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Enabling 5G in the UK

Discussion document

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About this document

5G is the next generation of mobile technology. It is expected to deliver faster and better mobile broadband, and to enable more revolutionary uses in sectors such as manufacturing, transport and healthcare. This may create benefits for people and businesses and expand the role of wireless connectivity within the economy and society.

As the UK's communications regulator, we have a role to play alongside Government and industry in enabling the development and rollout of 5G, and unlocking its benefits. In this document we provide an update on the actions we will be taking to facilitate 5G rollout in the UK.

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1. Executive summary

1.1 5G is the next generation of mobile technology. It is expected to deliver faster and better mobile broadband, and to enable more revolutionary uses in sectors such as manufacturing, transport and healthcare. This may create benefits for people and businesses and expand the role of wireless connectivity within the economy and society. As the UK's communications regulator, we have a role to play alongside Government and industry in enabling the development and rollout of 5G, and unlocking its benefits.

1.2 Ofcom shares the Government's ambition for the UK to become a world leader in 5G.[1] In this document we provide an update on the actions we will be taking to facilitate 5G rollout in the UK.

1.3 We plan to release different types of spectrum bands for 5G as soon as practicable. We already make innovation and trial licences available to enable 5G trials and are today launching our Innovation and Trial portal to help applicants access spectrum for innovative uses.[2] We see great potential to use these licences to test innovative 5G applications using high frequency spectrum, in particular 26 GHz, the 5G millimeter wave[3] pioneer band.

1.4 We will continue to work with the UK Government and governments in the nations to ensure site access and planning are not a barrier to the deployment of 5G, and we will ensure there are a range of solutions available for 5G sites to connect to core telecoms networks ('backhaul'). Finally, we will collaborate with other European regulators to ensure that net neutrality regulation is not a barrier to 5G evolution.

1.5 We will act as a facilitator, working across different sectors to encourage them to work together, and with other countries to further understand the potential applications of 5G, and how they might work in practice in the UK.

What benefits will 5G bring?

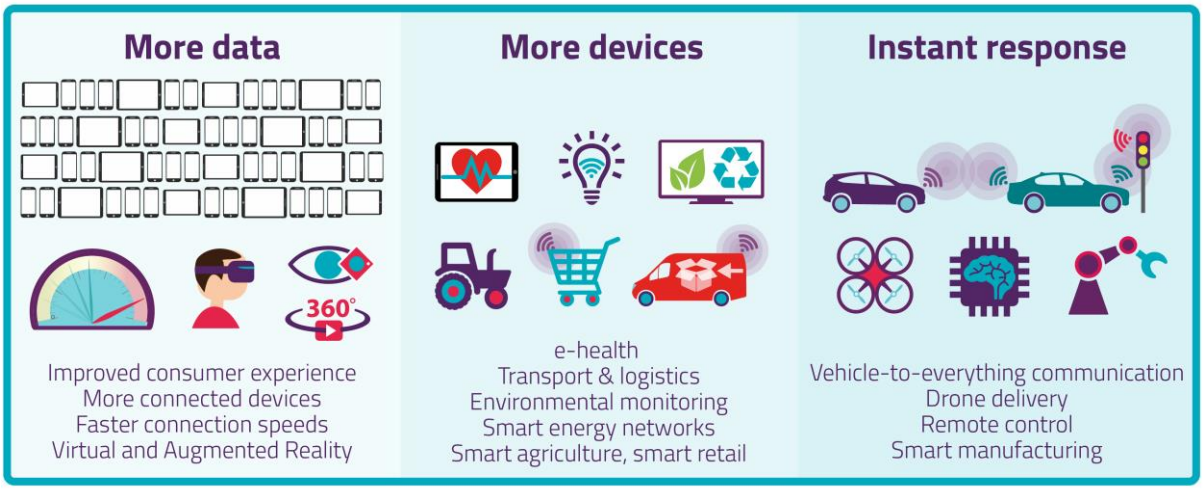
1.6 People are becoming more reliant on accessing broadband services wherever they live, work or travel. The amount of mobile data we use continues to grow, increasing by over 40% last year.[4] While this document focuses on the enablers and the wider implications of 5G, wireless technologies such as satellite, wifi and other short range technologies (e.g. sensors and radar for vehicle-to-vehicle communications) are also evolving and will provide complementary solutions to 5G.

[1] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/597421/07.03.17_5G_strategy_-_for_publication.pdf
[2] www.ofcom.org.uk/innovation
[3] Millimetre wave (mmWave) is a term that indicates the spectrum between 30 GHz and 300 GHz – wavelengths at these frequencies are between 1mm and 1cm long. The term is commonly used refer to frequencies above 24 GHz and this is how we use it in this document.
[4] https://www.ofcom.org.uk/__data/assets/pdf_file/0016/108511/connected-nations-2017.pdf

1.7 5G is being developed and will be rolled out across wireless networks over the next few years. Initially, 5G is expected to improve speed and capacity for mobile broadband. This means that mobile network operators are likely to be the first to deploy 5G networks and services on their existing sites to meet growing demand for data.

1.8 In the longer term, we expect more innovative uses of 5G to benefit a variety of sectors such as manufacturing, transport, healthcare; also known as industry verticals. There are many potential uses for 5G, but users will ultimately choose which applications and services are widely used. The greater versatility and capability of 5G means that it will likely be used for a much wider range of purposes than mobile broadband for businesses and consumers, and by a diverse set of providers – beyond the mobile network operators.

Figure 1: Expected uses of 5G



What we are doing to make 5G available in the UK

1.9 We describe in more detail below the actions we are taking to help deliver the early rollout and use of 5G in the UK, specifically:

i) making spectrum available for 5G and other wireless services;

ii) working with Government and policy-makers to ensure access to sites is not a barrier to 5G;

iii) ensuring access to appropriate connectivity between 5G base stations and the core network (also known as backhaul);

iv) ensuring net neutrality regulation is not a barrier to deployment; and

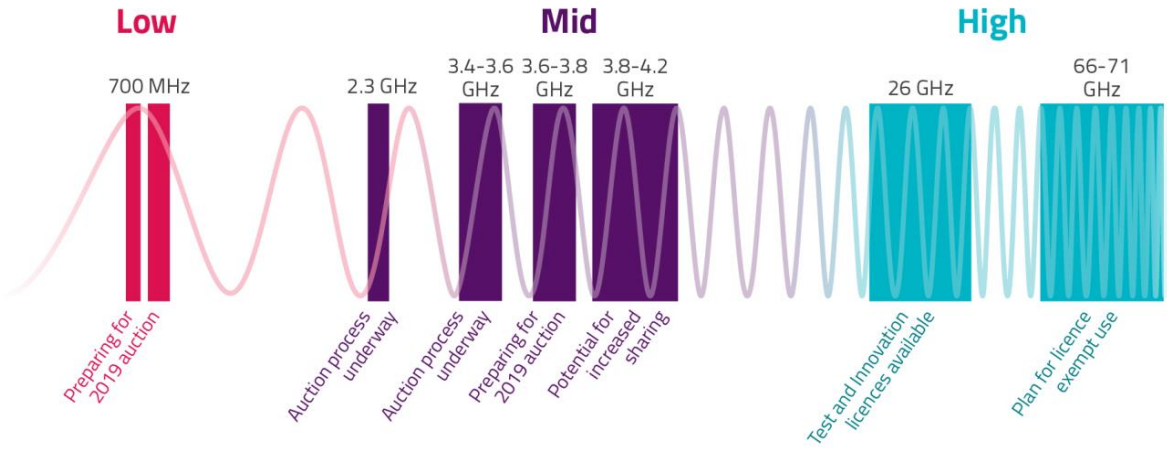
v) acting as a facilitator, working with Government, different industry sectors and other countries to further understand potential applications of 5G.

We are making spectrum available for 5G and other wireless services

1.10 Our work to meet the increasing demand for 5G and other wireless services is driven by our objectives to secure benefits for consumers and business and deliver optimal use of the spectrum.

1.11 We have identified spectrum bands at low, mid and high frequencies which have different characteristics and can be used to deliver different benefits. For example, lower frequencies are better suited to providing coverage as they travel further, while higher frequencies have a shorter range. As illustrated in the figure below, we make spectrum available in a variety of ways at each range; for example, national dedicated licences, shared spectrum access, and access on a licence exempt basis are available to meet demand for deployments at national, regional and local level.

Figure 2: Spectrum pipeline



1.12 **Low-frequency spectrum** will support improved coverage and user experience. We are planning to auction the 700MHz band in 2019, and are currently consulting on proposals for coverage obligations that could be attached to the award process.[5]

1.13 **Mid-frequency spectrum** will meet the increasing capacity demand for mobile services including 5G. The 3.4-3.8 GHz band has been identified as the primary band for 5G in Europe as it offers increased capacity for mobile broadband over wide areas. We have begun the process of auctioning the 2.3 GHz and 3.4 GHz bands and plan to auction the 3.6-3.8 GHz band for mobile services in 2019.

1.14 We also plan to further consider the possibility of increased sharing in the 3.8-4.2 GHz spectrum for innovative new uses. We believe we could extend shared access to broadband wireless systems within the 3.8–4.2 GHz band, building on the current coordination arrangements for shared use already in place in the lower part of the band.

[5] https://www.ofcom.org.uk/consultations-and-statements/category-2/700-mhz-coverage-obligations

1.15 **High-frequency (mmWave) spectrum** which, to date, has not been used to deliver mobile services, is likely to be used to support new 5G applications, in particular those that require high capacity and very low latency by both MNOs and other players.[6] Latency is the amount of time between a command and its corresponding action, 5G will make this delay unnoticeable.

1.16 While responses to our 26 GHz call for input indicated that the band is likely to be become important for 5G, many suggested that it is too early to say how the band will be used, and for what purposes. We will continue to collate evidence from stakeholders across different sectors and continue our engagement internationally to inform our understanding given the wide international interest in using high frequency spectrum for mobile. We are particularly keen to encourage trials at 26 GHz, the 5G mmWave pioneer band.

