Mobile Data Strategy

Update on our strategy for mobile spectrum

Update

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About this document

This document is an update to our long term strategy for addressing the increasing use of data by mobile devices like smartphones, tablets and laptops. Spectrum plays a key role in enabling future mobile data growth, and our role is to secure the optimal use of spectrum to benefit citizen and consumers and make communications work for everyone. The strategy was first set out in a document published in May 2014 but, as this is a fast moving industry, we will update stakeholders from time to time on any changes in our priorities.

There have been some changes in the landscape for mobile data since May 2014 due to technological and international developments - in particular the early development of 5G technology. Although most of our strategy continues to be fit for purpose, we have decided that some adjustments should be made to continue to ensure that the UK is at the forefront of mobile technology.

This document is an update to our previously published strategy rather than a consultation. Nevertheless, if stakeholders wish to provide evidence or comment to any aspect of it they may do so by emailing mds@ofcom.org.uk.

Contents

Section 1

Executive Summary

1.1 Consumers increasingly rely on wireless connectivity, both over mobile networks and Wi-Fi[1]. Spectrum is the key enabler of wireless connectivity. This document updates our long term strategy to address the increasing use of data by mobile devices such as smartphones, tablets and laptops.

1.2 We first set out a strategy in 2014[2], including a priority list of spectrum bands with potential for mobile data taking into account market, international and technology developments. This document refines that strategy to ensure we will continue to identify the best opportunities for UK consumers.

1.3 Since our 2014 statement, we have achieved significant progress against our priorities; consumer interest in mobile data applications continued to grow quickly; and the industry has been evolving fast. Mobile data traffic has been growing at a rate of around 60% a year, enabled by technology development, in both handsets and applications, allowing consumers to carry out ever more activities wirelessly. Two thirds of consumers own a smartphone, making it the most popular device for consumers to go online.

1.4 Consumers' increasing reliance on mobile data as an everyday necessity have highlighted challenges such as need for increased capacity and demand for coverage of the latest mobile technologies right across the UK. Our plans to enable these include making more spectrum available, use of coverage obligations, and improved backhaul across the country.

1.5 While most of our priorities remain the same, we continue to monitor the evolution of new technologies and demand for mobile data, and therefore their impact on spectrum. We are conducting additional work to ensure consumers will continue to benefit from new and improved services. In particular, future 5G technologies will bring new services and faster versions of existing services to consumers. We aim to ensure that lack of suitable spectrum will not inhibit the rollout of 5G in the UK, and that the benefits of these new technologies can reach everyone.

1.6 5G technologies will require more spectrum in terms of wider channels and at different (much higher) frequencies such as mmWave[3] – frequencies above 24 GHz which had not previously been used for mobile. We are pursuing global harmonisation in the mmWave bands to ensure that the technology will be as cost effective as possible. We are also working to make available other spectrum bands which can support wide carriers, including frequencies in the 3.4 - 3.6 GHz band and potentially 3.6 - 3.8 GHz. These frequencies are being discussed as a potential early European 5G band[4].

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[1] In addition to Wi-Fi, there are other technologies using the same licence exempt frequencies which also provide mobile data; we use Wi-Fi here as a general term for this class of technologies.
[2] *Mobile Data Strategy Statement*, May 2014, http://stakeholders.ofcom.org.uk/consultations/mobile-data-strategy/
[3] Strictly speaking, mmWave is the band of 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 here.
[4] See Radio Spectrum Policy Group, *Strategic Roadmap towards 5G for Europe*, Draft Opinion, June 2016, http://rspg-spectrum.eu/2016/06/public-consultation-on-5g-launched/

1.7 Since our previous publication, our work on most bands has progressed as planned, and we achieved many important milestones:

- We proposed plans to accelerate availability of the 700 MHz band and increase the amount of spectrum available to mobile[5];
- We announced that will seek to include a coverage obligation as one of the conditions of using one or more licences in the 700 MHz band and that we will consult on its inclusion and form when we consult on conditions for that award.[6]
- We published our information memorandum for the forthcoming 2.3 GHz and 3.4 GHz auction[7];
- We authorised use of White Spaces in the UHF spectrum[8];
- We set out our plan to make more 5GHz spectrum available for Wi-Fi and similar technologies[9];
- We announced initiatives which will help improve reach, cost and availability of fibre and copper and help improve backhaul. These include new rules to improve BT's performance in installing high speed business lines as part of our Business Connectivity Market Review; and our Strategic Review of Digital Communications, which include measures to improve fixed broadband to consumers' homes.

