HOUSE OF COMMONS LIBRARY

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5G

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Summary

What is 5G?

5G is the next generation of wireless communications technology. It is expected to provide faster connections with much higher capacity and very fast response times, allowing many more users and devices to access fast internet connections and large amounts of data at the same time. Mobile broadband is the first commercial application of 5G. 5G is also expected to be used in applications beyond mobile networks, for example in healthcare, smart cities, transport and manufacturing.

A more detailed discussion of 5G technology and applications is provided in the Parliamentary Office of Science and Technology POST brief on 5G technology (24 July 2019). This paper focuses on policy challenges and developments surrounding the roll-out of 5G in the UK.

When and where will 5G be rolled out?

5G for mobile broadband and is being rolled-out by private mobile network operators: EE, O2, Vodafone and Three. The first commercial networks went live in major UK cities in 2019. Initially, 5G is expected to be deployed largely from existing 4G base stations in busy urban areas. Detailed roll-out plans of private operators are not publicly available.

Government 5G policy

The Government has a target that the majority of the population will be covered by a 5G signal by 2027. The Government's strategy for future digital infrastructure – full-fibre and 5G – is set out in DCMS's Future Telecoms Infrastructure Review (FTIR), published on 23 July 2018.

5G policy challenges

5G presents some new and different infrastructure challenges compared to 3G and 4G. 5G is expected to see a greater number of small cells (low powered base stations that can be mounted on buildings and street furniture) and will require wider deployment of full-fibre broadband infrastructure. Additionally, 5G deployment will require significant investment from mobile operators and other stakeholders, which still presents commercial risks and uncertainties as 5G applications and business cases develop.

Spectrum for 5G

5G will require spectrum of different frequencies to suit different applications. Ofcom is working on making spectrum available in three categories:

- Low frequency spectrum (the 700 MHz band) to enable wide coverage;
- Mid-frequency spectrum (the 3.4–3.8 GHz band) for large bandwidths to provide necessary capacity and to enable higher speeds; and
- High-frequency spectrum (26 GHz band) providing ultra-high capacity but with very small coverage ranges.

Some 5G spectrum was auctioned in April 2018 (the 3.4–3.6 GHz band; see the Library paper: Spectrum Auctions 2018 for background). Ofcom plans to auction spectrum in the 700 MHz and 3.6–3.8 GHz bands by Spring 2020. Trial licences are available in the 26 GHz band.

1. 5G in the UK

1.1 What is 5G?

5G is the next generation of wireless network technology. It is expected to support many other uses beyond mobile broadband.

5G follows on from the development of 2G, 3G and 4G mobile technology:[1]

- 2G was the first digital mobile technology. It is suitable for making calls, sending text messages and supports very-low speed data connections;
- 3G made it possible to access the internet more effectively through a mobile phone (called mobile broadband), supporting voice, text and data services. 3G provides typical download speeds of over 5 Mbps (in 2014, the UK average was 6 Mbps).[2]
- 4G, launched in 2012, made it much quicker to surf the web on mobile phones, tablets and laptops, supporting faster upload and download speeds and faster response times. 4G supports download speeds over 10 Mbps (in 2014, the UK average was 15 Mbps).[3]

5G technology is expected to bring three main differences to 4G: faster data speeds, high capacity and faster responsiveness (low latency):[4]

5G is expected to bring much faster data speeds, high capacity and low latency.

- **Faster data speeds**: means very high data upload/download speeds. Ofcom states that peak speeds of 10–20 gigabits per second will be possible with 5G.
- **High capacity**: means the ability to connect very large numbers of devices. Ofcom states that 5G could support up to one million devices per square kilometre.
- **Low latency**: latency is the delay time for a communications signal, that is, the time between when you click something and when you see a response (such as a website beginning to load). Low latency means fast signal response times. Ofcom states that 5G is expected to have latency in the order of 1 millisecond, which means that 5G response times will feel instantaneous, which is important for real-time communications applications such as virtual reality and driverless cars (see below).

The first sets of technology standards for 5G have been agreed by the international industry standardisation body 3GPP (3rd Generation Partnership Project) and standards are still developing.[5] Formal

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1 Ofcom, Connected Nations 2018, 18 December 2018, Main Report, page 22.
2 Ofcom, Connected Nations 2017, Detailed analysis: mobile voice and data services, 22 December 2017, page 35; Ofcom, Ofcom publishes 4G and 3G mobile broadband speeds research, 13 November 2014 [accessed 7 February 2019].
3 Ofcom, Connected Nations 2017, Detailed analysis: mobile voice and data services, 22 December 2017, page 35; Ofcom, Ofcom publishes 4G and 3G mobile broadband speeds research, 13 November 2014 [accessed 7 February 2019].
4 Ofcom, What is 5G, 9 March 2018; [accessed 7 February 2019]; Ofcom, Enabling 5G in the UK, 9 March 2018, para 2.6.
5 3GPP, RAN adjusts schedule for 2nd wave of 5G specifications, 14 December 2018.

standards are expected to be agreed by the International Telecommunications Union (ITU) by 2020.[6]

5G applications

The above listed features – fast data speeds, high capacity and low latency – mean that 5G is expected to support a variety of uses beyond mobile broadband.

5G is likely to support many applications beyond mobile broadband.

Use cases for 5G can be grouped into three broad categories, which Ofcom summarises as applications that support more data, more devices and instant response times: [7]

- **Enhanced mobile broadband (more data)**: this means an evolution of the 4G services already used, including improved consumer experience (such as a more consistent service), more connected devices and faster connection speeds. 5G may also be used for wireless home broadband and could support virtual and augmented reality technology. While 5G is expected to provide faster speeds and extend capacity at existing mobile sites, it would not, of itself, extend the coverage of mobile networks.
- **Massive Machine Type Communications (more devices)**: this means that 5G is expected to support many internet-connected devices and applications – known as the Internet of Things (see Box 1). This could include applications from e-health, transport and logistics, environmental monitoring, smart energy networks and smart agriculture.
- **Ultra-reliable and low latency communications (instant response):** this means that 5G will be able to support near real-time communications applications with high reliability. Applications may include driverless vehicles, drone delivery, smart manufacturing, remote healthcare and emergency response and management.

These different use cases and services will have different requirements in terms of speed, coverage, reliability and security, which will demand different network designs, spectrum bands, infrastructure requirements and roll-out models.[8] Most of these use cases are still developing in terms of technology and businesses cases that would support their deployment.

More information about 5G technology standards and applications beyond mobile broabdand is provided in the Parliamentary Office of Science and Technology POST brief on 5G technology (24 July 2019).

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6 ITU, Futuristic mobile technologies foresee "IMT for 2020 and beyond, Setting the Scene for 5G: Opportunities & Challenges report; 10 September 2018 [accessed 6 September 2019].

7 Ofcom, What is 5G, 9 March 2018; [accessed 6 September 2019]; Ofcom, Enabling 5G in the UK, 9 March 2018; ITU, Setting the Scene for 5G: Opportunities & Challenges report; 10 September 2018.

8 Ofcom, Update on 5G spectrum in the UK, 8 February 2017; ITU, Setting the Scene for 5G: Opportunities & Challenges report; 10 September 2018.

Box 1: The Internet of Things

The Internet of Things (IoT) refers to a network of connected devices that talk directly to each other without needing to interact with human beings. 5G is likely to be the networking technology that supports the Internet of Things in the future, due to its low latency and capacity to support many devices at one time. Examples of possible uses are numerous and encompass a vast range of sectors. Some of these technologies already exist or are in development, some are not. Examples suggested to date include smart energy meters, wearable health sensors, driverless cars, smart bins that send warnings when they are full, and smart fridges that can tell you how much food you have left or even order replacement items when you run out.

1.2 When and where will 5G be rolled-out?

5G mobile broadband

Mobile broadband is the first commercial use of 5G. The roll-out of 5G mobile broadband is led by commercial mobile network operators (MNOs) who choose when and where they will roll-out services. There are four MNOs in the UK: EE (owned by BT), Three, Vodafone and O2.

EE, Vodafone and Three launched commercial 5G services in several major cities in 2019 and O2 is also expected to launch services later in 2019 (see Box 2).

Detailed roll-out plans, for example where infrastructure is located, are not usually publicly available. Initially, 5G infrastructure is likely to be deployed on existing 4G mobile sites in busy urban areas to enhance the capacity of existing mobile broadband (that is, the number of people that can use the network at one time with a high-quality of service).

Initially, 5G mobile broadband is likely to be deployed largely from existing 4G sites.

Box 2: 5G networks launched by mobile network operators

- EE launched its first commercial 5G mobile broadband network in London, Cardiff, Edinburgh, Belfast, Birmingham, and Manchester on 30 May 2019.[9] EE plans for its network to reach 26 cities by 2020.[10]
- Vodafone launched 5G mobile broadband in seven cities on 3 July 2019 (Birmingham, Bristol, Cardiff, Glasgow, Manchester, Liverpool and London) with further cities to be connected throughout 2019.[11]
- Three launched a 5G home broadband service in London on 19 August 2019, to be followed by a further 25 cities in which it intends to launch both 5G mobile and home broadband by the end of 2019.[12]
- O2 annouced it will launch its first 5G networks in parts of Belfast, Cardiff, Edinburgh, London, Slough and Leeds from October 2019, with plans to reach 20 towns and cities by the end of 2019 and 50 cities by summer 2020.[13]

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9 EE press release, EE launching UK's first 5G service in six cities, bringing a new era in faster, more reliable connectivity, 22 May 2019 [accessed 6 September 2019].