1.17 We have also identified 66-71 GHz as a potential band for 5G licence exempt use. We recently sought views from stakeholders on the kind of use cases and technical parameters envisioned for the band.

1.18 In order to facilitate innovation and enable the development of 5G technologies, we make spectrum available in the form of innovation and trial licences[7] for testing and development.

1.19 We are today launching our innovation and trial portal to improve accessibility to these licences for short term trials. We want to encourage innovative new uses of spectrum by a range of players. We will ensure spectrum is made available for companies to test and trial both the technology and the potentially new applications enabled by 5G. Under the updated terms of these licences, triallists will now be able to charge participants (specifically for the purposes and duration of the trial only), meaning as well as trialling technology, they can test business models and potential pricing structures.

1.20 Because we make spectrum available in a way that is technology and service neutral, 5G can also be rolled out in bands with existing authorisations, such as bands currently used for 2G, 3G and 4G, as long as it falls within the technical parameters.[8]

1.21 We also recognise that access to licence exempt spectrum enables innovation, helping consumers to access reliable broadband wherever they live, work, or travel. We recently made new spectrum available for technologies including wifi at 5.8 GHz.

We are also implementing other enablers for 5G

1.22 **Ensuring access to sites is not a barrier to 5G**: We will continue to work with the UK Government and governments in the nations to ensure site access and planning requirements are not a barrier to the deployment of 5G. In the past few years, reforms to planning policy and the UK's Electronic Communications Code have been introduced to

[6] Whilst mmWave bands offer larger bandwidths, providing higher capacity, they have a much shorter range than traditional mobile bands.
[7] Previously called Test and Development licences
[8] 900 MHz and 1800 MHz are not licensed on a technology neutral basis, as set out in European Commission Decision 2011/251/EU.

make it easier to build mobile networks. For example, planning reforms were introduced in England in 2016 to make it easier to deploy masts to support rural coverage, with Scotland introducing its own reforms in 2017. Wales has identified planning reform as a possible step under its 2017 mobile action plan, but is still considering its approach, and Northern Ireland is currently considering changes following a consultation in 2016.

1.23 The reforms to date have focused on making it easier to deploy macro cells, however 5G in the longer term is likely to see much greater deployment of small cells (small base stations). For small cells additional steps may be required to make their deployment, including access to site, power and backhaul, practical and cost effective. There are likely to be practical challenges associated with the rollout of small cells. This is because rollout will require coordination and agreements with many different parties, from local authorities to shops, property owners and utilities, amongst others. As such, further action may be required in order to provide appropriate sites, as well as suitable backhaul.

1.24 **Backhaul connectivity**: Increasing capacity demand from macro cells, the deployment of small cells and new trends in network evolution, are likely to place new demands on backhaul connections in terms of increased capacity and widespread availability. This might require a denser fibre network infrastructure and a change in the nature of the services provided by network operators, away from managed capacity connections to more flexible links such as those provided by dark fibre.

1.25 Mobile network operators have been actively seeking a diversity of suppliers for the benefits that competition offers in terms of price and service.

1.26 To encourage competition in network services we have relaxed the previous usage restrictions on access to BT's ducts and poles to provide both broadband and non-broadband services (such as mobile backhaul), provided the purpose of the network deployment is primarily the delivery of broadband services to consumers.[9]

1.27 We would expect competition to lead to a diverse range of services in the market, including provision of dark fibre links. Where competition does not provide the necessary services, we will need to consider regulation to ensure such services are available.

1.28 We also provide a range of options for fixed wireless connections for mobile backhaul. We recently consulted on our proposed next steps to enable future use of fixed wireless connections, including the role of wireless backhaul as a complement to fixed backhaul in meeting the increasing demand for capacity. We are currently analysing stakeholder responses.[10]

1.29 **Ensuring net neutrality is not a barrier:** One of the innovative aspects of 5G is to enable wireless technologies to be used by different industries. It allows networks to be 'sliced' into different segments with pre-defined quality of service characteristics that can be

[9] https://www.ofcom.org.uk/__data/assets/pdf_file/0012/111513/Wholesale-Local-Access-Market-Review-Draft-Statement-Volume-1.pdf

[10] https://www.ofcom.org.uk/consultations-and-statements/category-2/fixed-wireless-spectrum-strategy

tailored to particular uses, for instance, robotics in factories. We support the guidelines on net neutrality from the body of European regulators[11] and will continue working with our partners to ensure net neutrality rules, designed to preserve the benefits of the open internet, do not prevent this kind of innovation.

1.30 **Acting as a facilitator**: To take advantage of the new, innovative uses for wireless made possible by 5G, businesses across the economy may consider how to make greater use of wireless technologies. We will act as a facilitator, working across different sectors to encourage them to work together, and with other countries to further understand the potential applications of 5G, and how they might work in practice in the UK.

Wider implications of future 5G deployment

1.31 Once deployment of 5G takes place, other policy implications could arise that we, and other policy-makers, will need to consider:

1.32 **Mobile coverage:** While 5G is expected to play an important role in providing higher speeds and extending capacity at existing mobile sites, it is unlikely that 5G will, in itself, extend the current coverage of mobile networks. In order to facilitate better and wider mobile coverage, we will shortly consult on new coverage obligations as part of the 700MHz spectrum band award planned for 2019.

1.33 **Security**. For consumers and businesses to have confidence in 5G services, they must be secure. The challenge of ensuring network security is not unique to 5G, but will become more important as networks evolve, hardware is substituted by software functions and the number of connected devices increases. On the other hand, the evolution of networks could lead to a more customised approach to security with greater ability to address the needs of different users and services.

1.34 **Competition and consumers' choice.** 5G could enable new companies to enter the market and offer new services to businesses and consumers. In addition, fixed and wireless broadband could offer increasingly similar speeds. This means wireless operators may be able to offer a competitive product to fixed broadband providers, and more people may choose a wireless provider for their home broadband using fixed wireless access. There may also be greater convergence of the networks used to deliver fixed and wireless services and this is likely to continue to affect the competitive landscape, for example by making it more worthwhile for operators to have interests in both fixed and wireless networks.

1.35 **Sites and asset sharing.** From a commercial perspective, sharing of sites and network assets such as masts and equipment could make the deployment of 5G more efficient. We welcome industry initiatives to share sites and infrastructure to enable cost effective deployment of 5G, provided it doesn't restrict competition.

[11] Body of European Regulators for Electronic Communications (BEREC)

1.36 **Consumer information**. As the number of services available to consumers grows, they must have access to clear information on services available through 5G. We will need to consider how to make sure that this information is available, including on coverage, capabilities, service quality and mobile data speeds of 5G. People need to be able make the choice that is right for them, including whether to upgrade or not.

2. Introduction

Aim of this document

2.1 5G is the next generation of mobile technology. The initial technological standard for 5G was released in December 2017 (with further iterations planned for later this year).[12] The Government published its strategy for 5G in March 2017, with a subsequent update in December,[13] and is currently funding a programme of testbeds and trials.

2.2 As the UK's communications regulator, we have a principal duty to further the interests of citizens in communications matters, and consumers in relevant markets, where appropriate by promoting competition. There are a number of things we are required to do in carrying out our functions including, of particular relevance to 5G, is ensuring a wide range of communication services are available throughout the UK, and securing the optimal use of spectrum. In fulfilling our duties, we must also have regard to a number of factors, including the desirability of encouraging investment and innovation.

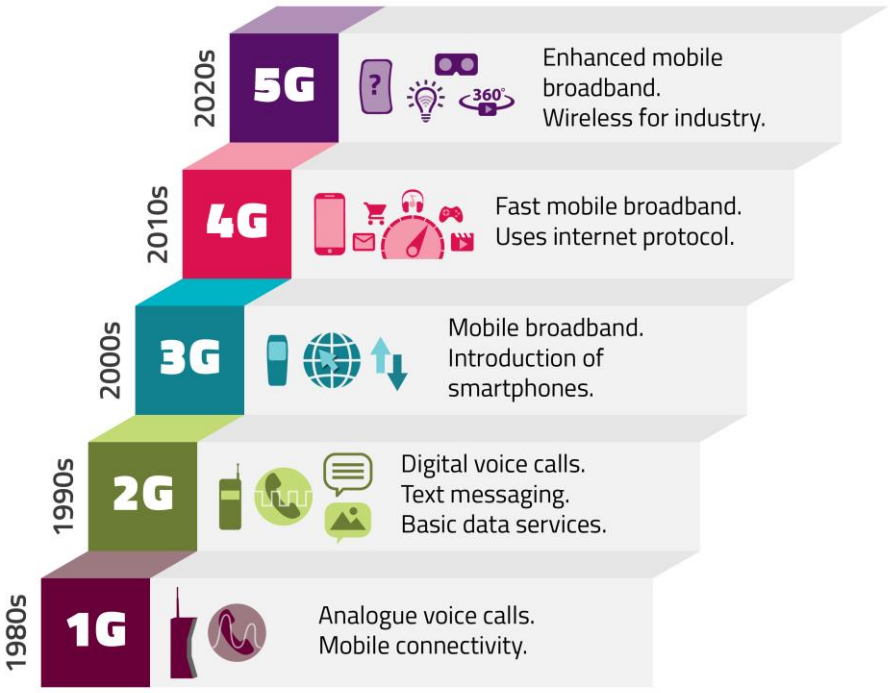
2.3 This discussion document describes the likely 5G benefits for consumers and businesses and sets out the actions that we are taking to facilitate 5G rollout in the UK. The document builds on and complements our previous update on 5G spectrum in the UK[14] and our publication on ensuring the availability of suitable spectrum at higher frequencies for early 5G deployment across the UK.[15]

5G is the next generation of mobile technology and will include both evolutionary and revolutionary aspects

2.4 Since the 1980s, a new generation of mobile technology has been launched every decade or so, and each has brought new capabilities for consumers as seen in Figure 2. Consumers are increasingly relying on mobile connectivity where they live, work and travel to carry out everyday activities such as watching videos and browsing the internet. And as demand for fast, reliable connections has increased, mobile services have continued to evolve. But advances in mobile have not merely been in response to people's changing needs, they have also played a key role in driving that increased demand.