1.8 We also have made some changes to our priorities as highlighted overleaf in bold. The main changes are an increase in priority of the 1400 MHz band (1427-1518 MHz) and the inclusion of mmWave bands. We have removed some bands, reducing uncertainty for other industry sectors, and intensifying our focus on our high priorities. Table 1 summarises our previous and current priorities, with changes highlighted in bold.

[5] See *Maximising the benefits of 700MHz clearance*, March 2016 http://stakeholders.ofcom.org.uk/binaries/consultations/maximising-benefits-700-MHz-clearance/summary/maximising-benefits-of-700MHz-clearance.pdf
[6] *Making communications work for everyone*, *Initial conclusions from the Strategic Review of Digital Communications* http://stakeholders.ofcom.org.uk/binaries/telecoms/policy/digital-comms-review/DCR-statement.pdf
[7] The award of 2.3 and 3.4 GHz spectrum bands - Information Memorandum http://stakeholders.ofcom.org.uk/consultations/2.3-3.4-ghz-auction-design/statement-further-consultation/information-memorandum/
[8] See http://stakeholders.ofcom.org.uk/spectrum/tv-white-spaces/
[9] *Improving spectrum access for consumers in the 5 GHz band*, Consultation, May 2016, http://stakeholders.ofcom.org.uk/consultations/5-GHz-Wi-Fi/

Table 1 – Previous priorities and current priorities

Priority for further work	2014	2016
Current priorities	• 700 MHz • 2.3 GHz, 3.4 GHz • UHF white space (shared)	• 700 MHz • 2.3 GHz, 3.4 GHz • Implemented
High	• 1452-1492 MHz • 1980-2010 / 2170-2200 MHz ('2 GHz MSS') • 3.6-3.8 GHz • 5-6 GHz Wi-Fi (5350-5470 MHz, 5725-5925 MHz) (shared)	• Implemented • **1427-1452 & 1492-1518 MHz (increased priority)** • **Removed** • 3.6-3.8 GHz • 5-6 GHz Wi-Fi (**emphasis now on 5725-5850 MHz**) • **mmWave bands added**
Medium-High	• 1427-1452 MHz (shared) • 3.8-4.2 GHz (shared)	• **Increased priority** • **Examining responses to our call for inputs**
Medium	• 470-694 MHz (very long term) • 2.7-2.9 GHz • 1492-1518 MHz • 5.925 – 6.425 GHz	• 470-694 MHz (very long term) • **Removed** • **Increased priority** • **Removed**

Section 2

Introduction

2.1 This document updates our long term strategy for how we will prepare for future increases in the use of mobile data services while taking account of other users of spectrum.

2.2 We published the previous version of this strategy two years ago[10]. This is a sector undergoing fast technology innovation, and the focus of great consumer interest. For this reason, we have revisited our strategy and priorities to ensure that we continue to make the most effective use of our resources and to pursue the best opportunities for improving services for UK consumers.

Mobile data use has been evolving rapidly

2.3 Since our 2014 mobile data strategy statement, a lot has happened that is relevant:

- Smartphones have overtaken laptops as the most popular device for going online. Two thirds of adults now own a smartphone, and data usage has been growing at around 60% a year[11];
- 4G mobile technologies are being deployed rapidly on UK networks. At the end of 2015, more than seven in ten premises (73%) had 4G coverage from three of the four networks[12];
- Industry has stepped up investment in 5G research, with the first large scale trials expected to take place in Korea and Japan. This includes developing handsets that are able to achieve very high data speeds using very high frequencies (known as millimetre wave, or mmWave). The 3rd Generation Partnership Project (3GPP), the global body that develops mobile standards, started work on 5G standards;
- The World Radiocommunication Conference 2015 (WRC-15) has included very large bands at mmWave frequencies in the agenda for WRC-19;
- WRC-15 also created the potential for a globally harmonised band at 1400 MHz. Qualcomm sold part of this band, 1452-1492 MHz, to Three and Vodafone in the UK.