10 EE, 5G coverage where it matters most, [accessed 6 September 2019]

11 Vodafone press release, Vodafone 5G goes live on 3 July 2019 in the UK, with 5G roaming available this summer, 19 May 2019 and Vodafone 5G is Live [accessed 6 September 2019]

12 Three press release, Three switches on 5G today: 5G is in the house, 19 August 2019 [accessed 6 September 2019].

13 O2 press release, O2 announces October 5G launch, prioritising areas where customers will benefit most, 25 July 2019 and O2 5G [accessed 6 September 2019].

5G trials: developing new 5G applications

5G presents many potential use cases beyond mobile broadband. Most of these use cases are still in development. Commonly cited applications include healthcare, smart cities, transport and manufacturing. 5G applications for rural areas (see section 2.3 of this paper) include providing broadband connectivity, agri-tech, precision farming and tourism applications.[14] These kinds of wider 5G applications may use dedicated networks (i.e. separate from the main mobile networks).

Developing these wider 5G applications involves collaborations and input from academia and local Government as well as industry. A report from Digital Catapult (the UK's digital innovation centre)[15] – 5G Nation: the UK 5G Ecosystem 2018 – provided a map of 135 5G-relevant trial projects across the UK, involving 39 academic institutions, 29 local authorities and 57 companies.[16] Further information and examples are available on the Digital Catapult website: 5G mapping.

The Government is supporting 5G trials through its 5G testbeds and trials programme (see Box 3). Another large source of 5G trial activity is UK universities (see Box 4).

Box 3: 5G Testbeds and Trials

The Government's 5G Testbeds and Trials programme (led by the Department for Digital Culture Media and Sport (DCMS)) is supporting 5G trial projects across a range of sectors to identify opportunities for 5G, develop business models and improve understanding of potential deployment challenges.

Trial projects include:

1. 5G Smart Tourism (Bath and Bristol)
2. Liverpool 5G Testbed (Liverpool)
3. AutoAir: 5G Testbed for Connected and Autonomous Vehicles (Millbrook)
4. Worcestershire 5G Consortium - Testbed and Trials (Worcestershire)
5. 5G Rural Integrated Testbed (5GRIT) (Cumbria, Northumberland, North Yorkshire, Inverness-shire, Perthshire and Monmouthshire).
6. 5G RuralFirst: Rural Coverage and Dynamic Spectrum Access Testbed and Trial (first trial to focus on Orkney Islands, Shropshire and Somerset).
7. The West Midlands Combined Authority (WMCA) will lead a 5G Urban Connected Communities (UCC) project that will trial a large-scale 5G testbed in a UK city.

Two further competitions under the 5G testbeds and trials programme have been launched, one focusing on industrial applications of 5G such as logistics and manufacturing and the other focusing on applications of 5G in rural communities. Both competitions are open for applications.

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14 Digital Catapult report: 5G Nation: the UK 5G Ecosystem 2018, 11 June 2018.

15 Digital Catapult is one of a network of Catapult Centres established by Innovate UK (an executive agency of the Department for Business, Energy and Industrial Strategy) as independent, not-for-profit physical centres to connect businesses with academic researchers by providing facilities and programmes to support collaboration. 5G is one of three core technology programme streams that Digital Catapult focuses on.

16 Digital Catapult report: 5G Nation: the UK 5G Ecosystem 2018, 11 June 2018, Figure 4, pages 18 and 20.

Box 4: UK Universities and 5G

UK universities are leading work on 5G technology development. For example:

- The 5GUK project is a collaboration between the University of Surrey, University of Bristol and Kings College London to develop a 5G test network that can then be used to trial other projects. The project funding included £16 million awarded by DCMS in July 2017.[17]
- University of Surrey's 5G Innovation Centre opened in 2015.[18] The centre supports several research groups as well as partners across industry, other universities and local and national government.
- University of Bristol's Smart Internet Lab includes projects on smart city applications of 5G in Bristol.
- Kings College London's Centre for Telecommunications Research has been running 5G trial projects in collaboration with Ericsson at their London campus.

1.3 Government's 5G strategy and policy

The Government's strategy for future digital infrastructure – 5G and full-fibre networks – is set out in DCMS's Future Telecoms Infrastructure Review (FTIR) published on 23 July 2018.[19] The Government had published two previous 5G strategies prior to the FTIR, in March and December 2017.[20]

In the FTIR the Government stated an ambition to be a world leader in 5G, noting that 5G has the potential to generate "significant economic benefits from the digital transformation of many sectors".[21] The Government set a target that "the majority" of the population would be covered by a 5G signal by 2027.[22]

The Government has set a target that the majority of the population will be covered by a 5G signal by 2027.

The Government's policy focus set out in the FTIR is to support a "market expansion model" for 5G in the UK. This means 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.[23]

The FTIR identified four priority areas that Government policy for 5G will focus on to support the market expansion model:

1. Make it easier and cheaper to deploy mobile infrastructure and support market expansion, including the implementation of the wide-ranging Electronic Communications Code (ECC) on site access and consideration of further planning reforms;
2. Support the growth of infrastructure models that promote competition and investment in network densification and extension;

[17] DCMS, Three universities to develop £16m 5G test network, 6 July 2019, [accessed 6 September 2019].
[18] University of Surrey, 5G Innovation Centre officially opens at the University of Surrey, 15 September 2015, [accessed 6 September 2019].
[19] DCMS, Future Telecoms Infrastructure Review, 23 July 2018.
[20] DCMS, Next Generation Mobile Technologies: A 5G Strategy for the UK, 8 March 2017; and Next Generation Mobile Technologies: An Update to the 5G Strategy for the UK, 19 December 2017.
[21] DCMS, Future Telecoms Infrastructure Review, 23 July 2018, page 53.
[22] DCMS, Future Telecoms Infrastructure Review, 23 July 2018, para 158.
[23] DCMS, Future Telecoms Infrastructure Review, 23 July 2018, para 187.

3. Fund beneficial use cases through the Government's £200 million 5G Testbeds and Trials Programme that helps de-risk business models for 5G; and
4. Promote new, innovative 5G services from existing and new players, through the release of additional spectrum. We should consider whether more flexible, shared spectrum models can maintain network competition between MNOs while also increasing access to spectrum to support new investment models, spurring innovation in industrial internet of things, wireless automation and robotics, and improving rural coverage.[24]

The Library briefing papers on Mobile Coverage in the UK and Full-fibre networks in the UK provide information about the reforms to the Electronic Communications Code as relevant to mobile and fibre networks, respectively, and section 2 of this paper provides information about proposed planning reforms. Box 3 above explains the Testbeds and Trials programme (the third listed priority area) and section 3 of this paper covers spectrum policy (the fourth listed priority area).

The FTIR was broadly welcomed by industry stakeholders as a statement of Government ambition to facilitate digital infrastructure build.[25] Mobile UK, the trade body for mobile operators, said that the FTIR was a "step in the right direction" but argued that the strategy lacked urgency and clear deadlines for action:

> The publication of the DCMS's Future Telecoms Infrastructure Review is a step in the right direction and begins to provide the mobile industry with a view of the Government's ambitions and how it wants to achieve them. Its recommendations by and large mirror much of what the industry has highlighted is required for the UK to become a world leader in digital connectivity. The problem, however, is that its sense of urgency and emphasis on action needed 'at a pace' is not matched by a solid timetable for reform or firm commitments to reform the planning system which is not yet fit for purpose for the upcoming 5G deployment. Urgency should be the watchword here but without set deadlines and firm commitments it is difficult to see how or even when these recommendations will come about.[26]

The Confederation of British Industry (CBI) commented in a report published in December 2018, that a "step-change" in Government action was required to meet the ambitious coverage targets set in the FTIR.[27] Rural stakeholder groups have raised concerns about rural areas being left behind in the 5G roll-out (see section 2.3).[28]

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24 DCMS, Future Telecoms Infrastructure Review, 23 July 2018, page 12.

25 Wireless Infrastructure Group, Wireless Infrastructure Group welcomes DCMS Future Telecoms Infrastructure Review (FTIR), July 2018; Mobile UK, Government published its Future Telecoms Infrastructure Review, July 2018; techUK, initial response to Future Telecoms Infrastructure Review, 23 July 2018. [Accessed 11 February 2019].

26 Mobile UK, Future Telecoms Infrastructure Review is a positive step but it is deadlines that will achieve its goals, Gareth Elliott, July 2018 [accessed 11 February 2019].

27 Confederation of British Industry, Ready, Set, Connect, 7 December 2018 [accessed 11 February 2019].

28 Country Land and Business Association, Rural areas still lacking 4G at risk of being side-lined amid 5G rollout, says CLA, 9 August 2019, [accessed 11 June 2019].

Government funding for 5G

Government funding support for 5G since 2016 has been allocated through the National Productivity Investment Fund (NPIF).[29] The NPIF, which also covers other areas such as housing and transport, was first announced in the Autumn Budget 2016 and, following extensions every year since then, is now a £37 billion overall fund running to 2023–2024.[30]

In the Autumn Statement 2016, the Government announced £740 million from the NPIF would be set aside for full-fibre networks and 5G. From that funding, the main investment for 5G has been £200 million for the testbeds and trials programme (see Box 3).[31] That funding has included:[32]

- £10 million set aside for testing the security of 5G networks.
- £5 million to test 5G applications and deployments on roads.
- £40 million for the industrial applications 5G testbed and trials competition.[33]
- £30 million for the Rural Connected Communities Project.[34]

Mobile UK and the CBI have both called for further funding support for mobile infrastructure, arguing that the Government should support mobile infrastructure to the same extent as initiatives for fixed-broadband (full-fibre) networks.[35]

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29 Note this section does not include funding allocated through research grants.

