In 2019, Orange and Vodafone have extended their existing active network sharing agreements to cover a total of 14,800 sites. The active sharing initiative will be extendable to cover 5G. In addition, Orange has also entered into a network sharing agreement with Masmovil for fibre services, which will facilitate 5G network development. The agreement is expected to save Masmovil around €40 million a year.[66]

Germany

Deutsche Telekom has announced its intention to enter into a network sharing agreement with Telefónica Deutschland and Vodafone. The MNOs plan to coordinate the set-up and operation of up to 6,000 new cell sites. Under the plan each participating MNO should set up an equal number of new sites which can then be used by each party and fitted with their own antennas and the appropriate network technology as required.[67] Deutsche Telekom has announced:[68]

> We want to share the infrastructure needed for 5G with other network operators, particularly in rural areas. Therefore, we are opening up our fiber-optic network to other providers. Just how we recently agreed with Telefónica/O2. We give our competitors the opportunity to share all of our cell towers in rural areas and alongside traffic routes. We also hope for similar agreements with other network operators. Not only does this speed up network build-out. It also ensures that expansion, particularly in rural areas, is simpler and more cost-effective. Together, we cover the white spots.
>
> – Deutsche Telekom

Up to four 5G networks

2022

Target date for 50% coverage

High and mid-band spectrum

3.6 Singapore

5G services have not yet launched in Singapore, however, the Government has concluded its 5G consultation. The Government has laid out plans to invite the four existing MNOs to compete to build the two proposed nationwide networks, commencing in 2020.

3.6.1 Market characteristics

The Singaporean mobile market is served by three larger MNOs (Singtel, StarHub, and M1) and a smaller MNO, TPG. Mobile revenues have declined in recent years, with a contraction of 5% expected in 2019, which has been attributed to a fall in post-paid ARPU (for example, the ARPU of StarHub 3Q19 postpaid ARPU declined 8% compared to the previous year).

3.6.2 National policy

Singapore's Infocomm Media Development Authority (IMDA), has signalled the need for network competition to bring 5G to the country. Plans have been outlined for two national wholesale networks to be built and all four existing MNOs will be invited to participate in the tender. The IMDA believes that network competition is key to driving success in 5G:[69]

> IMDA holds the view that competition at the infrastructure layer, where feasible, will ensure that operators are incentivised to invest in new technology, innovate, upgrade and compete. Thus, it will be important to have at least two nationwide networks as a start.
>
> – IMDA

The two national networks are expected to be built on a standalone basis, rather than relying on upgrades to existing 4G infrastructure. The Singaporean Government believes that only standalone 5G networks have the capacity to support the capabilities offered by 5G such as speeds of up to 20 Gbps, more reliable broadband and more connections for devices.[70]

Whilst the Government set out its initial intention for two national networks, it has also recently revealed plans for a further two networks. The IMDA will award further spectrum to allow another two operators to deliver localised 5G networks on a non-standalone basis. The expectation is that these networks will help support industrial demands for 5G such as smart ports and smart factories which make use of remotely operated machinery.[71]

The IMDA's approach to 5G is built on the following principles:[72]

— **Infrastructure readiness**

Singapore intends to commence the rollout of 5G networks by 2020, with 5G standalone capability to cover at least of half of Singapore by the end of 2022. This will be possible due to the geography of Singapore as a small country with very high population density and strong existing telecoms infrastructure. The IMDA will also work closely with agencies to facilitate the deployment of 5G networks (for example, to ensure access to rooftop spaces and street lamps required for 5G equipment installation).

— **Holistic regulatory approach**

The IMDA has said it will take a holistic approach to 5G deployment and as such, will award spectrum to operators which it deems to be able to deliver the desired outcomes and at the best value. An auction was rejected as the IMDA did not deem it to be an appropriate way to achieve the desired policy outcomes.

For the two nationwide non-standalone networks, the IMDA has said it will allocate equal amounts of spectrum in the **3.5 GHz band; it stated that this was deemed to be the optimal band for 5G by the industry**. The mmWave bands will be allocated for use across the localised standalone networks. Spectrum will be awarded by mid-2020.

— **Public-private collaboration for 5G use cases**

The Government has committed to support research and innovation, including supporting 5G trials across a number of sectors (for example, maritime, urban mobility and smart estates) - S$40 million (USD $29.3 million) has been set aside by the Government for R&D purposes. It will also co-invest with industry to develop new 5G use cases, for both businesses and consumers.