[12] http://www.3gpp.org/release-15
[13] https://www.gov.uk/government/publications/next-generation-mobile-technologies-a-5g-strategy-for-the-uk
[14] https://www.ofcom.org.uk/__data/assets/pdf_file/0021/97023/5G-update-08022017.pdf
[15] https://www.ofcom.org.uk/__data/assets/pdf_file/0014/104702/5G-spectrum-access-at-26-GHz.pdf

Figure 2: Generations of mobile technology



2.5 The evolution of mobile services has provided faster speeds, greater capacity and more reliable service at each stage. As a result, we've seen increasingly innovative services and applications become available. The next phase of mobile evolution, 5G, has the potential to deliver new, added benefits for consumers and businesses. The high-level requirements for 5G have been defined by the International Telecommunications Union (ITU) in its 'IMT 2020' specification.[16] The 3GPP (3rd Generation Partnership Project), an industry driven standardisation body, is currently developing standards for 5G to reflect the ITU requirements.

2.6 The technical characteristics of these standards mean that 5G is expected to deliver faster speeds and much higher capacity – offering peak speeds of 10-20 gigabits per second and the ability to connect one million devices per square kilometre. In addition, the ability to achieve very low latency (less than 1 millisecond) is expected to support the development of new applications such as virtual reality on the go. Latency is the amount of time between a command and its corresponding action; 5G will make this response feel immediate.

2.7 Initially, 5G is likely to deliver an evolutionary improvement of consumers' and businesses' existing wireless services. 5G's ability to deliver high capacity and very low latency has the potential to enable the development of revolutionary new services and applications. These services are expected to extend the use of wireless technologies across new sectors of the economy, for example, manufacturing, healthcare and transport. Opportunities will also arise for both existing and new wireless providers to develop novel business models, and

[16] https://www.itu.int/en/mediacentre/Pages/2017-PR04.aspx

to offer new types of wireless services and products to different groups. We discuss some of the benefits of these capabilities in section 3.

The development of 5G in the UK and internationally

2.8 The development of 5G remains in its early stages but is gaining momentum. The initial phase of the first set of global 5G standards has been finalised, with further iterations likely later this year.[17] The first 5G-enabled handsets are likely to follow soon afterwards, probably becoming available from 2019. 5G is being developed with tests and pre-commercial trials underway all over the world.

2.9 In the UK, the Government has launched a testbeds and trials programme to develop 5G further, including a recent competition with up to £25 million of funding to explore, develop and test applications and services.[18] Three universities are heavily involved in the 5G developments in the UK.[19] Building on earlier work, the three universities are working together to create three small-scale mobile networks which together will form a 5G test network.

2.10 The UK government has also created a 5G Innovation Network to facilitate the engagement and coordinate the organisations working on 5G across the UK. Universities, mobile network operators and technology companies are collaborating on a number of UK pre-commercial trials to test the potential structure and capabilities of future 5G networks:

- UK MNOs are trialing some of the technologies that will underpin 5G, especially 5G New Radio (NR) which could provide increased data capacity and faster speeds by using wider spectrum bandwidths. In December, Vodafone jointly with Ericsson and King's College London conducted a pre-standard 5G test and made a 5G connection at 3.5 GHz using new 5G antennas techniques which will enable users to send and receive more data.[20]
- Arqiva, in collaboration with Samsung, is currently trialing 5G fixed wireless access (FWA) broadband in the 28 GHz frequency band in central London.[21] FWA broadband using 5G could offer a new way of providing broadband at superfast or even ultrafast speeds.

2.11 In the rest of the world, some operators have already announced plans to trial or launch 5G services, typically based on what they see as the most immediate commercial imperative:

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[17] In December 2017 the 3GPP unveiled its initial 5G specification (Phase 1), which is part of Release 15 and focuses on delivering better broadband. It defines a non-standalone version of 5G, where 4G is used for the control elements of setting data sessions.

[18] https://www.gov.uk/government/publications/5g-testbed-and-trials-programme-phase-1-competition-guidance/5g-testbed-and-trials-programme-phase-1-competition-guidance

[19] https://www.gov.uk/government/news/three-universities-to-develop-16m-5g-test-network

[20] https://www.v3.co.uk/v3-uk/news/3023421/vodafone-uk-and-ericsson-team-up-on-pre-standard-5g-test

[21] https://www.arqiva.com/news/press-releases/arqiva-and-samsung-kick-off-uks-first-5g-fixed-wireless-access-trial/

- In South Korea, mobile operator Korea Telecom, working with Samsung Electronics, Intel and Ericsson showcased a 5G network during the Winter Olympics in PyeongChang.
- In the US, AT&T is carrying out 5G trials (both mobile and FWA broadband) across a number of US cities and plans to launch mobile 5G services as soon as 2018.[22] Verizon plans to launch commercial 5G FWA broadband in three to five US cities in 2018.[23] T-Mobile US has said that it plans to begin deploying 5G-branded mobile services in 2019 with full nationwide coverage in 2020 using the 600MHz band.[24]
- Chinese telecoms provider ZTE anticipates that a 5G network will be commercially available in China in 2020.[25] ZTE is also working on a joint 5G trial with Japanese provider Softbank in Tokyo using spectrum at 4.5 GHz. China Telecom is adding 5G testing base stations ahead of the 5G commercial launch in 2020, expanding its pilot project for 5G networks to six cities.[26]
- In Spain, Telefonica is deploying 5G in two cities in order to trial the technology, use cases and business models.[27] Initially this will be an enhancement of current 4G networks but will then evolve into standalone 5G networks.
- Italy has announced 5G trials in five cities, with a public commitment to make spectrum available in the 3.6-3.8 GHz band to mobile network operators.[28]
- Ericsson and MTS have partnered to trial a 5G network during the 2018 World Cup in Russia.[29]
- In Germany, Ericsson, BMW and the three operators Vodafone, DT and Telefonica have established a cross-industry consortium in order to build a 30-kilometre long test track to research and develop 5G infrastructure and applications for cars and trains.[30]

Structure of this document

2.12 In section 3 we provide an overview of the 5G use cases currently being discussed and the benefits they will deliver, considering both the evolutionary and revolutionary aspects of 5G. In section 4 we discuss our action plan to enable 5G rollout in the UK. The deployment of 5G is also likely to have wider policy implications and will not solve all of the challenges that we face today, particularly the need to secure better mobile coverage across the UK. In section 5 we discuss the wider policy implications of 5G.

[22] http://about.att.com/story/att_to_launch_mobile_5g_in_2018.html
[23] https://www.rcrwireless.com/20171130/5g/verizon-5g-fixed-wireless-access-2018-tag17
[24] https://newsroom.t-mobile.com/news-and-blogs/nationwide-5g.htm
[25] http://wwwen.zte.com.cn/endata/magazine/ztetechnologies/2017/no3/articles/201705/t20170517_463809.html
[26] https://www.rcrwireless.com/20171211/5g/china-telecom-adds-5g-testing-sites-tag23
[27] https://www.telefonica.com/en/web/press-office/-/telefonica-leads-the-way-towards-5g-with-deployments-in-two-spanish-cities
[28] https://www.mobileeurope.co.uk/press-wire/tim-and-fastweb-launch-5g-trials-in-italian-cities
[29] https://www.rcrwireless.com/20151228/carriers/5g-trials-coming-to-2018-world-cup-tag23
[30] https://www.mobileeurope.co.uk/press-wire/ericsson-builds-5g-motorway-with-deutsche-telekom-vodafone-and-telefonica

3. Benefits of 5G

3.1 In this section we look at some of the potential new services and applications and their benefits, considering both the evolutionary and revolutionary aspects of 5G. The examples given are based on areas of particular current focus by industry and are not intended to represent an exhaustive list of the new applications that might be enabled by 5G.

5G is expected to enable both an evolution of existing services and revolutionary new services

Consumers and businesses are demanding more from wireless networks

3.2 Communication services are becoming ever more important to UK people and businesses and they expect to be able to access them everywhere they live, work, or travel. Consumers are increasingly using wireless connections for data-hungry purposes such as watching video. In addition, new services such as augmented and virtual reality are emerging that will require even faster speeds and further enhancements such as more capacity and low latency.

3.3 In order to meet consumers' and businesses' changing demand, wireless networks are evolving and becoming more efficient to provide a better, more consistent experience. This means faster speeds, greater reliability, more capacity, and better responsiveness.

3.4 Furthermore, people and businesses are connecting ever more different types of devices – such as fitness trackers, smart meters, thermostats, industrial machinery - to the internet, creating the so-called 'Internet of Things' (IoT). The IoT has the potential to deliver significant benefits for people and businesses in sectors such as healthcare, energy and transport. Businesses are also increasingly using the IoT, in combination with more powerful computer processing, to increase productivity and cut costs. And they are employing wireless networks to provide added flexibility, for example for easily adjustable production lines, or for newer purposes such as autonomous, responsive robots in manufacturing with further new developments in the pipeline.