30 The NPIF was first announced in the Autumn Budget 2016 as a £23 million fund to 2020–2021; the Autumn Budget 2017 extended the overall NPIF to £31 billion, which corresponded to an extra £7 billion for 2022-2023. The Autumn Budget 2018 extended the NPIF to 2023-24, and expanded it to £37 billion overall.

31 DCMS, 5G testbeds and trials programme webpage lists projects funded under the programme. The 5G Testbeds & Trials Programme Update (September 2018) states the total funding for the programme is £200 million.

32 HM Treasury, Autumn Budget 2017, 22 November 2017, section 5.19, set aside £160 million for 5G testbeds and trial programme.

33 DCMS, Government to boost 5G and simplify planning to support mobile deployment, 12 June 2019, accessed 28 August 2019.

34 DCMS, £30m to spark rollout of next generation 5G in rural areas and help countryside capitalise on tech revolution, 27 August 2019; accessed 28 August 2019.

35 Mobile UK, Budget 2018: Fibre progress welcomed but mobile infrastructure cannot be forgotten, 29 October 2018; Confederation of British Industry, Ready, Set, Connect, 7 December 2018, page 7. [Accessed 11 February 2019]

2. Challenges for 5G

2.1 Building 5G infrastructure

Mobile operators argue that there are barriers holding back the roll-out mobile infrastructure (generally, both 4G and 5G) and have called for further reforms such as to the planning regime, access to public assets, and for better collaboration between local authorities, landowners and industry.[36] 5G infrastructure presents some challenges that make these concerns particularly acute for 5G-roll out compared to mobile coverage generally; some of these challenges are set out below. Box 5 below provides an overview of key mobile infrastructure terminology used in this section.

In the FTIR (July 2019) the Government reiterated its support for facilitating the roll-out of mobile infrastructure and stated it would consider planning reforms. In August 2019, the Government launched a consultation on changes to planning rules to facilitate the roll-out of 5G and extend mobile coverage (see Box 6).

Box 5: Mobile infrastructure explainer

Base stations: mobile base stations contain radio communications equipment that sends and receives mobile voice/data signals over an area surrounding the station and connects them to a mobile operator's network. Mobile masts, macro cells and small cells are all types of base stations. Mobile base stations require access to power and a backhaul connection.

Macro cell: a mobile base station that provides wide-area coverage for a mobile network. The antennas for macro cells can be mounted on ground-based masts, rooftops or other existing structures.

Small cell: a low-powered base station that provides coverage over a smaller area than macro cells. Small cells are already used for 4G networks in some areas. Small cells are used to boost mobile network capacity and coverage in localised areas e.g. dense urban areas where there are large numbers of users. They are smaller and lighter than macro cells so can be mounted in more places, for example on street furniture.[37] There are different types of small cells (e.g. femtocells, picocells, microcells) that operate with different coverage ranges.

Backhaul: the link that connects a mobile base station to the core internet and phone network. Backhaul is usually provided by full-fibre broadband cables or fixed-radio links.

[36] Mobile UK, Building Mobile Britain, [accessed 8 February 2019]; Broadband Stakeholder Group, Forging our 5G Future: Barriers and Solutions to network deployment, 20 July 2018; DCMS, Future Telecoms Infrastructure Review, 23 July 2018, para 194-200; Digital Catapult. 5G Nation: the UK 5G Ecosystem 2018, 11 June 2018, page 44.

[37] GMSA, Improving wireless connectivity through small cell deployment (pdf) December 2016.

What are the challenges to building 5G infrastructure?

5G presents some new and different infrastructure challenges compared to the roll-out of 3G and 4G.[38] Mobile operator EE listed the following as examples of infrastructure challenges faced by 5G equipment:

- Rooftop sites often need significant strengthening to carry the new 50kg 5G antennas – and some sites house three of these
- The level of upgrade work required can cause delays in obtaining planning permission, and can necessitate repeat visits, which means multiple access requests to landlords
- Location for 5G antennas can be dictated by the need to stay below regulated power output levels.[39]

Small cells: Initially, 5G is first expected to be deployed from existing macro sites used for 3G and 4G (which require an upgrade to support 5G). In the longer term, 5G networks are also likely to require a greater number of small cells compared to 3G and 4G to provide capacity for the large numbers of users and devices that 5G is expected to support. Also, high-frequency applications of 5G require base stations to be placed closer together because high-frequency signals cannot travel long distances (see Box 8 for information about frequency characteristics). The large-scale deployment of small cells for 5G is a longer-term prospect and there is still uncertainty about the number of small cells that will be required or ultimately deployed.[40]

There is still some uncertainty about the number of small cells that will be deployed for 5G networks.

In the FTIR the Government stated that its analysis indicated that the roll-out of 5G on existing macro sites with some smalls cells in dense urban areas appeared feasible by 2020, but that the larger scale deployment of small cells would likely require new approaches to building infrastructure from operators and local stakeholders to enable more efficient deployment.[41]

Backhaul: Backhaul connections to 5G sites present another infrastructure challenge. Backhaul connections at some 3G and 4G base stations are not suitable for 5G and require upgrading to support much higher capacity connections that 5G requires.[42] Further, a dense array of 5G small cells is likely to require a dense full-fibre network to support it, which also faces infrastructure challenges. The roll-out of 5G is therefore strongly linked to full-fibre roll-out. The Library briefing paper on Full-fibre networks in the UK provides information about building full-fibre networks.

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38 Broadband Stakeholder Group, Forging our 5G Future: Barriers and Solutions to network deployment, 20 July 2018; Arqiva, Rolling out 5G in the UK: What's involved?, Jonathan Freeman, 5 December 2017 [accessed 11 February 2019].
39 EE, EE switches on 5G trial sites in East London, 7 November 2018, [accessed 15 January 2018].
40 DCMS, Future Telecoms Infrastructure Review, 23 July 2018, para 181.
41 DCMS, Future Telecoms Infrastructure Review, 23 July 2018, para 184-185.
42 Digital Catapult. 5G Nation: the UK 5G Ecosystem 2018, 11 June 2018, page 44-45.

Box 6: Consultation on planning changes for mobile masts in England

Do mobile masts require planning permission?

The installation of a mobile phone mast would count as a development and would normally require a full application for planning permission. However, designated mobile network operators,[43] have certain permitted development rights, which means that they can build prescribed infrastructure without having to apply for planning permission from the local authority.[44] "Prior approval" from the local planning authority regarding the *siting and appearance* of the development is required in certain circumstances; for example, all new ground-based masts require prior approval.

Permitted development rights for electronic communications infrastructure in England are set out in the 2015 Town and Country Planning Order[45] as amended by the *Town and Country Planning (General Permitted Development) (England) (Amendment) (No 2) Order 2016*.[46]

Background information about planning rules for mobile masts is provided in the Library briefing paper: Mobile Coverage in the UK (22 February 2019), which applies to all mobile infrastructure (4G and 5G).

What changes are proposed?

In August 2019, the Government opened a consultation on changes to planning rules to facilitate the roll-out of 5G and extend mobile coverage in England. The consultaion seeks views on proposed changes to permitted development rights in the following areas:

- Enabling deployment of radio equipment housing on land without prior approval, excluding sites of special scientific interest. Radio equipment housing means the cabinets containing equipment needed to support the mast such as the power source. Currently, equipment housing of more than 2.5 cubic meters and all equipment housing on protected land[47] and sites of special scientific interest require prior approval.
- Allowing existing masts to be widened without prior approval to enable sites to be strengthened and upgraded for 5G and increase sharing between operators. Currently, masts can be widened by up to one third without prior approval, this proposal would remove the one-third limit.
- Enabling the deployment of building-based masts nearer to highways.
- Enabling higher masts (subject to prior approval) to encourage the development of taller but fewer masts.

Any changes would apply to all mobile infrastructure in England, not just 5G. The consultation is open until 4 November 2019.

Devolved Administrations

As planning is a devolved policy area, different permitted development regulations apply in each nation. Page 24 of the Library briefing paper on Mobile Coverage in the UK provides information and resources about permitted development rights in the devolved Administrations.

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43 The rights only apply to network operators licenced under the Electronic Communications Code (see Section 3.3 of the Library paper on Mobile Coverage in the UK).

44 Permitted development rights derive from a general planning permission granted by Parliament, rather than from permission granted by the local planning authority. For more information, see the Library briefing paper on Permitted Development Rights, SN 00485 17 May 2019.

45 *The Town and Country Planning (General Permitted Development) (England) Order 2015* SI 2015/596.

46 *Town and Country Planning (General Permitted Development) (England) (Amendment) (No 2) Order 2016* SI 2016/1040.

47 Protected land means land defined in Article 2(3) of the *Town and Country Planning (General Permitted Development) (England) Order 2015*, which includes conservation areas, areas of outstanding natural beauty, national parks and world heritage sites (amongst others).