2.4 We have also made significant progress on our plans for improving mobile services in the UK:

- We are progressing with our plans to auction 190 MHz of spectrum in the 2.3 and 3.4 GHz bands;

[10] *Mobile Data Strategy Statement*, http://stakeholders.ofcom.org.uk/consultations/mobile-data-strategy/
[11] See *Smartphone Cities*, March 2016, http://stakeholders.ofcom.org.uk/market-data-research/other/telecoms-research/broadband-speeds/smartphone-cities, and *The Communications Market 2015 (August)*, http://stakeholders.ofcom.org.uk/market-data-research/market-data/communications-market-reports/cmr15/
[12] *Connected Nations Report*, December 2015, http://consumers.ofcom.org.uk/news/connected-nations-report/

- We have set out our ambition for a global 5G band and influenced the outcome of WRC-15;

- We have published our consultation to make more 5 GHz spectrum available to Wi-Fi and other technologies, subject to protection to existing users.

This document focuses on spectrum for mobile data, and takes other work into account

2.5 Our strategy takes account of a number of other relevant Ofcom initiatives already underway or completed, including:

a) Our **strategic review of digital communications**[13]. This focus on five areas, one of which is improvement in the quality of service delivered by the whole of the telecoms industry, including the mobile industry;

b) Our **spectrum management strategy**[14], which sets our overarching approach to managing spectrum over a period of 10 years, with a key objective of delivering the greatest value to UK citizens and consumers. It outlined six sector-focussed priorities, one of which is to address future mobile data demands, recognising the importance of improving mobile coverage and the availability of new mobile services;

c) Our work on **promoting investment and innovation in the Internet of Things (IoT)**[15]. Previously unconnected devices are increasingly able to communicate and share data with one another, forming the "Internet of Things". We have set out a number of priorities to help support the growth of the IoT, including spectrum availability. We have also recently confirmed that some existing spectrum is already available for IoT[16];

d) Our **spectrum sharing framework**, which we will apply to future spectrum authorisation decisions[17]. We also introduced the 3.8-4.2 GHz as a candidate band for enhanced spectrum sharing, potentially for innovative applications[18];

e) Our **fixed wireless spectrum strategy**: We are currently working on a strategic review of spectrum used for fixed wireless links[19]. Fixed wireless links are used for the provision of communication between fixed points for many sectors including mobile backhaul (the connection between a given mobile site and the remaining network). The review will consider the growing requirement for increased fixed wireless link capacity to support mobile backhaul and the potential use for 5G mobile of bands currently used by fixed links, among other issues;

[13] http://stakeholders.ofcom.org.uk/telecoms/policy/digital-comms-review/dcr-feb-16/
[14] http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/statement/statement.pdf
[15] http://stakeholders.ofcom.org.uk/consultations/iot/next-steps/
[16] *VHF radio spectrum for the Internet of Things*, Statement, March 2016.
[17] *A framework for spectrum sharing*, Statement, April 2016, http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-sharing-framework/statement/statement.pdf
[18] *3.8 GHz to 4.2 GHz band: Opportunities for Innovation*, call for inputs, April 2016, http://stakeholders.ofcom.org.uk/consultations/opportunities-for-spectrum-sharing-innovation/
[19] Call for Input planned to be published in the third quarter of 2016.

f) Our **space spectrum strategy**: we are currently consulting on use of spectrum by the satellite and space science services[20]. Satellite services share some bands with mobile and Wi-Fi, and may share additional bands in the future. In addition, they may also be used to bring mobile data services to remote locations in the UK;

g) Our work in the Radio Spectrum Policy Group (RSPG) on spectrum for 5G, which has led already to the draft opinion on 5G spectrum which is out for public comment[21].

[20] *Space spectrum strategy*, consultation, March 2016, http://stakeholders.ofcom.org.uk/consultations/space-spectrum-strategy/

[21] The RSPG is a high-level advisory group that assists the European Commission in the development of radio spectrum policy. See *Strategic Roadmap towards 5G for Europe*, Draft Opinion, June 2016, http://rspg-spectrum.eu/2016/06/public-consultation-on-5g-launched/

Section 3

Context

3.1 This section explains the context in which we are refining our strategy, in line with market, technology and international developments. In particular it examines current consumer demand and its geographic distribution and considers how this might translate into future demand and potential implications for spectrum.

Ensuring that high quality mobile services are available to everyone continues to be a high priority

3.2 We seek to make spectrum available so that industry can deliver the services that consumers demand. Spectrum is an essential enabler of mobile services. It is our goal that spectrum should not hold back the deployment of future mobile services, including 5G services.