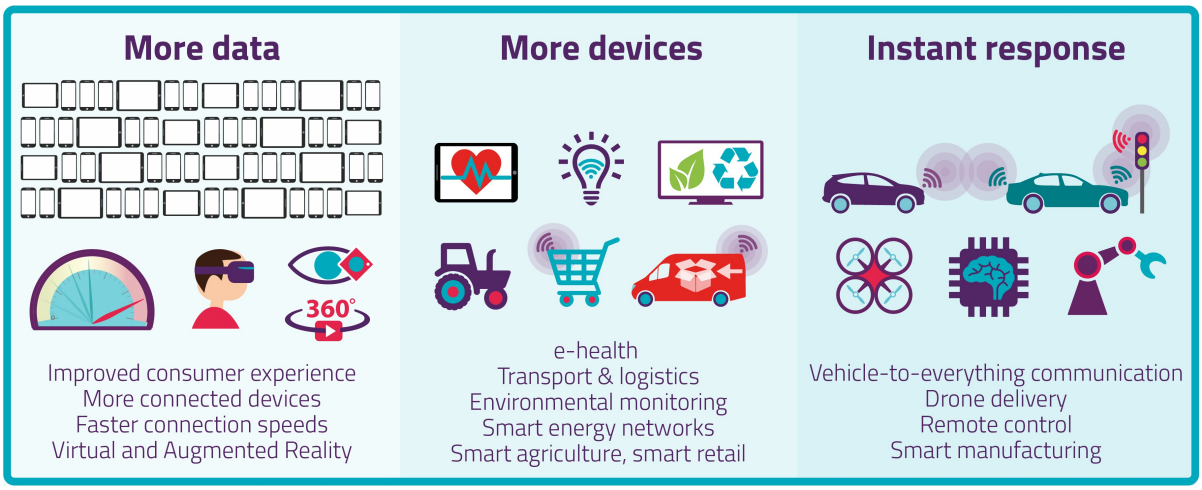
3.5 Different networks are likely to be used for different purposes at different times to meet consumers' and businesses' needs. For example, wifi will continue to play an important role in providing indoor mobile broadband. And a range of technologies is likely to be used by autonomous vehicles: short-range sensing technologies such as radar and image recognition; vehicle-to-vehicle communications; and mobile networks to access a variety of other data such as traffic conditions or parking availability.

Three broad categories of use for 5G

3.6 In our February 2017 Update on 5G Spectrum, we grouped the types of services and applications 5G is likely to support into three broad categories: enhanced mobile broadband (eMBB), massive machine type communications (mMTC) and ultra-reliable low-

latency communications (uRLLC).[31] These are illustrated in Figure 3 under the titles of more data, more devices and instant response and are discussed in more detail below.

Figure 3: Expected Uses of 5G



More data: improved quality of experience for wireless broadband

3.7 The evolution of 4G networks will support faster speeds, more capacity and better quality of experience. In addition, 5G is expected to lead to further improvement, including very low latencies and high reliability to enable a whole set of new services. In particular, 5G is expected to bring the following benefits for consumers:

i) **Better quality of experience for mobile services**: 5G will likely enable mobile networks to better meet the demand for increasing capacity. This may improve the consumer quality of experience of using mobile services.

ii) **New and existing services that require much faster speeds:** 5G may support very high speeds and more responsive connections with less delay. In turn, this could enable more effective wireless delivery of newer services such as virtual and augmented reality, as well as enabling higher speeds for existing services such as fixed wireless access (FWA).

More devices: capacity for the Internet of Things

3.8 Consumers are already taking advantage of some IoT devices, especially in the areas of smart homes and wearable technology such as fitness and health devices.

3.9 In March 2017, we published a study summarising developments in the IoT over the previous two years and its likely evolution in different sectors.[32] This study concluded that IoT applications were going to become more popular over the next few years. As IoT usage grows, there is potential to boost productivity and reduce costs, particularly when IoT is

[31] https://www.ofcom.org.uk/__data/assets/pdf_file/0021/97023/5G-update-08022017.pdf
[32] https://www.ofcom.org.uk/research-and-data/telecoms-research/review-of-latest-developments-in-the-internet-of-things

combined with other technologies such as advanced computing (especially artificial intelligence and machine learning). Examples of sectors that could benefit from greater use of IoT applications include:

- Health and social care: IoT enables remote health monitoring, creating timely alerts for patients, nurses or carers.
- Smart cities: possible applications include optimisation of street lighting, monitoring of parking, rubbish collection timing, and environmental monitoring.
- Utilities: smart meters and smart thermostats allow more accurate billing and better control of energy consumption.
- Automotive: several car manufacturers already offer connected vehicles that use IoT for diagnostics, vehicle tracking and media streaming.
- Manufacturing: businesses are already increasing digitisation and automation of production lines, supply chains and logistics. In the longer-term, businesses are likely to make greater use of robots and remote control of industrial processes (which, in turn, may have wider social implications for employment, skills etc).

3.10 Until 5G becomes available, the evolution of 4G and other wireless technologies will likely be capable of addressing much of the growing demand for IoT devices over the next few years. 5G may therefore initially play a limited role in the development of IoT. But future 5G evolutions are likely to target IoT, offering capacity for many more devices than other wireless technologies [33], as well as improved battery life and innovative capabilities, such as instant response communications.

Instant response: revolutionary new services

3.11 Every generation of new wireless technologies leads to the development of new applications and services that make use of its capabilities. For example, 3G and later 4G, allowed video-streaming on mobile devices that was previously impossible on 2G. Similarly, it is likely that 5G will also lead to the development of new applications given its low latency capabilities. This is particularly the case when used in conjunction with other technologies such as robotics, automation, machine learning and artificial intelligence. We have grouped these potential applications as those requiring 'instant response'.

3.12 There is great potential for instant response-type services using 5G. And although the specific benefits will not be fully known until different sectors start to develop new services and applications, it is useful to consider some of the potential uses. These could result in innovations that bring significant benefit to consumers and the wider economy, while also potentially raising wider questions about the role of automation in our society. Three different instant response applications widely discussed in the public domain are:

Tactile internet. These uses rely on the development of haptic technology: the science of emulating the sensation of touch when remotely controlling and interacting with a connected device. There are a number of potential benefits to

[33] In the order of one million per cell compared to a few hundred thousand with 4G.

society from this. For example, is it could allow medical students to practise surgery in a connected, virtual reality environment. Students wearing haptic gloves would be able to 'feel' the procedure as they develop their skills in a safe setting.

The technology works by transmitting different types of motions to the user. The combination of these capabilities with low latency communications and very high reliability may play a role across a wide range of sectors, including education, healthcare, online shopping and games.[34]

Remote control. Remote control of machines is already taking place but the instant response capabilities of 5G could significantly improve and extend its use. For example, robots and drones might be used more extensively in warehouses or for delivery of online orders. 5G could also allow better control of machinery involved in industrial processes or in dangerous tasks. For instance, we are likely to see a new generation of low-cost machinery, using artificial intelligence, able to collaborate with human workers in a safe and efficient production environment. 5G will also facilitate flexible, smart manufacturing with more autonomous machines, use of data and advanced computing. For instance, a manufacturer using wireless rather than wired solutions for robots and other machinery could benefit from greater flexibility and improved response rate in the production line.

Autonomous vehicles. While 5G may play some role in facilitating autonomous vehicles, the contribution of other wireless technologies such as radars, sensors, image recognition and vehicle to vehicle communications will also be vital. In addition, innovation in this area will, to a large extent, be a result of new software capabilities – particularly the fast data analysis and autonomous decision-making capabilities of artificial intelligence.

5G will create new opportunities for existing and new wireless operators

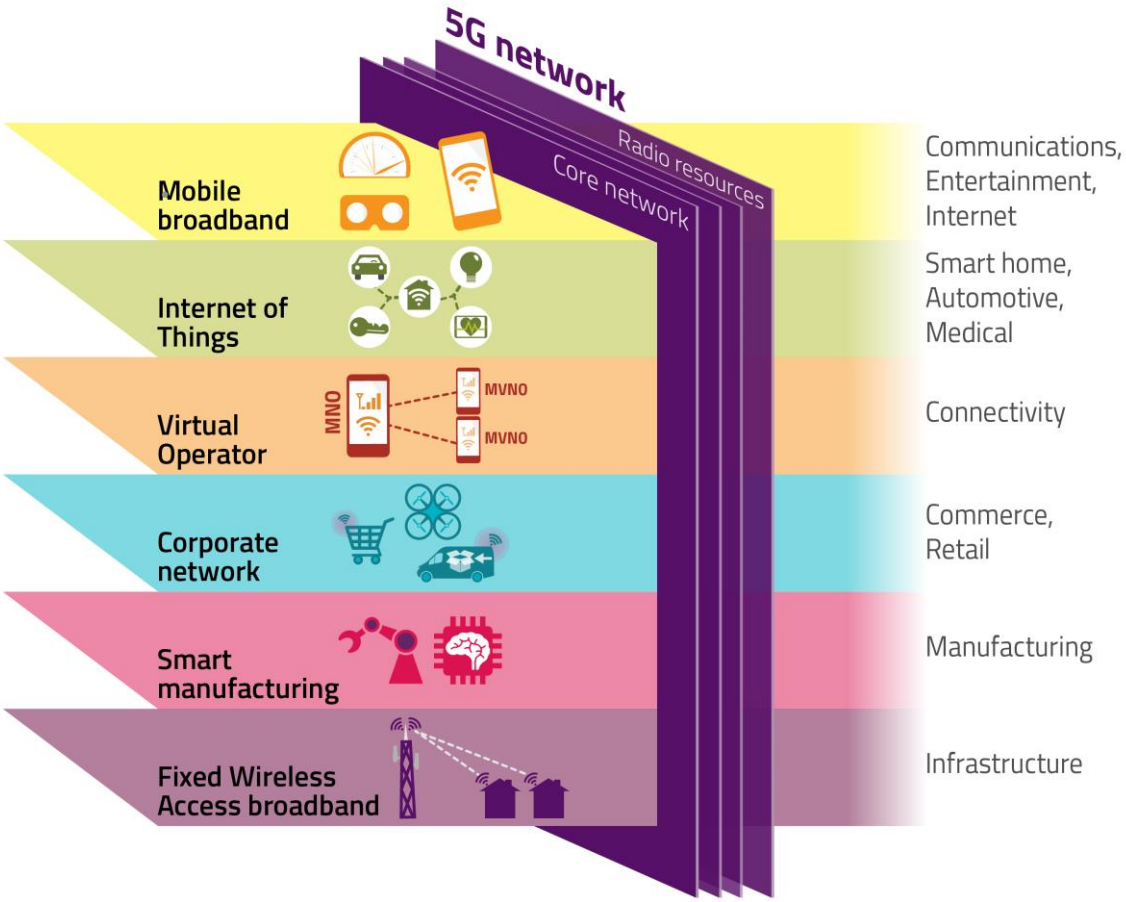
3.13 The driver for initial investment in 5G networks will likely be 'more data'. MNOs are already implementing improvements to their 4G networks and architectures to deliver more capacity, increased flexibility and efficiency. The greater capacity of 5G may also be a cost-effective way of addressing rapidly growing mobile data demand, provided 5G mobile devices are widely adopted.