2.2 Investment and commercial risks

Deployment of 5G will require significant investment from mobile operators and other relevant stakeholders (for example wireless and full-fibre infrastructure providers).[48] In the FTIR the Government estimated that deployment of 5G will require a total of £3–4 billion overall investment. The Government highlighted that the large-scale roll-out of 5G still presents commercial risks for mobile network operators as business cases and demand are still developing, describing this uncertainty as a "policy puzzle":

> On the demand side, there remains uncertainty about exactly where 5G will make the biggest impact and the extent to which demand for new applications and services will emerge. On the supply side, it is not yet clear how and where 5G networks will be deployed. It is likely that their development will be part of a wider ecosystem of wireless connectivity, building on investment in 4G networks and the ongoing development of fixed network infrastructure, with different upgrades required to deliver different use cases in different areas.
>
> This puzzle could mean that 5G deployment may be less extensive than would be optimal for society.[49]

The Broadband Stakeholder Group highlighted "investment uncertainty" as one of the biggest overarching barriers to 5G deployment, stating that this makes removing other barriers to 5G deployment (such as to infrastructure build highlighted above)"all the more important".[50] Mobile operators have called for tax relief for mobile infrastructure and for more funding to local and regional bodies to support mobile infrastructure deployment.[51]

The International Telecommunications Union (ITU) (the UN Agency for communication technologies) also identified investment risk and uncertainty as important policy challenges for 5G deployment and urged policy makers internationally to also focus on boosting 4G networks while 5G investment cases develop (September 2018).[52]

2.3 5G in rural areas

In the context of encouraging policy makers to continue to focus on boosting 4G coverage, the ITU also noted in general that there is a risk that 5G could widen "digital divides" if rural areas fall behind urban areas on 5G roll-out.[53] Rural stakeholder groups in the UK have raised this as a potential concern in the UK: the Country Land and Business

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48 ITU, Setting the Scene for 5G: Opportunities & Challenges report, 10 September 2018, pages xii and 9 [accessed 14 February 2019].
49 DCMS, Future Telecoms Infrastructure Review, 23 July 2018, page 53.
50 Broadband Stakeholder Group, Forging our 5G Future: Barriers and Solutions to network deployment, 20 July 2018.
51 Mobile UK, Mobile UK Budget Submission: Time to Prioritise Mobile Infrastructure, 29 October 2018, [accessed 7 February 2019].
52 ITU, Setting the Scene for 5G: Opportunities & Challenges report, 10 September 2018, pages xii and 9 [accessed 14 February 2019]. For information about 4G roll-out in the UK, see the Library briefing paper on Mobile Coverage in the UK.
53 ITU, Setting the Scene for 5G: Opportunities & Challenges report, 10 September 2018, pages xii and 9 [accessed 14 February 2019].

Association (CLA) stated that rural areas risk being left behind on 5G roll-out, with some areas still lacking 4G coverage in the UK.[54] Similarly, the House of Lords Committee on the Rural Economy, in their April 2019 report, stated that "it is important that rural areas, and businesses within them, are not left behind during the rollout of 5G for mobile services".[55] The challenge for rural areas is that commercial investment cases for 5G are more difficult due to higher infrastructure costs and lower population densities (lower demand and revenues for operators).

Some network operators and suppliers have highlighted that 5G offers opportunities for rural areas and could help bridge digital divides, if frameworks for encouraging investment and take-up of digital technologies are in place.[56] For example, some of the Government 5G testbed and trial projects are focusing on 5G applications in rural areas (see Box 3). Further, in August 2019 the Government launched a new competition as part of the testbeds and trial programme, called the Rural Connected Communities Project, which will fund up to ten projects trialling 5G in rural communities.

The release of low frequency 5G-compatible spectrum (700 MHz band, see section 3.2 of this paper) is an important factor in delivering 5G in rural areas. Spectrum sharing (section 3.4) aims to make more spectrum available for use in rural areas, including spectrum not being utilised there by the major operators.

2.4 5G and security

There is an ongoing debate about the extent to which foreign-supplied products should be used in UK 5G networks, in particular from Chinese company Huawei (pronounced "Wah-Way").[57] In addition to manufacturing devices such as smart phones and tablets, Huawei also manufactures equipment used in building mobile networks such as radio access equipment and core network infrastructure. There are not many companies that provide radio access equipment; Nokia (Finnish) and Ericsson (Swedish) are the only other providers in the UK.

Security concerns about telecoms supply chains are not unique to 5G;[58] for background information, see Box 5 in the POSTnote on Cyber Security of UK Infrastructure (May 2017) and the Intelligence and

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54 Country Land and Business Association, Rural areas still lacking 4G at risk of being side-lined amid 5G rollout, says CLA, 9 August 2019, [accessed 11 June 2019].

55 House of Lords Committee on the Rural Economy, Time for a strategy for the rural economy, Report of Session 2017–19, HL 330, 27 April 2019, para 258.

56 O2 blog, UK Cities Face a Digital Divide: 5G is the Answer, Derek McManus, 12 July 2018; Cisco blog, The UK is ready for 5G, Nick Chrissos, 28 March 2018. [Accessed 14 February 2019].

57 Urgent Question, UK Telecoms: Huawei, HC Deb 658, 25 April 2019.

58 See for example the 2013 Intelligence and Security Committee Report: Foreign involvement in the Critical National Infrastructure: The implications for national security, Cm 8623, June 2013.

Security Committee's 2013 report, Foreign involvement in the Critical National Infrastructure: The implications for national security.[59]

This issue has come to the fore again recently as new commercial supply agreements for 5G equipment are negotiated worldwide. 5G involves new approaches to network architecture and design, which raises both new security challenges as well as opportunities to develop more secure systems.[60] An explanation and discussion of the technical aspects of 5G and security is provided in a blog post written by the National Cyber Security Centre's (NCSC) technical director, Dr Ian Levy: Security, complexity and Huawei; protecting the UK's telecoms networks (20 February 2019).

Concerns about foreign involvement in telecommunications networks – and Chinese involvement in particular – also touch on broader strategic and geopolitical issues. There are concerns about the security standards of Huawei equipment in general,[61] the extent to which Chinese law could compel the company to assist the State's intelligence services, coupled with broader ethical and ideological concerns about the growing global presence of Chinese technology companies. Some countries, for example the US,[62] and Australia,[63] have restricted the role that foreign telecommunications providers can play in national 5G and/or telecoms networks. There have been some calls for the UK Government to follow suit and take a stricter approach to Huawei in UK 5G networks, including reported pressure from the US on its allies to ban the use of Huawei equipment in 5G networks.[64]

Other experts, however, such as Robert Hannigan (former head of GCHQ), have commented that an outright ban on Chinese technology companies would not be an effective approach to managing security

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59 For background, see the Intelligence and Security Committee, Foreign involvement in the Critical National Infrastructure: The implications for national security, Cm 8623, June 2013.

60 Technical Report on 5G Network Architecture and Security, University of Surrey 5G Innovation Centre and DCMS Phase 1 5G Testbeds and Trials projects, 17 December 2018; 5G Whitepaper: 5G Security Overview, University of Surrey 5G Innovation Centre, March 2018.

61 Cabinet Office, Huawei cyber security evaluation centre oversight board: annual report 2019, 28 March 2019. Note: this report does not consider 5G technology.

62 White House, Executive Order on Securing the Information and Communications Technology and Services Supply Chain, 15 May 2019; Federal Register, A rule by the Bureau of Industry and Security, Department of Commerce, Addition of Entities to the Entity List, 21 May 2019; 'John S. McCain National Defense Authorization Act for Fiscal Year 2019' (2018).

63 Australian Ministers for Communications and the Arts, Government Provides 5G Security Guidance To Australian Carriers, 23 August 2018. The Australian Government did not name specific companies but the August 2018 statement has been widely interpreted as a ban on Huawei and ZTE, see for example: Huawei and ZTE handed 5G network ban in Australia, *BBC News*, 23 August 2018.

64 See for example: Trump is absolutely right about Huawei – our national security depends on getting this right, William Hague, *The Telegraph*, 3 June 2019; China's dominance of 5G is a threat, Tom Tugendhat, Mike Gallagher, *The Times*, 19 April 2019; Huawei role in UK 5G network an unnecessary risk, ex-MI6 chief says, *BBC News*, 16 May 2019.

arguing that decisions should be made based on "technical expertise and rational assessment of risk" rather than geopolitical concerns.[65]

The mobile industry has warned that restrictions on the use of Huawei equipment would cause a delay to the roll-out of 5G in the UK and could cause significant economic and productivity losses.[66] Others have noted that because Nokia, Ericsson and Huawei are the only suppliers of radio access equipement to the UK, a ban on Huawei would limit the market to just two players, increasing dependence on a few providers and reducing competition.[67]

The Intelligence and Security Committee issued a statement on 5G suppliers on 19 July 2019 that provides a good overview of the key technical and geopolitical issues arising. The Committee urged the Government to take a final decision about whether Huawei should be allowed to supply 5G equipment in the UK.[68]

Box 7: How is Huawei equipment used in exiting UK telecoms networks?