3.3 Quality is also important. Consumers expect a good quality of experience[22], rather than peak speeds achievable for a small amount time or only in confined areas; we want to enable mobile data technologies that deliver improved experiences to consumers everywhere.

3.4 Our aim is to ensure that groups of consumers do not get left behind. Our vision for the next 10 years includes the latest mobile phone technologies rolled out across the UK's geography, as we outlined in our Digital Communications Review.

3.5 In addition to the direct needs of individual consumers, there is growing emphasis on the need for direct machine to machine and/or Internet of Things (IoT) communications. This is an umbrella term that covers a large number of use cases, such as support smart homes, smart factories, smart cities, transport, agriculture and others.

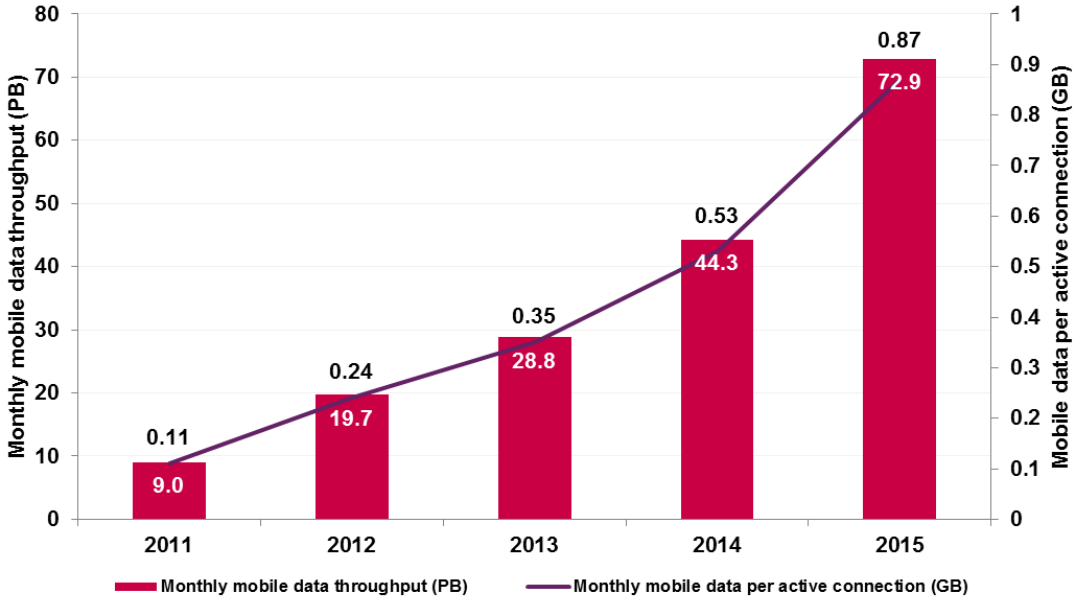
3.6 These different use cases will have a wide range of different requirements – which could include lower data rates, ubiquitous geographic coverage (including deep in-building coverage), massive connectivity (billions of devices), low or ultra-low latency and ultra-reliability. The industry is currently working on ways to enable future mobile networks to connect large number of devices and cover a variety of these types of requirements.

[22] See for example our research *Quality of service in telecoms*, February 2016 http://stakeholders.ofcom.org.uk/binaries/telecoms/policy/digital-comms-review/Jigsaw_quality_of_service_in_telecoms.pdf

Consumer and business use of mobile data is growing fast

3.7 Mobile data traffic has increased eight fold from 2011 to 2015 with very high annual growth rates, around 60% per year recently[23]. This exceeds the forecast we quoted in our 2014 Statement, which predicted data carried on mobile networks could increase 25 times to 2030, an implied annual rate of growth of 22%[24]. Figure 1 below shows recent growth in total monthly data consumption and data per active connection.