3.14 Therefore, MNOs are likely to be the first to deploy 5G networks and services to deliver greater capacity to meet the increasing demand from consumers and business. Over time they may extend the use of 5G beyond mobile broadband and leverage innovation such as network slicing to offer services to industry verticals, for example manufacturing, healthcare and logistics.

[34] 5G will support a latency of around 1ms, which is 10 times less than early 4G deployment. However, providing a tactile service between two end points will not only involve the optimisation of the wireless network infrastructure, but will also require optimising the whole network infrastructure involved in the communications between the two points.

3.15 Network slicing allows for parts of a network - with predefined specifications and quality of service – to be available for different purposes and/or users. Network operators can thereby provide dedicated virtual networks to different customers over a common network. This will enable new ways of managing services and capabilities delivered over the same network (Figure 4 illustrates how it could work). Specific users and/or services would have a dedicated portion of the network allocated to them, allowing for a much better quality of experience.

Figure 4: Network slicing



3.16 The extra versatility and capabilities of 5G could also open up opportunities for new wireless providers, with consequent benefits for people and businesses.

3.17 Connectivity solutions geared towards a particular class of users or uses could be delivered by new players or in new ways, such as at very localised areas or private networks. Depending on their requirements, verticals may choose to deploy their own private networks rather than enter into an agreement with MNOs, for example in a connected factory.

3.18 Some companies may also decide to act as intermediaries or system integrators and provide infrastructure to a number of wireless network providers in a particular location such as a business park or a factory.

4. Our actions to help deliver 5G in the UK

4.1 In this section, we provide an overview of the actions we are taking to enable 5G rollout in the UK. As well as covering areas where we have a specific role, we also discuss areas where we are working with Government to support 5G rollout. Specifically, we will:

i) make spectrum available for 5G and other wireless services;

ii) ensure appropriate connectivity between 5G base stations and the core network (also known as backhaul);

iii) work with Government and policy-makers to ensure access to sites is not a barrier to 5G;

iv) ensure that net neutrality regulation is not a barrier to deployment; and

v) act as a facilitator, working across different sectors to encourage them to work together, and with other countries to further understand potential applications of 5G.

We are making spectrum available for 5G and other wireless services

4.2 Our programme of work is driven by our objectives to ensure that spectrum is made available in the most appropriate and timely way to enable investments, innovation and competition in the development of 5G services to benefit consumers and businesses. We played a key role internationally in the identification of early 5G spectrum bands (700MHz, 3.4-3.8 GHz and 26 GHz) and we continue to influence international debates with regards to future bands for 5G. We will continue to be active in promoting 3.4-3.8 GHz, 26 GHz, 40 GHz (40.5-43.5 GHz) and 66-71 GHz as 5G bands in CEPT and in ITU, ensuring that the harmonised technical conditions developed are appropriate to facilitate 5G whilst ensuring sensitive incumbent services are adequately protected.

4.3 In this section we also consider the potential for increased shared access for innovative new uses at 3.8-4.2 GHz.

5G will use a variety of spectrum bands

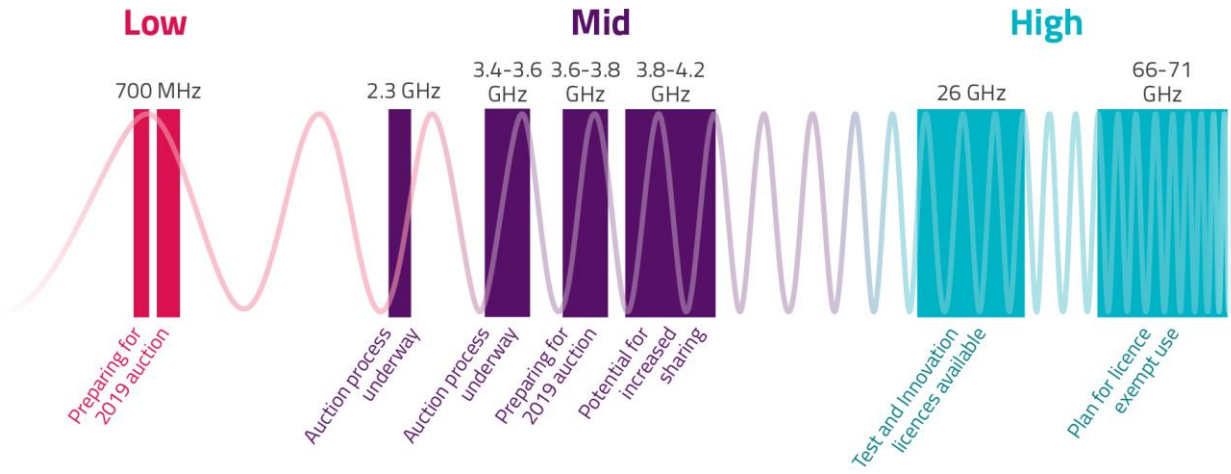
4.4 In February 2017 we published a document setting out our spectrum programme of work to meet the increasing demand for mobile services including 5G.[35] We identified spectrum bands at low, mid and high frequencies which have different characteristics and can be used to deliver different benefits.

4.5 As illustrated in the figure below, we authorise access to spectrum in a variety of ways at each range; for example national dedicated licences, shared access, and access on a license

[35] https://www.ofcom.org.uk/__data/assets/pdf_file/0021/97023/5G-update-08022017.pdf

exempt basis are available to meet demand for deployments at national, regional and local levels.

Figure 2: Spectrum pipeline



Low frequency spectrum

700 MHz

4.6 700 MHz is likely to be deployed initially as 4G because devices using this band are already widely available. The physical characteristics of this spectrum mean that it is particularly well-suited to achieving coverage over wide areas and indoors.

4.7 Our work to clear the 700 MHz band to make it available for mobile services is well underway. We published an update in October 2017 in which we outlined that our clearance work is on track to meet our target for completion in Q2 2020.[36] We expect to conduct an award for this band in 2019.

4.8 To ensure widespread improvements in mobile coverage across the UK, we are proposing to attach coverage obligations to some of the licences we will award for the 700 MHz band. These obligations will require winning bidders to roll out improved mobile coverage in rural areas including in the Nations. We are currently consulting on our proposals for these coverage obligations.[37]

4.9 In the longer term, low frequency spectrum such as 700 MHz could be used to extend the reach of MNOs' 5G offering and offer a potential uplift in service quality. By rolling out 5G at 700 MHz on their current sites that use low frequency spectrum, MNOs would achieve similar coverage to 4G for 5G devices, as well as potentially improving consumer experience at the cell edge in rural areas. Furthermore 700 MHz, as all other sub 1GHz bands, is well suited for narrowband IoT services that require wide coverage area or high penetration into buildings and basements.

[36] https://www.ofcom.org.uk/__data/assets/pdf_file/0022/106933/700mhz-clearance-timescale-review.pdf
[37] https://www.ofcom.org.uk/consultations-and-statements/category-2/700-mhz-coverage-obligations

Medium frequency spectrum

4.10 4G evolution and 5G in this range will involve both evolutionary and revolutionary services by providing a significant uplift in capacity and supporting low latency applications over large areas. Bands in such a range are also capable of supporting low latency applications requiring high reliability such as industrial automation and robotics.

4.11 The Radio Spectrum Policy Group (RSPG)[38] has identified 3.4-3.8 GHz as the first primary band for 5G in Europe, delivering capacity for new 5G services.[39] MNOs are currently focusing on mid frequency spectrum as it provides high bandwidth which enables the delivery of high capacity services and can be deployed on existing base stations.

2.3 and 3.4 GHz award

4.12 Ofcom's final policy decisions for the 2.3 and 3.4 GHz award are set out in the Statement "Award of the 2.3 and 3.4 GHz spectrum bands: Competition issues and Auction Regulations" published on 11 July 2017. Aspects of Ofcom's decisions were the subject of judicial review proceedings in the High Court brought by British Telecommunications Ltd (BT) and EE Ltd (EE) and H3G UK Limited (H3G). On 20 December 2017 the High Court rejected the claims of BT, EE and H3G and upheld the decisions of Ofcom as set out in the 11 July 2017 statement. H3G sought permission to appeal the High Court's decision in the Court of Appeal which was refused following a hearing on 13 February 2018.

4.13 Ofcom was keen to minimise the delay arising from H3G's appeal. We therefore proceeded to make the auction Regulations on 24 January 2018 and progressed a number of the preliminary administrative steps in the auction process, pending the outcome of H3G's appeal. These were steps that we would have needed to take whether or not the Court of Appeal upheld our decision. In light of the Court of Appeal's decision, we are now proceeding with the auction process.

3.6-3.8 GHz

4.14 In 2016 we initiated work to make the spectrum not already assigned for electronic communications services[40] in the 3.6-3.8 GHz band available for future mobile services including 5G.

4.15 In our October 2017 statement we confirmed our approach to make the band available for mobile and commenced the statutory process of notifying stakeholders of the proposed changes.