Network sharing

The IMDA has also noted the benefits of network sharing agreements:[73]

> … in the initial years of 5G deployment, coupled with the anticipated large-scale deployment of small cells, **network sharing could be an effective means for MNOs to reduce the cost of building and operating a mobile network infrastructure**, thereby accelerating the rollout of 5G services in Singapore.
>
> – IMDA

3.6.3 5G progress and plans

There has been speculation in the local press about M1 and StarHub being in talks over a network sharing agreement in order to reduce costs ahead of a nationwide rollout of 5G.[74] As noted above, after reviewing responses to its 5G consultation, the IMDA has deemed network competition to be the most efficient means to achieve its desired outcomes.

The four MNOs have engaged in a number of testing activities in readiness for 5G. Some examples of recent activities include:

— The creation of a '5G Garage' by Singtel (in partnership with Ericsson and Singapore Polytechnic), where a number of 5G applications such as 4K video drones and augmented reality/virtual reality assistance, cloud gaming and autonomous vehicles have been tested;[75]

— Pilots on the 3.5 GHz band for outdoor use by StarHub in conjunction with Nokia, demonstrating manufacturing uses;[76] and

— The trial of both standalone and non-standalone network by M1. M1 has also partnered with both Nokia and Huawei. With Nokia, M1 has been testing on a number of smart city applications (such as smart street lighting) and with Huawei, M1 has been testing virtual reality applications.[77]

Beauty contest for spectrum

2023

Completion of first 5G network

High and mid-band spectrum

3.7 Japan

Commercial 5G services have not yet been launched in Japan. However, following the allocation of spectrum in April 2019, 5G services are expected to reach the market by spring/summer 2020 in readiness for the 2020 Olympics.

3.7.1 Market characteristics

There are three major Japanese MNOs: NTT Docomo, KDDI and Softbank. A new MNO has also entered the MNO market in recent years: Rakuten. As a new player, Rakuten is also looking to launch 5G services, having been awarded spectrum by the Japanese Government.

Japanese mobile ARPU is relatively high when compared to their European peers at around 50% higher than European levels and mobile revenues have increased around 2% over the last 10 years.[78]

3.7.2 National policy

The Japanese Government has allocated spectrum to be used for 5G services to four MNOs via a beauty contest whereby operators submitted detailed business cases in order to receive licences. Allocations were made to operators at no cost based on the assessment of their business cases. Specifically, spectrum in the 3.7 GHz, 4.5 GHz and 28 GHz bands was allocated.[79]

In return for spectrum, the Japanese Government required that operators provide significant coverage throughout the country, specifically:

— all four MNOs must launch 5G services using the new spectrum in every Japanese prefecture within two years; and

— following the division of the country into 4,500 zones, all four MNOs are required to set up base stations in at least half of these within five years.

On a regional level, some local governments have expressed their intentions to reform local policies to aid in 5G deployment. For example, the Tokyo Metropolitan Government is looking to open up access to buildings and other facilities owned by the city to the MNOs to promote the installation of base stations.[80]