In the UK, the Huawei Cyber Security Evaluation Centre (HCSEC, run and funded by Huawei but jointly overseen and staffed by GCHQ) has since 2010 evaluated the security of Huawei products being used in UK telecoms networks. Although most of the major UK telecoms providers use the HCSEC for information, not all providers do – its use is not mandatory.[69] Ciaran Martin, CEO of the NCSC, in a speech in February 2019 described how Huawei equipment is currently deployed in UK networks as follows:

> We also have strict controls for how Huawei is deployed. It is not in any sensitive networks – including those of the government. Its kit is part of a balanced supply chain with other suppliers. Our regime is arguably the toughest and most rigorous oversight regime in the world for Huawei.
>
> And it is proving its worth. Last July, our annual Oversight Board downgraded the assurance we could provide to the UK government on mitigating the risks associated with Huawei because of serious problems with their security and engineering processes. As we said then, and repeat today, these problems are about standard of cyber security; they are not indicators of hostile activity by China.
>
> The company have accepted these findings and have pledged to address them, acknowledging that this will be a process of some years. We will monitor and report on progress and we will not declare the problems are on the path to being solved unless and until there is clear evidence that this is the case. We will not compromise on the improvements we need to see from Huawei.[70]

Several other Parliamentary Select Committees have considered the issue and sought assurances from the Government, including:

- The House of Commons Science and Technology Committee wrote to three Ministers and to Huawei in January 2019; the Government's reponse was published in March 2019. In June the Committee held an evidence session with suppliers, network

[65] Blanket bans on Chinese tech companies like Huawei make no sense, Robert Hannigan, *Financial Times*, 12 February 2019.
[66] Mobile UK, £6.8bn potential risk to UK economy if use of Huawei for 5G rollout is restricted, report finds, Mobile UK, 5 April 2019.
[67] Intelligence and Security Committee of Parliament, Statement on 5G suppliers (pdf), 19 July 2019, page 2.
[68] Intelligence and Security Committee of Parliament, Statement on 5G suppliers (pdf), 19 July 2019.
[69] NCSC, Security, complexity and Huawei; protecting the UK's telecoms networks, 20 February 2019, [accessed 20 February 2019].
[70] NCSC, Ciaran Martin's CyberSec speech in Brussels, 20 February 2019.

operators and academics about potential risks to UK 5G networks and strategies to address them.[71] Following the session Committee Chair Norman Lamb MP wrote to the Secretary of State for DCMS summarising the evidence the Committee heard and making some recommendations regarding strengthening the oversight of telecoms security.[72] The Committee concluded that, subject to certain restrictions and continued close scrutiny, from a technical perspective, excluding Huawei from the UK's 5G or other telecommunications networks would not be a proportionate response to the potential threat.[73] The Committee noted however there may well be geopolitical or ethical grounds for the Government to decide to enact a ban on Huawei equipment.

- The Joint Committee on the National Security Strategy in its November 2018 report on the Cyber Security of UK Critical National Infrastructure asked the Government for assurances regarding the effectiveness of the HCSEC;[74] the Government's response was published on 7 March 2019. The Committee has since launched an inquiry on ensuring access to "safe" technology using 5G as a case study.
- The House of Commons Foreign Affairs Committee wrote to the Foreign Secretary about the issue on March 2019 (Government response received 2 April 2019).[75]

What has the Government said about Huawei products for 5G networks?

The Government's position on foreign supplied products in 5G networks was to be determined as part of DCMS's cross-government review of UK telecommunications supply chains, which was launched in November 2018 and involved an assessment of the supply arrangements for UK telecoms networks, focusing on full-fibre and 5G networks.[76]

The Review Report was published on 22 July 2019 but did not include a decision on whether Huawei would be allowed to supply to UK 5G networks. The Government stated that this was because it is still considering the implications of the recent steps taken by the US to place restrictions on exports of US products and services to Huawei.[77] Then Secretary of State for DCMS Jeremy Wright explained the position to the House of Commons as follows:

> The review also concludes that there should be additional controls on the presence in the supply chain of certain types of vendor that

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71 House of Commons Science and Technology Committee, UK telecommunications infrastructure inquiry [accessed 13 June 2019]
72 Letter from House of Commons Science and Technology Committee Chair to Secretary of State for DCMS, dated 10 July 2019.
73 Letter from House of Commons Science and Technology Committee Chair to Secretary of State for DCMS, dated 10 July 2019.
74 Joint Committee on the National Security Strategy, Cyber Security of the UK's Critical National Infrastructure, Third Report of Session 2017–19, HL 222, HC1708, 19 November 2018, paragraph 66.
75 House of Commons Foreign Affairs Committee, correspondence with the FCO relating to the potential involvement of Huawei in the UK's 5G telecommunications infrastructure, 27 March and 2 April 2019.
76 DCMS, Telecoms Supply Chain Review Terms of Reference, 8 November 2018.
77 DCMS, Telecoms Supply Chain Review Report, 22 July 2019, para 5.23 and 5.24.

> pose significantly greater security and resilience risks to UK telecoms. The House will be particularly concerned, of course, with the position of the Chinese technology firm Huawei. The Government are not yet in a position to decide what involvement Huawei should have in the provision of the UK's 5G network, and I want to explain why that is.
>
> On 16 May, the US Government added Huawei Technologies Ltd and 68 affiliates to its entity list on national security grounds. US companies now have to apply for a licence to export, re-export or transfer a specified range of goods, software and technology to Huawei and named affiliates, with a presumption of denial. On 20 May, the US Government issued a 90-day temporary general licence that authorises transactions in relation to specified areas. These measures could have a potential impact on the future availability and reliability of Huawei's products, together with other market impacts, and so are relevant considerations in determining Huawei's involvement in the network. Since the US Government's announcement, we have sought clarity on its extent and implications, but the position is not yet entirely clear. Until it is, we have concluded that it would be wrong to make specific decisions in relation to Huawei, but we will do so as soon as possible.[78]

The Report did however set out plans to develop a new statutory Telecoms Security Requirement (TSR) that telecommunications providers and vendors will be required to comply with. The new legislative framework will include new powers for Ofcom to enforce the security requirements. The Report states that legislation will be pursued "at the earliest opportunity" and in the meantime it would work with telecoms operators to ensure they adhere to new guidance on a cooperative basis.[79] The Report also states that the Government will pursue a diversification strategy to support the development and growth of new market players.

The issue continues to be raised in the press and in Parliament, for example:

- House of Commons Urgent Question, UK Telecoms: Huawei, HC Deb 658, 25 April 2019.
- UK phone firms demand clarity over Huawei, Simon Jack, *BBC News*, 11 June 2019.
- UK decision on Huawei 5G faces fresh delay, David Bond and George Parker, *Financial Times*, 4 June 2019.
- Donald Trump issues executive order laying ground for Huawei ban, Demetri Sevastopulo, Kiran Stacey and Nian Liu, *Financial Times*, 15 May 2019.
- Defence Secretary Gavin Williamson sacked over Huawei leak, *BBC News*, 1 May 2019.

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78 HC Deb 663, 22 July 2019, c1136 [Telecoms Supply Chain Review].
79 DCMS, Telecoms Supply Chain Review Report, 22 July 2019, page 6.

2.5 5G and health

Concerns about radio waves from communications technology such as those emitted from mobile phone masts are longstanding but more recently there have been specific concerns expressed relating to the roll out of 5G and the radio frequency spectrum (radio waves) that may be used for 5G.[80] For example, a recent Parliament and Government petition that called for an independent enquiry into the health and safety risks of 5G received 32,454 signatures before closing.[81] More information about radio frequency spectrum for 5G is provided in section 3 of this paper.

Public Health England (PHE), an executive agency to the Department of Health and Social Care, provides advice to the Government on public health issues. PHE updated its guidance document on Mobile phone base stations: radio waves and health in May 2019. This provides an overview on radio waves from mobile phone base stations, different generations of mobile technology and the research that has been undertaken internationally on this issue. It states that international and UK expert groups have examined the accumulated evidence base and "their conclusions support the view that health effects are unlikely to occur if exposures [to radio waves] are below international guideline levels."[82] PHE states that it continues to monitor the health related evidence on radio waves, and commits to updating its advice as required. Further detail about the research on radio waves and health is provided in the July 2019 POSTbrief, 5G Technology.

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80 See, for example, Written question 176373 and Written Question 176372 [5G: health hazards] 16 October 2018, DCMS,The Future Telecoms Infrastructure Review: Call for Evidence Responses, July 2018.

81 Government and Parliament Petitions, Launch an independent enquiry into the health and safety risks of 5G [accessed on 21 June 2019]

82 Public Health England Guidance, Mobile phone base stations: radio waves and health, 16 May 2019 [accessed 6 September 2019].

3. Spectrum for 5G

Box 8: Spectrum explainer

What is spectrum?

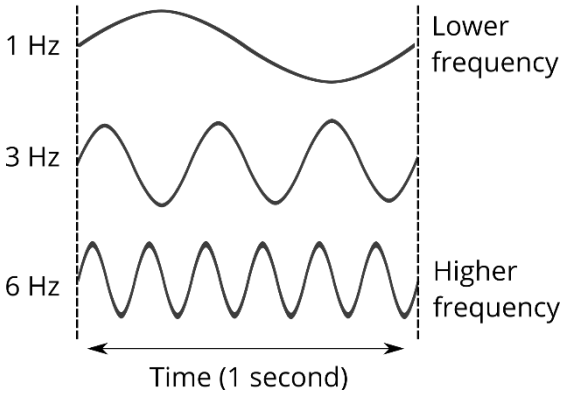
Spectrum (sometimes called airwaves) refers to the radio waves that mobile operators use to transmit data. Radio waves are a comparatively small part of the wider electromagnetic spectrum, which also includes light, microwaves, and X-rays. Radio waves cover the frequency range 3 Hz to 300 GHz. Other uses of the radio frequency spectrum include TV and radio broadcasting, Wi-Fi, and satellite communications.

Frequency and Hertz (Hz)

Radio waves are usually defined by frequency. Frequency refers to the number of wave cycles that pass a fixed point in a fixed unit of time.

Frequency is measured in Hertz (Hz). 1 Hz means one wave cycle per second. The diagram to the right shows waves with frequencies of 1, 3 and 6 Hz.

1 Megahertz (Mz) means one million waves per second. 1 Gigahertz (GHz) means 1000 MHz (one billion waves per second).



Bands and bandwidth

Bands are ranges of different frequencies. Bandwidth means the size of the band. For example, the frequency band 700–800 MHz has a bandwidth of 100 MHz; the band 2–3 GHz has a bandwidth of 1 GHz (1000 MHz). The latter band has a wider/larger bandwidth.

The bandwidth determines how much data a portion of spectrum can carry. A wider bandwidth can carry more data.