4.16 Having taken into account stakeholders' representations, on 2 February 2018 we published our update outlining the outcome of our decision.[41] We have issued notices to revoke all

[38] The Radio Spectrum Policy Group is a high level advisory group that assists the European Commission in the development of radio spectrum policy and is chaired by one of the Member States
[39] https://circabc.europa.eu/sd/a/fe1a3338-b751-43e3-9ed8-a5632f051d1f/RSPG18-005final-2nd_opinion_on_5G.pdf
[40] Complying with European Commission Decision 2014/276/EU
[41] https://www.ofcom.org.uk/__data/assets/pdf_file/0018/110718/3.6GHz-3.8GHz-update-timing-spectrum-availability.pdf

fixed links licences in the band as proposed, with an effective date of 23 December 2022; we have varied 12 Permanent Earth Station licences and three grants of RSA as proposed, with an effective date of 1 June 2020; and we have varied one grant of RSA with an effective date of 1 September 2020. The spectrum will be available for mobile in many areas from 2020, but not necessarily nationwide until 2022.

4.17 We intend to deliver the award of the spectrum not already assigned for electronic communications services in 2019. We will consult later this year to prepare for this award.

Potential for increased sharing at 3.8-4.2 GHz

4.18 In 2016 we identified 3.8-4.2 GHz as a band with the potential for increased sharing for future innovative applications, while taking into account existing users.

4.19 Following responses to this Call for Input we published a short update in August 2016[42], confirming the potential of this band for further shared access given the geographically defined location of existing users. In our July 2017 statement on the use of the 3.6 -3.8 GHz band[43] we noted that there was likely to be continued demand from existing users (receiving satellite Earth Stations and fixed links) in the 3.8 – 4.2 GHz band. We also stated that the band has potential for shared access between existing and future users based on geographically defined authorisations and that we were minded to develop proposals to facilitate this.

4.20 We plan to further consider the 3.8-4.2 GHz spectrum on an increased shared basis, while taking into account existing use. We consider that this band could be used by a range of different players. We believe we could extend shared access to broadband wireless systems, building on the current coordination arrangements for shared use already in place in the lower part of band and we plan to consider these ideas further. We understand this band may also be suitable for low power indoor industrial uses, such as connected factories and industrial Internet of Things and we will continue to monitor demand and seek evidence for these particular applications and use cases.

High frequency (mmWave) spectrum

4.21 As well as providing additional capacity, high frequency spectrum could enable more revolutionary use cases because it delivers very high speeds and high capacity with very low latency. Both MNOs and non-MNOs could play a role in offering these more revolutionary services enabled by 5G technologies.

4.22 The RSPG has identified 26 GHz (24.25-27.5 GHz) as the “pioneer” mmWave band for 5G in Europe. In its recently published Second Opinion on 5G, it also prioritised 66-71 GHz as a second stage high frequency band, alongside 40.5-43.5 GHz, which we have also identified as a priority band for study.[44]

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[42] https://www.ofcom.org.uk/consultations-and-statements/category-2/opportunities-for-spectrum-sharing-innovation
[43] https://www.ofcom.org.uk/__data/assets/pdf_file/0017/103355/3-6-3-8ghz-statement.pdf
[44] https://circabc.europa.eu/sd/a/fe1a3338-b751-43e3-9ed8-a5632f051d1f/RSPG18-005final-2nd_opinion_on_5G.pdf

4.23 Both the 26 GHz and 66-71 GHz bands are on the agenda of WRC-19 as potential new bands for 5G. 26 GHz is Europe's highest priority band and it has the potential to become a global band for 5G available in most countries across the world. We are working with our international partners in CEPT and ITU to ensure the necessary technical studies are carried out and that appropriate harmonised technical conditions are established (e.g. in the Radio Regulations at WRC-19 and in a new ECC Decision on 26 GHz).

4.24 In December 2017 the UK Government published its updated 5G strategy. The strategy reiterated Government's support for using 26 GHz for 5G, and committed to making 26.5-27.5 GHz available for 5G mobile.[45]

4.25 We initiated our programme of work on high frequency spectrum in summer 2017, with the publication of a Call for Input on 26 GHz and an overview of future mmWave bands for 5G.[46] In this document, we sought views from stakeholders on a number of issues including demand for 26 GHz spectrum; we also highlighted the potential for this band to meet different types of demand.

4.26 While responses to our 26 GHz Call for Input indicated that the band is likely to become important for 5G, many were of the view that it is too early to say how the band will be used, by whom and for what purposes.

We want to allow people to innovate and trial high frequency spectrum

4.27 Given the extensive international debate around use of mmWave spectrum for mobile, in particular 26 GHz, the pioneer mmWave band; and the expected availability of the spectrum at 26.5-27.5 GHz in devices from early 2019, we are keen to enable a range of players to test innovative new uses in this band.

4.28 We are today launching a new Innovation and Trial web portal (www.ofcom.org.uk/innovation), which will provide guidance to interested parties wishing to access spectrum to test and trial both the technology and the potentially new applications enabled by 5G. Innovation and trial licensing enables the use of radio spectrum for innovative purposes on a non-operational and non-commercial basis for a limited period of time. Our aim with these licences is to promote the research, development and trialing of innovative uses of the radio spectrum in the UK.

4.29 We will continue to offer two types of short term licences, both with slightly different terms. The innovation and research licence allows for the research and development of innovative spectrum equipment or to support academic/scientific research. The second product, the demonstration and trial licence, allows for the trial and demonstration of a new system, radio concept, application or service with the ability to include third-party end users in the process. Both licences cover any period up to twelve months and cost from £50.

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[45] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/677598/Next_Generation_Mobile_Technologies__An_Update_to_the_5G_Strategy_for_the_UK_Final_Version_with_Citation.pdf

[46] https://www.ofcom.org.uk/__data/assets/pdf_file/0014/104702/5G-spectrum-access-at-26-GHz.pdf

4.30 We have also updated the terms of these licence products to reflect changing demand and requirements for trials. Under the terms of the demonstration and trial licence, triallists will now be able to charge participants (specifically for the purposes and duration of the trial only) during the trial period. The idea is to offer triallists the opportunity not only to test the technology aspects but also business models and pricing structures. We see great potential to use these licences to test innovative 5G applications using high frequency spectrum, in particular 26 GHz, where potential business models may not yet have been explored.

4.31 In our summer 2017 document, we also identified 66-71 GHz as a potential band for 5G licence exempt use. As we outlined, this band has no incumbent users in the UK and we consider that 5G equipment could emerge relatively early by building on the existing 60 GHz multi-gigabit technology ecosystem and standards in the band immediately below this.[47] This band also has broad support across Europe.

4.32 In our Fixed Wireless Spectrum Strategy consultation, published in December 2017[48], in addition to making specific proposals relating to the 57 – 66 GHz band we also sought input from stakeholders on the use cases and technical parameters envisaged for the 66 – 71 GHz band in order to help inform our approach to making this additional band available. We are currently reviewing stakeholder responses and plan to publish a statement in H1 2018.

5G will likely be deployed in other bands

4.33 In parallel with the deployment of new spectrum, operators will likely deploy newer iterations of 4G within their existing spectrum holdings. These may evolve into 5G once it becomes available, increased demand requires it, and a large enough number of consumers have 5G handsets.

4.34 The first 5G New Radio specifications were standardised by 3GPP in December 2017. The initial list of bands that may be supported includes some existing mobile bands, and bands with existing authorisations in the UK. It includes 28 GHz, which is currently being used to trial fixed wireless access in the UK.

4.35 5G deployments in some bands already authorised for use is possible because we have a policy of offering technology and service-neutral licences.[49] This allows licensees to be able to innovate by changing the technology or service they wish to deploy without the need to approach us, providing the technology falls within its existing licensed technical parameters.

4.36 We remain committed to this policy of spectrum liberalisation and consider that it is an important enabler of innovation.

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[47] https://www.ofcom.org.uk/__data/assets/pdf_file/0014/104702/5G-spectrum-access-at-26-GHz.pdf
[48] https://www.ofcom.org.uk/__data/assets/pdf_file/0027/108594/Fixed-Wireless-Spectrum-Strategy.pdf
[49] 900 MHz and 1800 MHz are not licensed on a technology neutral basis, as set out in European Commission Decision 2011/251/EU

Consumers and businesses will rely on a mix of technologies, including wifi, that will complement the 5G offer

4.37 As discussed in section 2, consumers are using a range of different technologies to access broadband wherever they live, work and travel. In addition to mobile, fixed broadband (including more fibre deployment) and wifi are playing a key role, especially indoors.

4.38 We are seeking to ensure that spectrum is available to cater for growing demand. Wireless broadband in licence exempt spectrum, such as wifi, currently uses the 2.4 GHz and 5 GHz bands. In March 2017 we set out our decision to make regulations that will extend use in the 5.8 GHz band for wireless broadband.[50] This decision has allowed access to an additional 125MHz of spectrum in the 5.8 GHz band. We will continue to monitor the demand for licence-exempt uses of spectrum.

4.39 Ofcom also recognises the role of satellite in the provision of broadband connectivity for UK consumers. Our review of the space sector highlighted the role of satellite broadband, and one of our spectrum priorities is to enable growth in satellite broadband communications.

We will continue working with the Government to ensure that access to sites is not a barrier

4.40 In the past few years, regulations on planning and site access have been reformed to facilitate the deployment of communications infrastructure and we have been supporting this effort. The reforms primarily targeted the ease of deployment of taller masts in rural areas and of fixed fibre networks[51] but are also likely to ease some barriers to the deployment of 5G.[52] For instance, planning reforms were introduced in England in 2016 to allow higher mobile masts under 'permitted development rights' to support rural coverage, with Scotland introducing its own reforms in 2017. Changes to permitted development rights for operators of the Electronic Communications Code are currently being considered in Northern Ireland following consultation in 2016. Wales has identified planning reform as a possible step under its 2017 mobile action plan, but is still considering its approach.

4.41 In this section we focus on the additional challenges that 5G deployments could raise and the actions that may be required to facilitate those deployments.