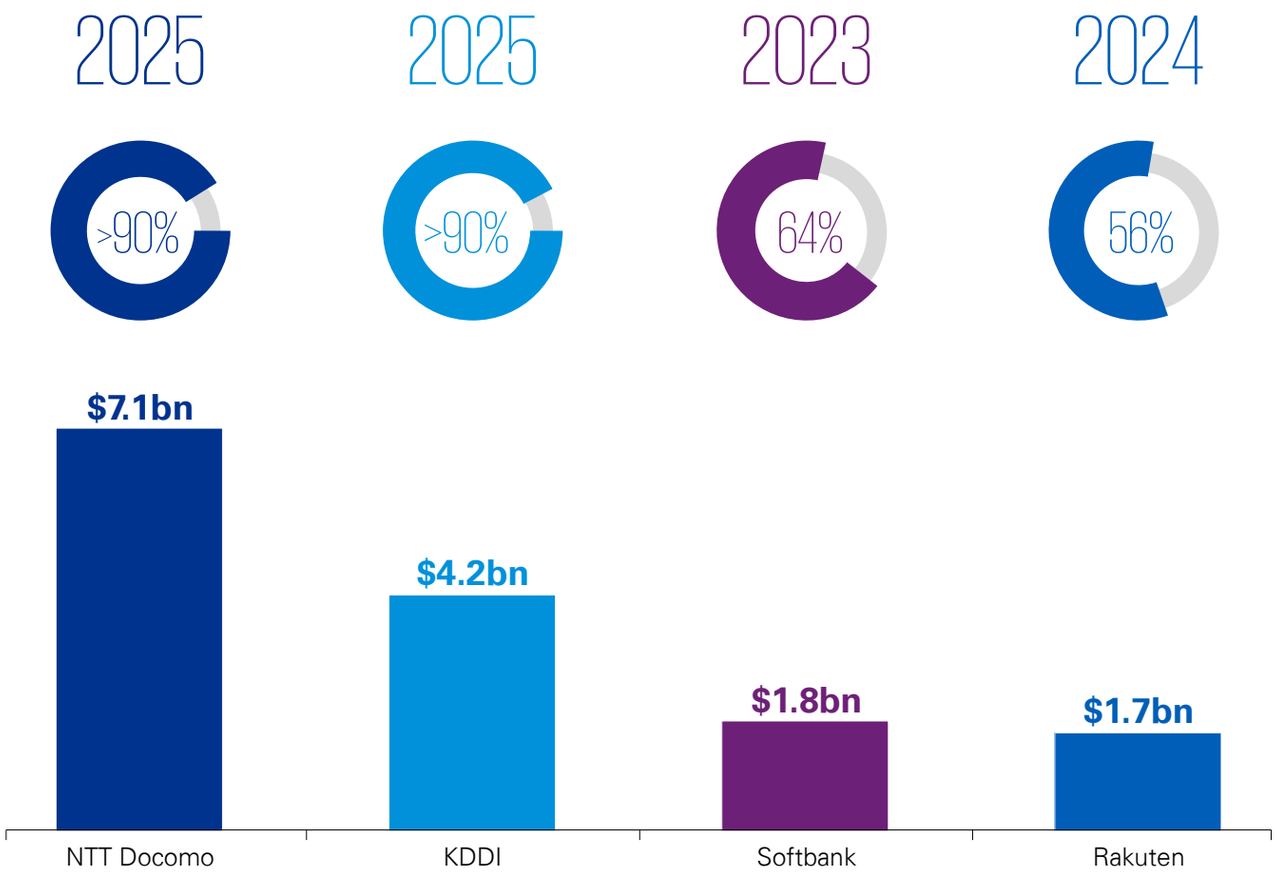
3.7.3 5G progress and plans

Commercial 5G services are expected to launch in spring/summer 2020 and ahead of this, the four MNOs have outlined their plans for coverage, investments and rollouts, these have been summarised in Figure 12 below.

Network sharing

It has been announced that KDDI and SoftBank have entered into a network sharing agreement to make use of each other's base stations to promote 5G rollout in rural areas. The two MNOs will explore options to establish a joint construction company that would facilitate construction designs and manage the construction work on behalf of both parties.[81]

Figure 12: Expected network completion date, coverage and expected total investment by completion



Source: Industry news[82]

Annex 1: An introduction to spectrum

The evolution of each generation of mobile technology has been supported by the use of various bands of spectrum, i.e. radio frequencies used for communication over the airwaves. Spectrum is a scarce resource and an essential input in the supply of mobile services. It contributes to the quality of service and coverage of a mobile network, as well as the capacity of the network. Without a sufficient range of spectrum, a mobile network will not be able to provide the optimal range of services.

5G infrastructure is likely to be a 'layered approach' of three new networks on top of the existing infrastructure – each using different spectrum bands. This is based on the international experience across the EU and the UK, the USA, South Korea, Japan and China.

The main bands identified by the Radio Spectrum Policy Group (SPG) of the European Commission as part of their strategic roadmap towards 5G for Europe are 700 MHz, 3.4-3.8 GHz and 26 GHz, which belong in the low, mid and high-band spectrum band respectively.[83] The various bands have their own respective characteristics which make them suitable for different uses:

— **Low-band frequency spectrum (<1GHz)** is used by 2G, 3G and 4G networks for voice and mobile broadband (MBB) services and Internet of Things (IoT). Low-band spectrum provides wide coverage from existing macro sites. However the limited amount of spectrum available and the limited spectral efficiency due to the inability to use massive MIMO means that it provides limited additional capacity or user bandwidth. It is therefore ideal for extending coverage, reach (inside/around buildings and reliability, and is used as a coverage layer in 5G network deployments;

— **Mid-band frequency spectrum (1-6 GHz)** is also used for 2G, 3G and 4G services. There are relatively large amounts of new spectrum available in this band. 3.4-3.8 GHz is ideal for delivering Gbps data speeds to mobile users and needs a Radio Frequency (RF) channel widths of at least 100 MHz. This wide RF channel bandwidth differentiates 5G in this spectrum range from a 4G world. This has by far been the most popular band for deploying 5G so far.