Different frequencies of spectrum are suited to different applications

Low frequencies (usually less than 1000 MHz) are well suited for providing rural and indoor mobile coverage. This is because lower frequency waves can travel longer distances and are better at penetrating physical objects than higher frequencies.

Higher frequencies are well-suited to support network capacity (the amount of data traffic the network can support) and tend to be used in cities and busy urban areas where lots of people are using the network. This is because at higher frequencies (typically 2–3 GHz) wider bandwidths are available, which can carry more data. However, higher frequencies cannot travel as far as lower frequencies, so require base stations (see Box 5) to be placed closer together.

5G will require a range of different frequency bands to support different applications (see section 3.1).

How is spectrum allocated?

Spectrum is a finite resource that is managed in the UK by Ofcom. Each mobile network operator transmits signals over separate frequency bands to avoid interference with each other. Owning more spectrum often means mobile operators can connect more people, offer faster speeds and provide more stable services.

Ofcom is responsible for allocating spectrum to different mobile operators by granting licences to transmit radio waves over defined frequency bands. To do so it uses spectrum auctions (also called spectrum awards).[83] Mobile operators bid to be allocated certain portions of spectrum and the money raised goes to HM Treasury.

[83] The *Wireless Telegraphy Act 1998* (as amended) enabled the use of auctions to grant spectrum licences, where appropriate.

3.1 Spectrum for 5G: an overview

5G will require access to different spectrum bands with different characteristics (see Box 8) to support the diverse uses, technologies and applications enabled by 5G.

Ofcom is preparing to make more spectrum available for 5G in the UK. It is also working with other European regulators and international spectrum bodies to identify bands that have the potential to be harmonised globally.

Ofcom and European Regulators have identified spectrum bands to enable 5G in Europe; they fall into three classes:[84]

1 **Low frequency spectrum** to enable 4G and 5G mobile coverage to wide areas (the 700 MHz band).

2 **Mid-frequency spectrum**: spectrum with large bandwidths to provide capacity to support many users accessing large amounts of data with high speeds (the 3.4–3.8 GHz band).

3 **High frequency spectrum**: spectrum at very high frequencies (above 25 GHz) and with very large bandwidths, providing ultra-high capacity and very low latency. Spectrum in this region is also sometimes called millimetre wave ("mmWave") spectrum.

5G will require access to different spectrum bands with different characteristics.

3.2 Low frequency spectrum (700 MHz band)

The 700 MHz band has been identified in Europe as the primary band for wide area 5G coverage in Europe. It can also be used for 4G coverage and is compatible with existing 4G handsets. It is not currently licenced for use for mobile networks in the UK.

The release of the 700 MHz spectrum for mobile is a key part of Ofcom and the Government's proposals to improve rural mobile coverage generally. Ofcom has proposed coverage obligations to be included on some licences for the 700 MHz band, which is aimed at improving rural mobile coverage. For more information, see the Library briefing paper on Mobile Coverage in the UK.

Ofcom intends to auction spectrum in the 700 MHz band in the UK by Spring 2020 as part of a combined auction with spectrum in the 3.6–3.8 GHz band (see below).

The first 5G spectrum was awarded in 2018 (3.4–3.6 GHz).

The next spectrum auction will be held by Spring 2020. It includes the 700 MHz and 3.6–3.8 GHz bands.

3.3 Mid-frequency spectrum (3.4–3.8 GHz band)

The 3.4 to 3.8 GHz band has been identified as the primary 5G band across Europe.[85] This band can provide the large bandwidths necessary for new 5G mobile services. It is likely to be used first in populated areas to increase network capacity using existing base stations.

In the UK, access to this band is being made available in two stages:

84 Ofcom, Update on 5G spectrum in the UK, 8 February 2017.
85 Ofcom, Enabling 5G in the UK, 9 March 2018, para 4.11.

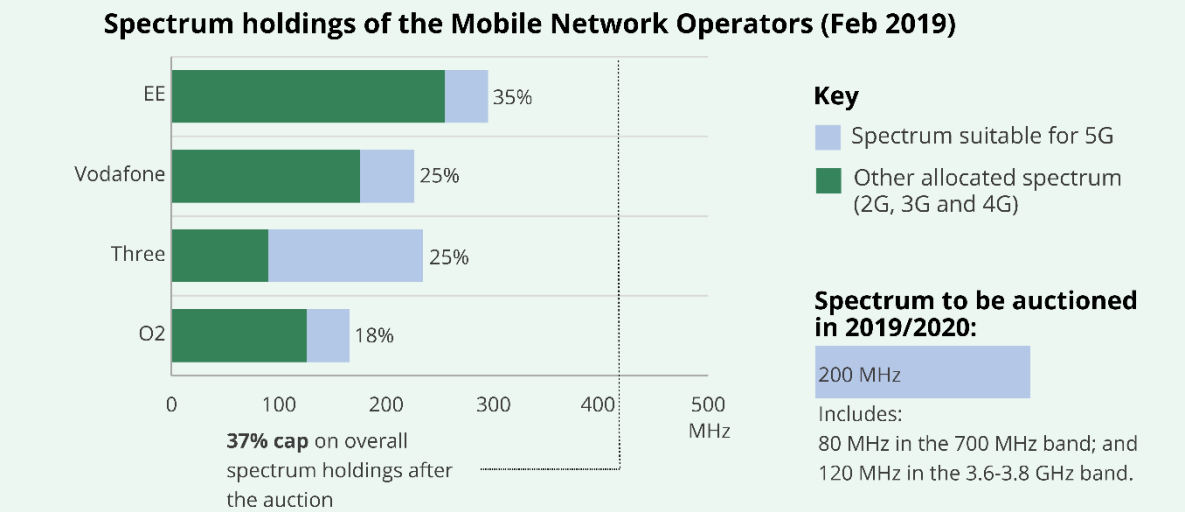
1 **The lower part of the band (3.4–3.6 GHz)** was auctioned in 2018. All four UK MNOs (BT/EE, Vodafone, O2 and Three) acquired spectrum in this band (see Box 9).[86] The Library briefing paper Spectrum Auctions 2018 provides background information about the auction. The first commercial 5G networks have used spectrum in this band.

2 **The upper part of the band (3.6–3.8 GHz)** is expected to be awarded by Spring 2020, in a combined auction with the 700 MHz band.[87] Ofcom is consulting on proposed auction rules. Ofcom has proposed to include a 37% cap on the spectrum shares that operators can hold after the auction (as it did for the 2018 auction).[88] This is intended to ensure that the mobile market remains competitive (see Box 9).

Box 9: Spectrum holdings by MNOs

The diagram below shows the spectrum shares held by each mobile operator for all mobile spectrum currently allocated, including spectrum suitable for 5G.[89] It also shows the spectrum to be auctioned in the 700 MHz and 3.6–3.8 GHz bands and the effect of the proposed 37% spectrum cap. Ofcom considers that asymmetry in the amount of spectrum held by mobile network operators could pose a risk to competition because providers with more spectrum are better placed to respond to increased consumer demand for mobile data than others; the cap is intended to address this concern.[90]

The effect of the proposed spectrum cap is that EE would be restricted to acquiring up to 120 MHz of the 200 MHz available, Vodafone up to 190 MHz, Three up to 185 MHz, with no restriction on the amount that O2 could acquire.[91]



Source: Ofcom, Award of the 700 MHz and 3.6-3.8 GHz spectrum bands, 18 December 2018.

86 Ofcom Results of principal stage of auction for mobile airwaves, 5 April 2018.
87 Ofcom, Consultation: Award of the 700 MHz and 3.6-3.8 GHz spectrum bands, 18 December 2018.
88 Ofcom, Consultation: Award of the 700 MHz and 3.6-3.8 GHz spectrum bands, 18 December 2018.
89 Spectrum allocated includes the 800, 900, 1400, 1800, 2.1, 2.3 and 2.6 GHz bands; spectrum suitable for 5G includes the 3.4 GHz band (auctioned in 2018) and the 3.6–3.7 GHz band (in which Three already owns 84 MHz and is included in the total percentage calculation).
90 Ofcom, Ofcom sets rules for mobile spectrum auction, 11 July 2017.
91 Ofcom, Consultation: Award of the 700 MHz and 3.6-3.8 GHz spectrum bands, 18 December 2018. The 37% spectrum cap is set at 416 MHz (37.2%). Values are rounded due to the minimum lot size for the auction (5 MHz); see page 77.

3.4 High frequency spectrum (26 GHz band)

High frequency spectrum (above 25 GHz) offers high data capacity and low latency but with a limited coverage range. Frequencies in this region are sometimes referred to as millimetre wave ("mmWave") spectrum.[92] This high frequency spectrum is most likely to enable new "revolutionary" use cases of 5G beyond mobile broadband.[93] It is likely be used in small, specific areas for services requiring high bandwidth.

The 26 GHz band is being prioritised across Europe as the first high frequency band for 5G.[94] Ofcom has stated that devices compatible with the 26 GHz band are likely to be available from early 2019.[95] Other high frequency spectrum bands that are being considered in Europe for 5G include the 66–71 GHz band and the 40.5–43.5 GHz band.[96]

In July 2017, Ofcom launched a call for inputs to inform its work to make spectrum in the 26 GHz band available for 5G networks in the UK.[97] In March 2018, Ofcom explained that the responses to the consultation indicated that the band is likely to become important for 5G but many were of the view that it is too early to say how the band will be used, by whom and for what purposes.[98]

Ofcom grants innovation and trial licences in the 26 GHz band.

Ofcom provides short-term trial licences for spectrum in the 26 GHz band for research and development purposes. Ofcom launched an Innovation and Trial web-portal in March 2018 to provide guidance on obtaining trial licences. The aim is to promote the research, development and trialling of innovative uses of the spectrum.