5G is likely to require wider deployment of small cells

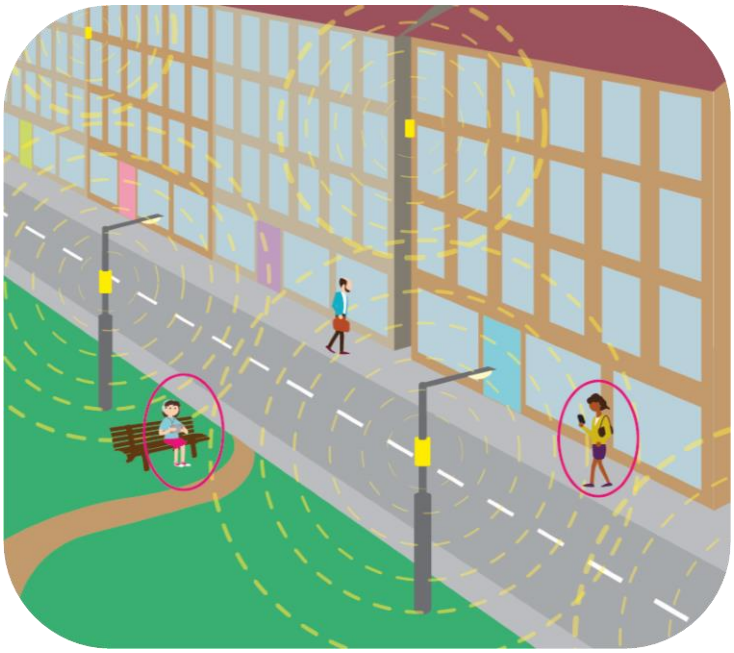
4.42 5G is expected to be deployed in new ways, for new purposes, and by new players and so will require flexibility around how and where it is deployed. In particular, 5G in the longer term is likely to see much greater deployment of small cells. These are particularly likely to be useful to provide capacity in specific locations with concentrated high demand for

[50] https://www.ofcom.org.uk/consultations-and-statements/category-1/5-GHz-Wi-Fi
[51] "A New Electronic Communications Code". DCMS. May 2016. pg 4
[52] The NIC for example also has noted that "recent planning changes and an amendment of the [ECC] have gone a long way to removing existing planning barriers." National Infrastructure Commission, Connected Future, December 2016. p16

wireless broadband. Examples of locations where such small cell deployment is likely to happen, as and when suitable handsets and equipment become available, include:

- City centres or town high streets, that have a high number of users and hence demand. We illustrate deployment in an urban street in Figure 6.
- Areas that have highly localised demand, such as transport hubs, and indoors in offices, shopping centres or sports stadiums.
- Specific locations that employ low latency applications enabled by 5G, for example, factories that use 5G for smart manufacturing.

Figure 6: Small cell deployment in a city centre



4.43 It is possible that 5G small cells will only be needed in high-demand locations rather than more widely. But if 5G services emerge that can only be deployed using high-frequency spectrum, and if these services have widespread interest amongst consumers, then more extensive deployment of small cells is likely to be needed – with the number of small cells necessary being an order of magnitude higher than the current number of mobile macro cells.

Further work to address the practical challenges of small cell rollout will be needed

4.44 Small cells, connected to a power source and the central telecoms network using backhaul, need to be practical and cost effective to deploy. There are likely to be practical challenges associated with the rollout of small cells, this is because rollout will require coordination and agreements with many different stakeholders, from local authorities to shops, property owners and utilities, amongst others.

4.45 The kind of city centre deployment shown in Figure 6 for instance will mean installing cells on street furniture (street lights, bus stops, and similar) as well as on buildings, with many

small cells required to meet capacity. Operators who wish to deploy small cells will therefore require access to suitable sites from a number of different property holders, as well as easily obtainable planning permission.

4.46 Under relevant planning legislation in the UK, radio antenna can qualify as "permitted developments" (either on their own or attached to buildings and structures) without the need for a planning application, subject to meeting certain criteria. We recognise that planning applications may continue to be appropriate in some circumstances. However, due to the large number of small cells needed for a 5G network, it will be important for the UK (including devolved governments) to consider whether the current restrictions on the scope of permitted developments might unintentionally restrict effective deployment of 5G small cells. Ensuring that small cells can be deployed under the permissive development rights regime could both reduce the timescales for 5G deployment, by making it easier for MNOs to secure small cell sites, as well as reduce the pressure on local authorities' planning departments.

4.47 Independent of government and industry, Ofcom is in a unique position to articulate the opportunities and challenges that 5G deployment presents. We welcome continued engagement with governments and industry to help develop solutions to the practical challenges involved in the deployment of widespread small cell networks. We also discussed this area in our March 2017 response to the NIC's Connected Future report.[53] We will continue to work with the UK Government and governments in the nations to ensure site access and planning requirements are not a barrier to the deployment of 5G. We welcome the UK Government's 5G Strategy's focus on potential deployment challenges and will play an active role in the Local Connectivity Group that is being established following a commitment in the recent 5G Strategy update. The Group will bring together local areas, government departments, landowners, industry and Ofcom to develop and highlight examples of deployment best practice.

We will ensure appropriate backhaul connectivity is available for 5G

4.48 Mobile networks require high capacity connections known as 'backhaul' to transmit data from cell sites at the edge of the network back to the operator's core network. Initially, the enhanced capabilities of 5G networks are likely to drive increasing volumes of data traffic through existing macro cells, meaning that network operators will need to upgrade backhaul connections to keep pace with demand.

4.49 Over time, as indicated above, operators may also deploy new small cells to meet localised demand for mobile broadband. This will see greater number of small cells deployed close to homes and businesses. Therefore, operators are likely to require access to high capacity infrastructure in these locations to provide backhaul connections from small cells back to the core network.

[53] https://www.ofcom.org.uk/__data/assets/pdf_file/0016/100528/ofcom-response-nic.pdf

4.50 For small cells, it will be important to have access to low cost backhaul solutions, given the high volume and high capacity requirements. It will also be important to have the option of integrating the backhaul termination with the radio infrastructure as this will maximise the ability to deploy flexibly and potentially reduce planning challenges.

4.51 Other technological development in the network architecture will also influence backhaul requirements. The deployment of cloud based radio access networks (C-RAN), could lead to much of the 'intelligence' moving away from individual cell sites and towards the centre of the network, enabling both better functionality and lower costs. On the other hand, the technical requirements of specific services, such as those requiring very low latency, may require computing capability to be brought closer to the user. These developments are likely to place new demands on backhaul connections, either to deliver increased capacity or support new features, which might require a denser network infrastructure for backhaul. Such developments will mean that the existing architecture of backhaul links, usually based on active services over other companies' fibre links which require third party equipment in cell sites, may no longer be appropriate. These technical and cost challenges have led to an increased interest in dark fibre rental.

A dense fibre infrastructure is key to the success of 5G

4.52 Mobile network operators continue to invest in upgrading the backhaul connections between their cell sites and core networks to handle greater volumes of data. Many of these connections are leased lines, which are the dedicated, point-to-point data transmission services also used by businesses and fixed network providers. Mobile network operators have traditionally been heavily dependent on BT's network for backhaul services using BT's active products which are currently largely provided on regulated terms and prices.[54]

4.53 However, Mobile Network Operators have been actively seeking a diversity of suppliers for the benefits that competition offers in terms of price and service. Where possible today they are using fibre services provided by competing network operators.

4.54 We consider that the best driver for investment and innovation is network based competition: and this is at the heart of our strategy. We believe competition between different networks (including those built from scratch or built using duct and poles owned by others) is the best way to drive investment in high quality, innovative services for consumers.

4.55 A key element of our strategy to enable investment in new competing fibre networks is to make it quicker and easier for operators to build their own fibre networks by improving access to BT's network of poles and underground ducts. Access to ducts and poles could

[54] We refer to this type of access as active infrastructure access or active regulatory remedies, whereby BT provides access to an active connection underpinned by the physical infrastructure as well as the electronic equipment required to activate the connection. Conversely, passive infrastructure access refers to access of passive elements of the network, such as dark fibre or ducts and poles.

have an important role to play in the deployment of new small cells, which will rely on the presence of fibre closer to the customer for backhaul connections.

4.56 Given the potential for large numbers of small cells to be close to customers' premises, backhaul requirements could be addressed by fibre networks deployed for fixed residential broadband. In this context, we have relaxed the previous usage restrictions on access to BT's ducts and poles, once reserved only for networks delivering broadband services, to allow 'mixed usage'. This means that network operators can deploy fibre to provide both broadband and non-broadband services (such as mobile backhaul), provided the purpose of the network deployment is primarily the delivery of broadband services.

4.57 We would expect competition to lead to a diverse range of services in the market, including provision of dark fibre links which are increasingly demanded by the industry. Where competition does not provide the necessary services, we will need to consider regulation to ensure such services are available.

Wireless backhaul will continue to play a role

4.58 Some small cells could use wireless technology for backhaul, either to cover shorter distances at the edge of the network (for example to connect multiple small cells to each other) or in areas where fibre is not available or cost effective. We are currently undertaking a review of the spectrum available and required for fixed wireless applications. We published a consultation on our strategy in December 2017[55], consulting on specific areas that would enable evolved uses of fixed wireless links, especially in light of the increasing capacity required as new technologies and networks evolve towards 5G. The document starts exploring new potential spectrum above 92 GHz, consults on changing the authorisation regime in the 64–66 GHz band to licence exempt and sought views on a revised technical condition across the 57–66 GHz band, commonly known as V band, in order to enable new fixed wireless access use cases. As discussed earlier in this section, we also sought views on the adjacent 66–71 GHz band. Our findings will help inform our policy in this sector.

Net neutrality regulation may need to evolve to facilitate innovations in networks

4.59 Communications networks are becoming more intelligent and powerful while often at the same time being simplified, with the functional elements of hardware undertaken by software instead. These improvements are already being implemented on 4G LTE networks, and 5G is likely to accelerate this further, thereby bringing efficiencies and consumer benefits by better addressing heterogeneous user needs, as well as offering more competition and innovation.

[55] https://www.ofcom.org.uk/consultations-and-statements/category-2/fixed-wireless-spectrum-strategy

4.60 As explained in section 3, 5G will enable network operators to provide dedicated virtual networks and better quality of experience to different customers over a common network by deploying network slicing.