— **High-band frequency spectrum (> 6 GHz**) has limited coverage capabilities (due to the shorter wavelengths) and poor indoor penetration. However the large amount of spectrum available, its suitability for massive MIMO, and the resulting gain in spectral efficiency allows it to deliver high bandwidths and traffic density using small cells.

Under current national policies around the world, the most common high-frequency spectrum being considered is the 26 – 28 GHz band; this band is collectively known as the 'mmWave' band.

26 GHz is ideal for delivering 10 Gbps or more to fixed locations of very high footfall such as railways stations and stadia. It is being used to serve nomadic rather than mobile users through tens of thousands of 'hot spots'. This is the primary spectrum band being deployed in the US for 5G.

According to the SPG:[84]

> …700 MHz band can be used to provide wide area coverage, the 3.6 GHz band can be used to provide high capacity and coverage, using both existing macro cells and small cells. The 26 GHz band is likely to be deployed in areas with very high demand, for example transport hubs, entertainment venues, industrial or retail sites and similar. Because of its characteristics, the 26 GHz band will not be used to create wide area coverage.

SPG further states that:[85]

> … lower frequencies, such as 700 MHz, are better suited to provide widespread coverage (both geographic and indoor) than the other bands identified by the SPG for 5G. Widespread coverage delivered across the different mobile bands is particularly important for the growth of the massive machine-type communications (mMTC) market.

Table 4: Summary of spectrum positions

Country	700 MHz	3.4-3.6 GHz	3.6-3.8 GHz	>24 GHz
US	×	+++ Mid 2020	×	✓ May 2019
S. Korea	×	✓ June 2018	×	✓ June 2018
China	×	✓ June 2019	×	+++ Dec 2019
Japan	×	×	✓ April 2019	✓ April 2019
Singapore	×	+++ Mid 2020	×	+++ Mid 2020
France	✓ 2015	+++ Q4 2019/Q1 2020	+++ Q4 2019/Q1 2020	+
Germany	✓ 2015 (700 – 1800 Mhz)	✓ June 2019	++	++
Portugal	+++ Mid 2020	++	+++ Mid 2020	++
Spain	+++	✓ 2016	✓ 2018	+
UK	+++	✓ 2018	+++ 2020	++

+ earmarked, ++ ongoing process, +++ plans scheduled, ✓ allocation carried out, × plans unknown

Source: KPMG analysis of industry and regulatory reports, European 5G Observatory[86]

	Other	Details
	×	Auction; licenses for 28 GHz made available in select areas; licenses for 24 GHz made available throughout the country.
	×	Auction; 3.5 GHz licenses valid for 10 years, 28 GHz licenses valid for 5 years.
	4.9 MHz allocated in June 2019	Standard spectrum fee per MHz for 5G licenses has been reduced, fees have been waived in its entirely for the first three years, and will not return to the full rate until seven years after licenses have been issued.
	4.5 GHz allocated	Beauty contest; security, coverage and investment obligations and commitments.
	×	Beauty contest; 100 MHz of 3.5 GHz to be allocated to two MNOs each for 15 years; coverage obligations; 26 – 28 GHz to be allocated without a license fee for a period of 16 years.
	1.5 GHz and 2.6 GHz earmarked	Initial beauty contest; with reserve prices; coverage obligations; planned minimum will be at least equal to 40 MHz, while the planned maximum is 100 MHz. Unallocated spectrum auctioned off.
	2000 MHz June 2019	Auction; coverage obligations.
	450 MHz, 900 MHz, 1500 MHz, 1800 MHz, 2.1 GHz and 2.6 GHz TBC	Auctions planned.
	×	Auction; 3.3-3.8 GHz licenses valid for 20 years (fees spread over the period).
	2.3 GHz allocated	In respect of the 700 MHz and 3.6-3.8 GHz spectrum: auction; amount available to any one MNO capped at 37%; no coverage obligations.