In November 2018, Ofcom expanded access to spectrum in the 60 GHz band (57–71 GHz) on a licence-exempt basis.[99] This means that companies can use the spectrum without a licence (as long as the equipment meets specific conditions). The conditions are such that it could be used for 5G technology or for fixed-wireless access, which could be used for home broadband, for example.

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92 Strictly speaking "mmWave" means waves with frequencies of 30–300GHz, which have wavelengths 1–10 millimetres (mm).
93 Ofcom, Enabling 5G in the UK, 9 March 2018, para 4.21.
94 The 26 GHz band ranges from 24.25–27.5 GHz. Ofcom, Enabling 5G in the UK, 9 March 2018, para 4.22. The European Electronic Communications Code (Directive (EU) 2018/1972, Article 54) contains a requirement that Member States allow the use of at least 1 GHz of spectrum in the 24.25–27.5 GHz band by 31 December 2020 "provided that there is clear evidence of market demand and of the absence of significant constraints for migration of existing users or band clearance".
95 Ofcom, Enabling 5G in the UK, 9 March 2018. para 4.27.
96 Ofcom, Enabling 5G in the UK, 9 March 2018. para 4.22-4.23.
97 Ofcom, 5G spectrum access at 26 GHz and update on bands above 30 GHz, 28 July 2017.
98 Ofcom, Enabling 5G in the UK, 9 March 2018, para 4.26.
99 Ofcom, Making it easier to launch new wireless services and 5G technology and Statement: Decision to implement technical and regulatory changes to the 57 – 71 GHz band, 8 November 2018. [Accessed 14 February 2019]

3.5 Spectrum sharing for 5G

Spectrum sharing is when the same spectrum band is accessed by multiple users. There are several different approaches to spectrum sharing that could be taken (see Box 10).

Currently spectrum mobile is licenced by Ofcom to mobile network operators (MNOs) on an exclusive national licence. This model leaves the utilisation of that spectrum—a finite national resource—to the MNO. There have been calls for Ofcom to move to a more flexible approach to licensing for 5G spectrum to allow spectrum that is not being used by the major MNOs to be used by other parties, for example in rural areas. This is also sometimes called spectrum efficiency, to ensure that spectrum is being used to its maximum capacity.

The National Infrastructure Commission in 2016 called for the Government and Ofcom to review the regulatory regime for spectrum management and consider how approaches to spectrum sharing could be utilised to maximise access to the radio spectrum for 5G.[100] It explained:

> Auctioning spectrum licences in large, national scale blocks, at these very high frequencies, risks a significant share of the radio spectrum lying fallow in large parts of the country, because deploying the dense networks described above may not be profitable for the major operators in these areas, yet the spectrum will still be inaccessible to other users. This could act as a barrier to entry for new firms to compete in the provision in mobile services and may impede the most widespread deployment of 5G high frequency small cells.[101]

The Government identified spectrum efficiency as one of its strategic priorities for 5G in the FTIR and asked Ofcom to consider flexible licencing models as part of the release of 3.6–3.8 GHz spectrum. This forms part of the Government's "market expansion model" for 5G (see section 1.3 of this paper) to support smaller new providers, which generally cannot acquire spectrum rights at national auctions due to the high price paid by MNOs. The Government has also asked Ofcom to include a "use it or lose it" condition as part of the licence conditions for the 3.6–3.8 GHz auction (see Box 10),[102] and included support for spectrum sharing in its Statement of Strategic Priorities to Ofcom (July 2019).[103]

The Government supports spectrum sharing as part of its strategic priority to ensure efficient use of spectrum for 5G.

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[100] National Infrastructure Commission, Connected Future, 14 December 2016, Recommendation 7.

[101] National Infrastructure Commission, Connected Future, 14 December 2016, page 20.

[102] Letter from James Heath, Director of Telecoms, DCMS to Katie Pettifer (Government and Parliament Director, Ofcom) dated 22 October 2018. The letter was published on Ofcom's webpage: Consultation: Award of the 700 MHz and 3.6-3.8 GHz spectrum bands, 18 December 2019 [accessed 8 February 2019].

[103] DCMS, Statement of Strategic Priorities for telecommunications, the management of radio spectrum and postal services, 18 July 2019, para 38. Sections 2A-2C of the *Communications Act 2003* (as amended) contains powers, (introduced through the *Digital Economy Act 2017*) for the Government to make a Statement of Strategic Priorities (SSP) to which Ofcom must have regard when carrying out its functions. This is the Government's first SSP to Ofcom.

The Institution of Engineering and Technology (IET) has formed an industry campaign group called 5G Further Faster which has been calling for flexible spectrum licencing for the 3.6–3.8 GHz band; it is supported by a number of industry partners including Nominet, Google, TalkTalk and the Wireless Infrastructure Group.[104] Other industry stakeholders that have made similar calls include the UK Wireless Internet Service Providers Association (WISPA)[105] and the Independent Networks Co-operative Association (INCA).[106]

Advantages of spectrum sharing articulated by these stakeholders, the Government and Ofcom, include:[107]

- Improving rural mobile coverage by opening up opportunities for new entrants to access spectrum in specific locations not covered by the main MNOs;
- Increasing spectrum available for rural broadband connectivity through fixed wireless technology. This could improve rural broadband in areas where fixed line broadband connections (e.g. full-fibre) are not commercially viable;
- Providing opportunities for private networks to develop new use cases for 5G, for example industrial automation and robotics;
- Speeding up the development and roll-out of 5G nationwide by increasing the number of companies and innovators able to participate and allowing new business models to be tested.

Challenges for spectrum sharing include protecting the existing rights of MNOs, protecting existing and future investment by MNOs in mobile networks, determining the value of spectrum that is shared, establishing commercial incentives for sharing, and technological challenges to protect against interference.[108] Mobile network operators generally argue for exclusive national licences and wish to ensure access to wide bandwidths that are necessary to provide high quality 5G services.[109] [110]

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104 Institute of Engineering and Technology (IET), 5G Further Faster, [accessed 8 February 2019].
105 UK WISPA, The UK's wireless spectrum management is no longer fit for purpose, [accessed 8 February 2019].
106 INCA, INCA calls for shared 5G spectrum following new report, [accessed 8 February 2019].
107 DCMS, Future Telecoms Infrastructure Review, 23 July 2018, para 219; Ofcom, Consultation: Enabling opportunities for innovation, 18 December 2018, para 1.3; Plum consulting (commissioned by WIPSA and INCA), High performance wireless broadband: an opportunity for rural and enterprise 5G, Ian Corden, Tony Lavender, Laura Wilkinson, 14 June 2016; Institute of Engineering and Technology (IET), 5G Further Faster White Paper (pdf), [accessed 8 February 2019]; Nominet, 5G Spectrum Sharing, September 2018.
108 Ofcom, Framework for Spectrum Sharing, 31 July 2015.
109 DCMS, Future Telecoms Infrastructure Review, 23 July 2018, para 222.
110 GMSA, Spectrum Sharing: public policy opinion, November 2018 [accessed 8 February 2019].

Box 10: Spectrum sharing

Spectrum is shared when the same spectrum frequency band is accessed by multiple users and/or for different uses.[111] This might mean different users operating in different places, at different times and/or at different frequencies within one spectrum band. Spectrum sharing needs to be coordinated in some way to ensure avoid interference.

There are different potential models for coordinating spectrum sharing, for example:

- **Licensed Shared Access (LSA)**: a form of priority licensing where a MNO may have an exclusive national licence but secondary users can be granted licences for specific uses at a specific frequency, place and/or time where spectrum is not being used by the MNO.[112]
- **Light licensing** means coordinated use of spectrum by multiple parties such as using localised licences for geographic areas, but without a priority licence holder. Access could be controlled by a registration process and a database with access allocated, for example, on a first-come, first-served basis.[113]
- **Dynamic spectrum access (DSA)** uses a database to monitor where, when and how spectrum is being used and to predict interference. Unused spectrum can then be licensed to users on a dynamic basis reflecting changes in use over time. DSA could be used to coordinate either of the above two models. A dynamic spectrum access model is already used in the UK for TV White Space (unused TV spectrum).[114]
- Other examples of spectrum sharing include: licence-exempt access (a common example is spectrum used for Wi-Fi),[115] voluntary commercial agreements between parties (for example, wholesale spectrum leasing and spectrum trading) and rural roaming agreements (where an MNOs allows customers of another network to access ('roam') onto their network).

Other policy mechanisms available to enforce efficient spectrum use by MNOs include:

- **Coverage obligations**, which require MNOs to deliver coverage to a defined minimum geographic area as a condition of their spectrum licence. Coverage obligations are expected for the 700 MHz spectrum auction, see the Library briefing paper on Mobile Coverage in the UK.
- **"Use it or lose it"** requirements would require MNOs to make use of the spectrum allocated to them in a timely way or risk having it taken away. The new European Union Electronic Communications Code (EECC) includes a "use it or lose it" principle.[116] The UK Government supports the new EECC and has stated that it intends to transpose it, including the "use it or lose it" principle, into UK law "subject to the ongoing Brexit negotiations".[117]

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111 Ofcom, Framework for Spectrum Sharing, 31 July 2015.
112 European Commission Radio Spectrum Policy Group, RSPG Opinion on Licensed Shared Access, 12 November 2013.
113 DCMS, Future Telecoms Infrastructure Review, 23 July 2018, para 221.
114 Nominet, TV White Space Deployment, [accessed 13 February 2019].
115 Some spectrum is set aside by Ofcom on a licence-exempt basis, which means that users do not use a licence to use the spectrum but equipment must meet certain criteria and operate according to specified rules to avoid interference. Wi-Fi is a common example of wireless technology, using licence-exempt spectrum in 2.4 GHz, 5.8 GHz bands. Ofcom, Supporting the expanding role of wireless innovation in UK industry: a discussion paper, 1 February 2019, page 6.
116 Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code (Recast)Text with EEA relevance, Recital 122 and Article 47; European Council press release, Better connectivity: EU adopts telecoms reform, 4 December 2018 [accessed 8 February 2019].
117 DCMS, Future Telecoms Infrastructure Review, 23 July 2018, page 13.