4.61 It will be important to ensure that regulation does not prove an impediment to such innovation, particularly net neutrality rules. These rules are designed to preserve the benefits of the open internet. They aim to maintain innovation in the services delivered over it, while at the same time keeping the incentives for network operators to invest and innovate intact. To this end, the rules ("Net Neutrality Regulation") currently require that all traffic on the internet is treated equally.[56] Operators have expressed concerns about the impact of those rules on their ability to develop and provide 5G services. It has been suggested that the way in which these rules are interpreted by regulators could preclude investment in 5G. Operators have argued that "the current Net Neutrality guidelines, as put forward by the Body of European Regulators for Electronic Communications (BEREC), create significant uncertainties around 5G return on investment".[57]

4.62 The Net Neutrality Regulation contains rules regarding the management of data traffic on internet access services.[58] We do not consider that it is the intention of either the Net Neutrality Regulation or the relevant BEREC guidelines to prevent investment and innovation in 5G services and are working with our fellow regulators to ensure that the regulatory framework does not create a barrier to innovative uses for 5G.

Our role in facilitating co-ordination between players

4.63 As discussed in section 3, 5G will allow new wireless innovations to be developed, and could facilitate new uses for wireless technology across different industry sectors. New wireless players could also emerge to address the needs of consumers and businesses in new ways.

4.64 Discussions between wireless providers and industry are already taking place. But in order to take advantage of these new innovative uses for wireless made possible by 5G, businesses across the economy will need to consider afresh how they could make greater use of wireless technologies.

4.65 In the short term, the Government's programme of test beds and trials will be critical to providing more insight into 5G technology, its use cases and deployment challenges. The lessons of this programme may indicate that more intervention may be beneficial. We will act as a facilitator, working across different sectors and with other countries to further understand the potential applications of 5G, and how they might work in practice in the UK.

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[56] As defined in the EU Regulation on Open Internet Access Regulation (EU) 2015/2120 of the European Parliament and of the Council of 25 November 2015, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2120&from=EN

[57] A number of operators and providers for instance published a '5G manifesto' that argued against over-restrictive net neutrality rules: http://ec.europa.eu/newsroom/dae/document.cfm?action=display&doc_id=16579

[58] Article 3(1) to (3) of the Regulation

5. Wider implications of 5G

5.1 Once the deployment of 5G takes place, other policy issues could arise that may need to be considered in more detail. Inevitably any consideration of future consequences is subject to considerable uncertainty, and this is especially the case with 5G as it is not yet a reality. Nevertheless, we consider it useful to set out some of the possible consequences in order to facilitate a discussion as we take our immediate work in relation to 5G forward. In this section we consider the following issues:

- 5G coverage
- Security
- The evolving nature of competition in fixed and wireless markets
- Policy issues in relation to shared network infrastructure
- Helping consumers get the benefit of 5G services

5G coverage

5G will not in itself extend mobile coverage

5.2 Consumers are increasingly expecting near-ubiquitous coverage for their mobile devices. But currently, coverage often falls far short of this. Data from our Connected Nations 2017 report show that coverage indoors in homes and offices, on road and rail networks, and in less densely populated rural areas is particularly poor. [59]

5.3 However, 5G deployment will not in itself solve these coverage problems. 5G is expected to play an important role in providing higher speeds and extending capacity at existing mobile sites but it is unlikely that 5G will extend the current geographic footprint of networks.

5.4 Nevertheless, the evolution of current wireless networks has the potential to improve indoor coverage and user experience by providing more seamless integration across heterogenous networks, for example when moving between mobile and wifi networks or through providing voice telephony over wifi.

5.5 We are working to improve mobile coverage by ensuring existing coverage obligations are met, and considering obligations for coverage where new spectrum is awarded, for example, we are currently consulting on new coverage obligations in the 700MHz band licences we plan to auction in 2019.[60]

[59] https://www.ofcom.org.uk/__data/assets/pdf_file/0024/108843/summary-report-connected-nations-2017.pdf
[60] https://www.ofcom.org.uk/consultations-and-statements/category-2/700-mhz-coverage-obligations

Security as a key priority

5.6 In order for consumers to have confidence in 5G services, it will be important to ensure that they are secure. This is a challenge for all communications networks and service providers, and indeed more generally.

5.7 Networks will also be more intelligent allowing a personalised experience for each individual user. For example, networks could work out when an individual is about to enter an area with a lower level of coverage or they could send content that is tailored to the location of the individual. It will be important that users' data is properly protected.

5.8 Furthermore, network virtualisation allows the replacement of dedicated network equipment such as routers with software that is located on remote servers. The centralised software will require a high level of protection as the consequence of breech could affect several parts of the network. Whilst network virtualisation is already being used today, it could play an increasingly important role. It will be important to ensure that approaches to security take into account this evolution.

5.9 On the other hand, the evolution of network architecture and the further possibility to create virtual slices of a network to assign to different services could lead to the ability to customise the level of security, for example an isolated virtual network or 'slice' of an MNO's network could now be more suitable than in the past to address the needs of local or private networks. In this context it will be important to ensure the different security requirements of the different virtual networks are maintained.

More choice for consumers as there is further convergence between fixed and wireless networks

5.10 The deployment of 5G is likely to mean that consumers benefit from more choice and innovation in communications services.

5.11 5G may enable fibre-like speeds over wireless networks, making fixed wireless access an increasingly attractive proposition for consumers. If fixed and wireless broadband begin to look increasingly alike and can deliver similar speeds, consumers may choose a wireless provider for their home broadband. Both existing mobile operators and new players may consider offering fixed wireless services to their customers.

5.12 Furthermore, fixed and mobile networks are likely to continue to become more similar. Consumers want to transition seamlessly from one network to the other, from mobile to wifi, both relying on fibre connectivity to the core network. Convergence of the assets used to deliver services is likely to increase with the advent of 5G because more fibre will be needed closer to the end user. Operators are likely to consider the benefits of leveraging their assets for both fixed and wireless networks rather than operating as stand-alone providers.

5.13 5G is also expected to enable new services, and therefore create the environment for new wireless providers, either directly offering services or using a "slice" of the network to

resells wireless services. New players may acquire spectrum and utilise it to offer wireless services to different providers, for example an operator could provide infrastructure access to businesses or retail providers who in turn sell services to consumers. In turn, new competition could help create a range of innovative services that use wireless networks.

5.14 The services enabled by 5G could also change the way consumers behave, for example including the degree of competition and potential substitution between fixed and mobile broadband. We would consider the extent to which any change in substitutability had occurred, and our regular market reviews, and our approach to assessing competition more generally, give us the tools to take new competitive developments into account in the way in which we regulate markets.

Greater sharing of network assets may happen

5.15 We will also consider the role that more infrastructure sharing could play for 5G services. MNOs have, in the past, made commercial agreements with one another to share some of the infrastructure used to provide their networks, for example masts, antennas, radio equipment and backhaul capacity.

5.16 5G could alter such arrangements. Given the extra costs of deploying 5G, particularly for small cells, MNOs and other wireless operators may increase efforts to share network assets at different levels of the value chain, including potentially through joint ventures, reciprocal access or neutral host arrangements. For example:

i) **Physical sites and assets**. Sharing of physical sites not only cuts costs, it also means that fewer mobile masts are needed. On the other hand, however, competition at the network level also provides important benefits including greater possibility for innovation and competition to provide good coverage.

ii) Electronics and backhaul. As well as sharing masts, providers may also share the radio equipment on the masts and/or the backhaul from the masts. As with physical infrastructure sharing, this can lower costs, subject to guarding against detriment to competition.

iii) **Sharing through user authentication**. Sharing where an operator sells access to its infrastructure to a number of wireless operators, could become more common. For instance, some operators have a network of wifi hotspots to which they provide access on commercial terms to other providers whose customers are then able to use them.

5.17 On the other hand, it is also possible that sharing arrangements may not be extended further as a result of 5G. This could be because 5G often requires more and bigger antennas on a mobile mast, making sharing less practical, or MNOs may choose to follow different network strategies, for instance, if they have very different spectrum holdings or want to pursue different network deployment strategies.

5.18 We have generally welcomed initiatives to share assets in the past, given their potential to deliver the benefits of increased investment and innovation to consumers. However,

because some forms of asset sharing can negatively impact competition, a balance needs to be struck. For instance, sharing may mean less competitive differentiation between networks, for example on service quality. Or concerns may arise if it is impractical or uneconomical to deploy several sets of small cells in a particular area since this might lead one provider to have a competitive advantage over another, which could result in potential competition issues or consumer detriment. While we therefore welcome industry initiatives to share sites and infrastructure to enable cost effective deployment of 5G, we will continue to work to protect competition as appropriate.

Helping consumers get the benefit of 5G services

5.19 As the number of services available to consumers proliferates, it will be important that they are empowered to choose effectively in the marketplace. Hence it will be important that consumers get clear information on services available through 5G, for instance, on the extent of coverage, capabilities or service quality including speeds they can expect when using 5G. People need to be in a position to make the choice that is right for them, including whether to upgrade.

5.20 The information currently available on mobile coverage and quality of service is often not good enough to enable consumers to make effective choices. We have sought to improve the level of consumer information available, for example by publishing information for consumers on quality of service[61] and by creating a checker tool that provides information on mobile and broadband availability[62] and we are continuing our work in this area. But as the wireless market evolves, we expect MNOs and other providers will also need to do more to provide better information to consumers about what to expect when they buy a service, for example, better coverage checking tools that reflect consumers' actual experience of the services they can use and where those services are available. Consumers should have the clear and comprehensive information they need to make effective choices.

[61] https://www.ofcom.org.uk/__data/assets/pdf_file/0022/100768/comparing-service-quality-overview.pdf
[62] https://www.ofcom.org.uk/phones-telecoms-and-internet/advice-for-consumers/advice/ofcom-checker