Annex 2: Network sharing

Network sharing: An introduction

Given the significant costs involved in developing a 5G network, network sharing agreements, both passive and active, help minimise these costs. Network sharing agreements can be adopted for the development of 5G networks to support competitors' different needs. There are two types of network sharing agreement:

Passive sharing is when MNOs share non-electronic infrastructure at a cell site such as masts, sites, cabinets, power, and air conditioning. Passive sharing agreements of non-electronic infrastructure in dense urban areas can help overcome issues with space.

Active network sharing is the sharing of active elements of the network such as antennas and radio network controllers. Active sharing agreements in rural areas can help overcome the significant infrastructure cost of serving some communities.

In a passive sharing agreement, competitors' networks remain separate, whereas with active sharing an operator can use another's network where it has no infrastructure. Tailoring agreements to specific situations would also allow MNOs to reduce their infrastructure cost and accelerate the commercialisation of 5G.

The rationale

5G is likely to need more fibre connections and base stations than previous generations of mobile technology. Therefore, mobile network operators will need to construct more base stations to provide complete 5G network coverage. In addition, in some high density areas there are limited locations available for each MNO to construct their own base stations. If MNOs are unable to construct sufficient base stations they cannot provide continuous and complete coverage to customers. Network sharing agreements could be used in this scenario to optimise the use of the limited space available to share base station infrastructure, allowing multiple MNOs to provide services.

The European Commission considers that the deployment of 5G could cost up to three times that of previous mobile generations. It has estimated that it will cost €500 billion to meet the EU's 2025 connectivity targets, which includes 5G coverage in all urban areas.[87] This increased cost of constructing 5G infrastructure may become prohibitive for MNOs to providing significant 5G coverage to a city or country.

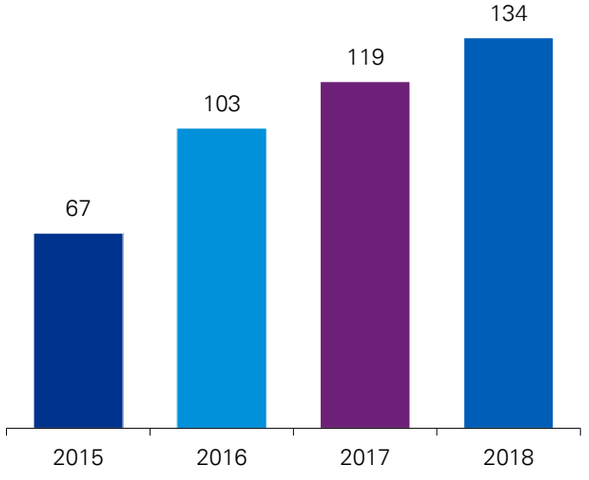
One solution is the use of network sharing agreements to share the cost operators of the network development. BEREC estimated the cost savings based on the type of network sharing agreement used, with passive agreements expected to save between 16%-35% on capex and opex, and active agreements saving between 33%-45% on capex, and 25%-33% on opex.[88] These cost savings could help accelerate the deployment of 5G technology.

A growing trend

Network sharing agreements have previously been used in the rollout of 3G and 4G, where MNOs used them to service customers in thinly populated rural areas where it may not have been feasible to support competing infrastructure. With the deployment of 5G, MNOs are likely to see this as an attractive option in some urbans areas where there is limited space for base stations.

Since 2015, there has also been a significant increase in the use of network sharing agreements around the world, as shown in Figure 13.

Figure 13: Number of countries where MNOs share infrastructure (passive or active)



Source: ITU [89]