Ofcom's proposals for spectrum sharing

Ofcom has not proposed to set aside specific spectrum for sharing as part of the 3.6–3.8 GHz auction and proposes to award national licences as for previous auctions – detailed reasoning is given in Ofcom's consultation document published in December 2018.[118] Ofcom also decided not to include a "use it or lose it" clause in the licence conditions for the 3.6–3.8 GHz spectrum for the following reasons:

- Such conditions are very difficult to make workable in practice because of the problem of defining what constitutes 'use' and therefore what the trigger for an enforced trade or revocation would be;
- There may be entirely legitimate reasons for spectrum remaining unused – the licensee may be holding back until it sees a suitable commercial opportunity or until the technology it wishes to use is ready; and
- Imposing such an obligation also has the potential to distort and/or chill the incentives to invest in the spectrum, and so reduce the benefits for consumers and citizens which the award would otherwise create.[119]

Instead, Ofcom has established two types of shared spectrum access, publishing its final statement on the plans in July 2019:[120]

1 Enable spectrum sharing in four shared access bands

Ofcom proposes to introduce managed spectrum sharing in four shared access bands: 3.8–4.2 GHz, 1800 MHz, 2300 MHz and 24.25–26.5 GHz (indoor use only). This would be a form of light licencing – see Box 10 – although Ofcom does not use that term.

Ofcom states that the 3.8–4.2 GHz band is included in 5G technology standards and could also be used for rural broadband services through fixed wireless technology; the 1800 and 2300 MHz bands are supported by 4G handsets.[121] The 24.25–26.5 is part of the 26 GHz band harmonised for 5G use across Europe (see Section 3.5 below).

Ofcom proposes to manage the licencing process in all three shared access bands on a first come first served basis. Potential users would be able to make an application to Ofcom for a Shared Access Licence, specifying the bands and locations in which they wish to operate. Ofcom would then assess interference with regards to

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118 Letter from James Heath, Director of Telecoms, DCMS to Katie Pettifer (Government and Parliament Director, Ofcom) dated 22 October 2018. The letter was published on Ofcom's webpage: Consultation: Award of the 700 MHz and 3.6-3.8 GHz spectrum bands, 18 December 2019 [accessed 8 February 2019].

119 Letter from Katie Pettifer (Government and Parliament Director, Ofcom) to James Heath (Director of Telecoms, DCMS), dated 13 December 2018; Ofcom, Consultation: Award of the 700 MHz and 3.6-3.8 GHz spectrum bands, 18 December 2019, para 10.19 [accessed 8 February 2019].

120 Ofcom, Enabling wireless innovation through local licensing, 12 March 2019 [accessed 28 August 2019].

121 Ofcom, Enabling opportunities for innovation, 18 December 2018, pages 2-3 [accessed 8 February 2019].

other licensees. People and businesses will be able to apply for Shared Access Licences by the end of 2019.[122]

2 *Facilitate licenced access to spectrum already awarded to mobile operators*

Under this approach, new users wishing to access spectrum that is licenced to MNOs can apply to Ofcom for a Local Access Licence to use specific frequencies at a particular location and Ofcom would engage with the MNO to facilitate access. This would be a form of Licensed Shared Access – see Box 10 – although Ofcom does not use that term.

Ofcom anticipates that spectrum is only likely available to share in remote locations, but in these areas it could be used to support private networks or wireless broadband services.People and businesses can apply for Local Access Licences from 12 March 2019.[123]

Ofcom believes these proposals would provide the quickest route to allow new users to access spectrum. Ofcom states that it is commencing work to consider whether to use a transition to a dynamic spectrum access (DSA) approach in future.[124]

[122] Ofcom, Statement: Enabling wireless innovation through local licensing, 25 July 2019, para 1.23.
[123] Ofcom, Statement: Enabling wireless innovation through local licensing, 25 July 2019, para 1.23.
[124] Ofcom, Statement: Enabling wireless innovation through local licensing, 25 July 2019, para 1.25.

4. Glossary

Backhaul: the link that connects a mobile site (either a mast, macro or small cell) to the core internet and phone network, usually by full-fibre broadband or a radio link.

Bandwidth: the term bandwidth is used differently in different contexts. In a spectrum context, bandwidth refers to the size of a band of spectrum, measured in Hertz (Hz). For example, a band of spectrum from 700–800 MHz has a bandwidth of 100 MHz. Bandwidth is also used to refer to broadband upload and download speeds (see below).

Base station: mobile network access points that send and receive mobile voice or data signals and connects them to the main network via a backhaul connection. Mobile masts, macro cells and small cells are all types of base stations.

Broadband upload/download speed: the amount of data that can be downloaded or uploaded per second on a broadband connection, usually expressed in megabits per second (Mbps). This is also called the **bandwidth** of a connection. Most internet connections have higher bandwidth for downloading (data going from the internet to a device) than for uploading (data going from a device, to the internet).

Full-Fibre: a fixed-line broadband technology where fibre optic cables run from the exchange directly to the premises. It is also called Fibre-to-the-Premises (FTTP) or Fibre-to-the-Home (FTTH). See the Library paper on Full-fibre networks in the UK (CBP 8293) for more information.

Hertz (Hz): a unit of measurement for frequency, one hertz means one wave cycle per second. Megaherts (MHz) = 1 million Hz; 1 Gigahertz (GHz) = 1000 MHz.

Latency: is the delay time for a communications signal. It is the amount of time it takes for a packet of data to travel from a device, to a third-party server and back to the device. In practical terms it is the time it takes from clicking something to when you see a response, such as a website beginning to load. Low latency (i.e. fast signal response times) is important for applications that require real-time response, for example, live-streaming, gaming, video calls, virtual reality applications and driverless vehicles.

> *Difference between bandwidth and latency*: both bandwidth and latency affect the broadband "speed" experienced by a user. Bandwidth refers to how fast a website is able load and latency is the time it takes to start the download process. A common analogy is a highway – bandwidth is like the number of lanes on the highway, and latency is like the speed the cars are travelling.

Macro cell: a mobile base station that provides wide-area coverage, usually mounted on ground-based masts or on rooftops.

Megabits (Mb) and megabytes (MB): units for expressing a quantity or amount of data. 8 megabits (Mb) is equal to 1 megabyte (MB);

8 gigabits is equal to 1 gigabyte (GB). Broadband speeds are usually expressed in megabits uploaded/downloaded per second (see above).

Mobile Network Operator (MNO): a provider of mobile wireless communications services that owns or controls all the elements necessary to sell and deliver services to an end user, including spectrum allocation, infrastructure, and customer services. There are four MNOs in the UK: EE (owned by BT), Vodafone, O2 (owned by Telefonica) and Three (owned by Hutchinson 3G). Contact details and spectrum allocations for each of the MNOs are provided on Ofcom's webpage: Mobile and Wireless Broadband below 5 GHz.

Mobile Virtual Network Operator (MVNO): a mobile service provider that does not own the infrastructure which is uses to deliver services. MVNOs have agreements with the MNOs to deliver services using the MNOs infrastructure. There are many MVNOs in the UK.

Mobile broadband, WiFi and fixed-wireless are all ways of connecting wirelessly to the internet. They use different spectrum frequencies, different signalling and receiver technology and infrastructure, are suited to different purposes/uses and are operated by different providers.

> **Mobile broadband:** usually means internet access provided wirelessly through a mobile network operated by a Mobile Network Operator (MNO). Mobile base stations are arranged in a 'cellular' format so that a user can move between different base stations and remain connected to a single network.
>
> **Wi-Fi**: short-range wireless broadband used in home or localised settings. A Wi-Fi router converts a fixed/wired broadband connection into a wireless signal so that Wi-Fi enabled devices (laptops, tablets, mobiles) can connect to. Wi-Fi uses specific licence-exempt spectrum bands (2.4 and 5 GHz).
>
> **Fixed wireless broadband:** wireless broadband networks can be used as a solution for rural broadband in areas where cables are difficult to build. There are a few different technologies available for delivering fixed wireless access, including mobile broadband technology.[125] Fixed wireless networks are usually operated in a localised area by a specific provider. Fixed wireless networks for rural broadband is one potential application of 5G technology.

mmWave: radio waves with frequencies between 30–300 GHz (which have wavelengths of 1 millimetre). In a 5G context, this term is sometimes used to refer generically to the high frequency bands discussed for 5G (above 25 GHz in Europe).

Small cell: low-powered mobile base stations that provide coverage to a small localised area.

[125] Ofcom, Mobile and wireless broadband, accessed 20 February 2019.

Radio frequency spectrum: electromagnetic waves in the frequency range 3 Hz to 300 GHz over which wireless communication systems are delivered.

Spectrum sharing or spectrum efficiency: refers to having more than one user in the same frequency band. See Box 10.

TV White Space: unused spectrum in frequencies ranges used for TV e.g. gaps left between TV channels. There is technology available that can deliver broadband networks using TV White Space.[126]

[126] Nominet, TV White Space Deployment, [accessed 13 February 2019].

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