Annex 3: 5G Infrastructure overview

Key components of 5G infrastructure

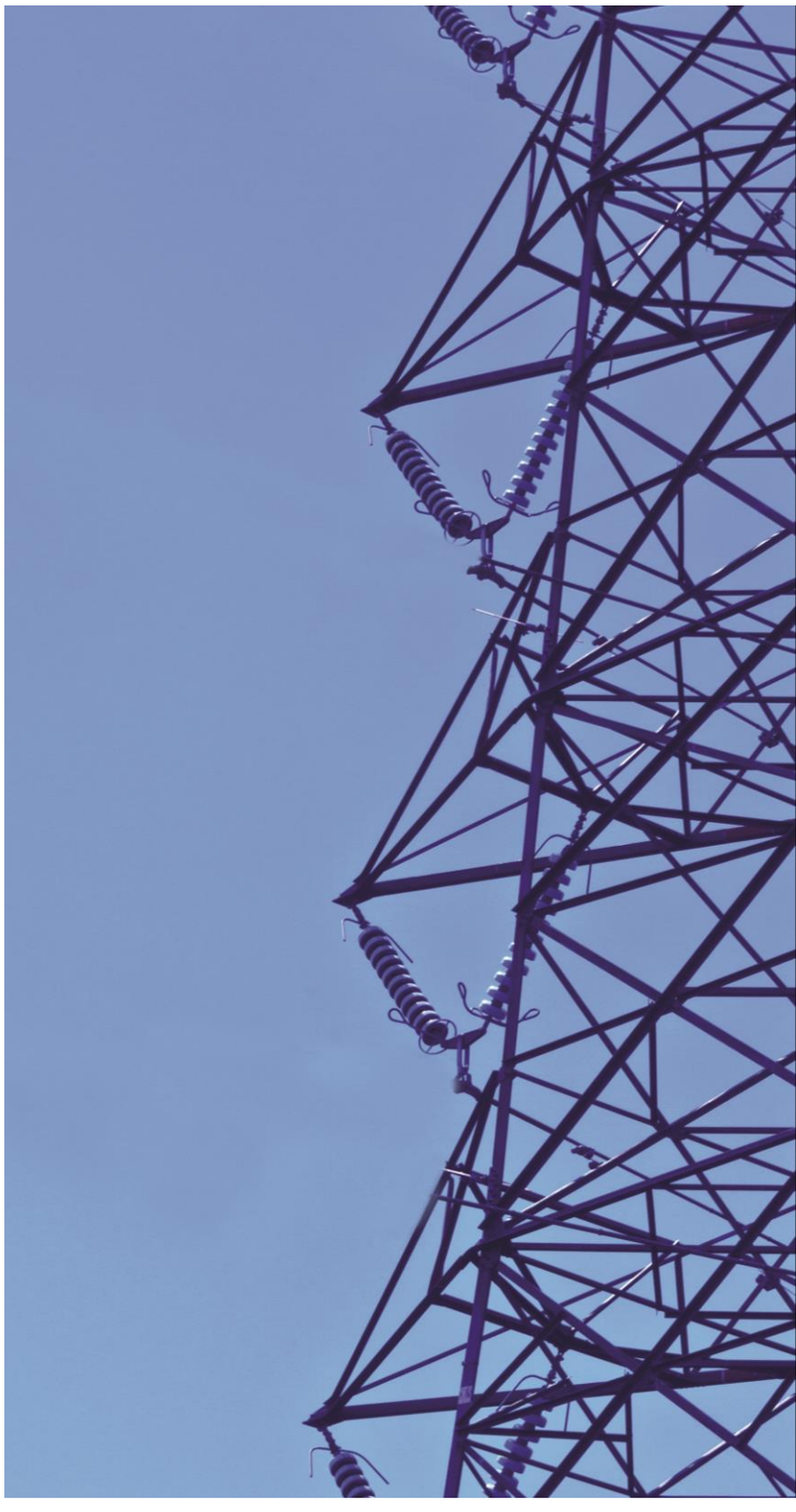
Base stations: equipment which contains radio communication equipment to send and receive mobile and voice data signals over the area surrounding the base station to the MNO network. Base stations must be connected to power and have a backhaul connection. These are several types of base stations including mobile masts, macro cells and small cells.

Macro cells: a type of base station which is used to provide coverage over large area. Macro cells are typically installed in ground-based masts, rooftops or other existing structures

Small cells: a type of base station which provides coverage to a much smaller area relative to a macro cell. Small cells are used to complement macro cells and provides coverage in localised areas where macro cells cannot provide adequate coverage and/or capacity, for example, in dense urban areas. Small cells can be mounted on a wider variety of locations compared to macro cells, for example, on street lamps and traffic lights.

Backhaul: the connection between base stations and the core internet and phone network.

5G standalone networks will require small cells to deliver the dense coverage and high capacity required. In particular, 5G standalone networks will make use of higher bands of spectrum which cannot travel across large distances and will require more small cells. Therefore, mobile operators will need to invest in additional base stations to improve their coverage if they follow a standalone approach.



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