Figure 1 – Total monthly mobile data consumption in the UK, Petabytes (mid-year)

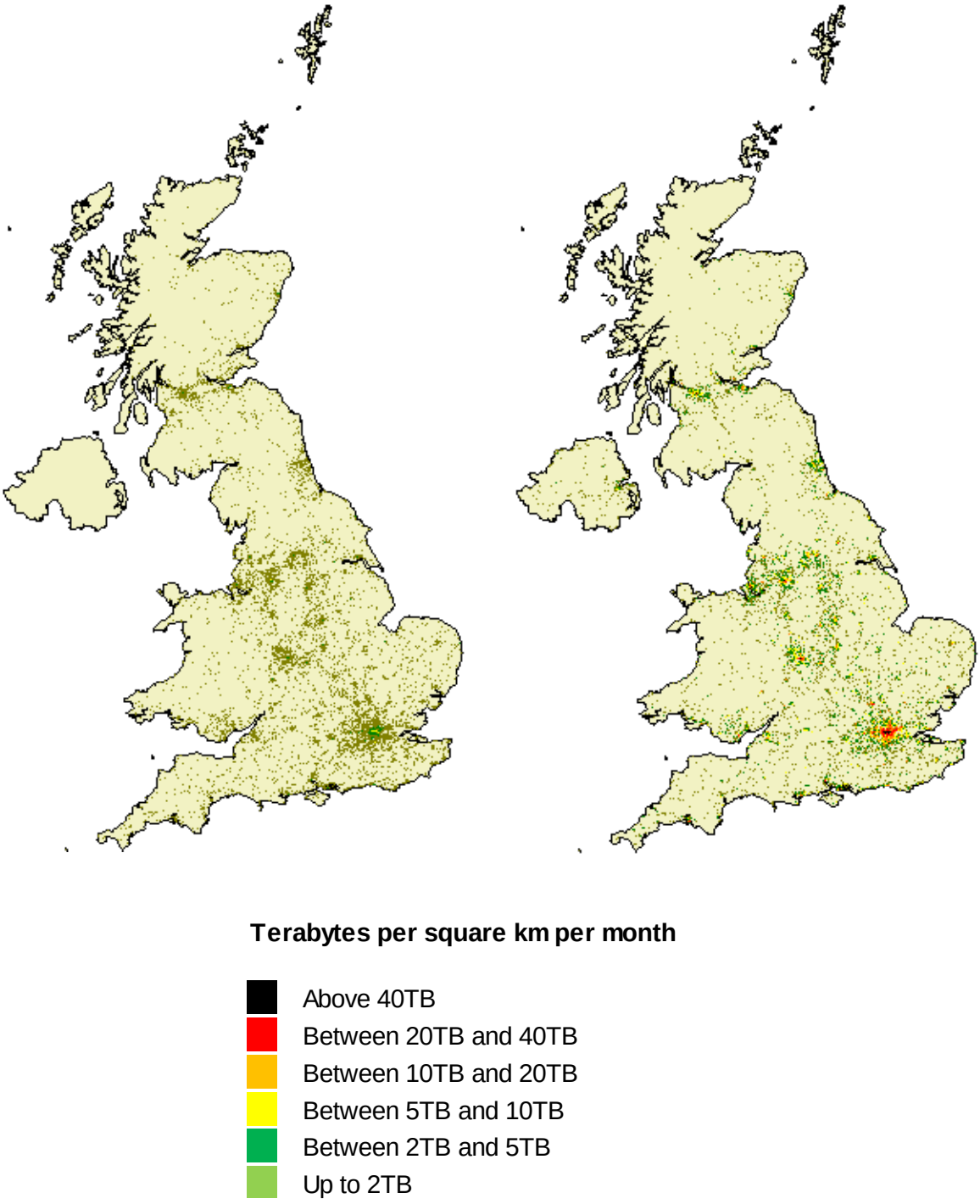


3.8 In order to inform our strategy we have carried out further analysis of the data traffic and its distribution across the UK geography. Figure 2 below illustrates the distribution of data traffic by depicting total mobile data traffic consumed within each km^2 area of the UK in 2011 and 2015.

[23] Growth rates were 65% (2015-14); 54% (2014-13); 46% (2013-2012); 119% (2012-11).See *Connected Nations Report*, December 2015, http://consumers.ofcom.org.uk/news/connected-nations-report/

[24] *Mobile Data Strategy Statement*, May 2014, http://stakeholders.ofcom.org.uk/consultations/mobile-data-strategy/ paragraph 4.43.

Figure 2 – Traffic in mobile networks across the UK geography



3.9 Distribution of traffic continues to be highly concentrated around major conurbations and is closely correlated with population density. Our analysis shows that more than 20% of data traffic is concentrated in just 1% of the UK geography[25]. This concentrated distribution highlights two distinct challenges as mobile data traffic

[25] Based on analysis of traffic on a grid of 10 km x 10 km pixels, based on the same dataset as used by our Connected Nations report.

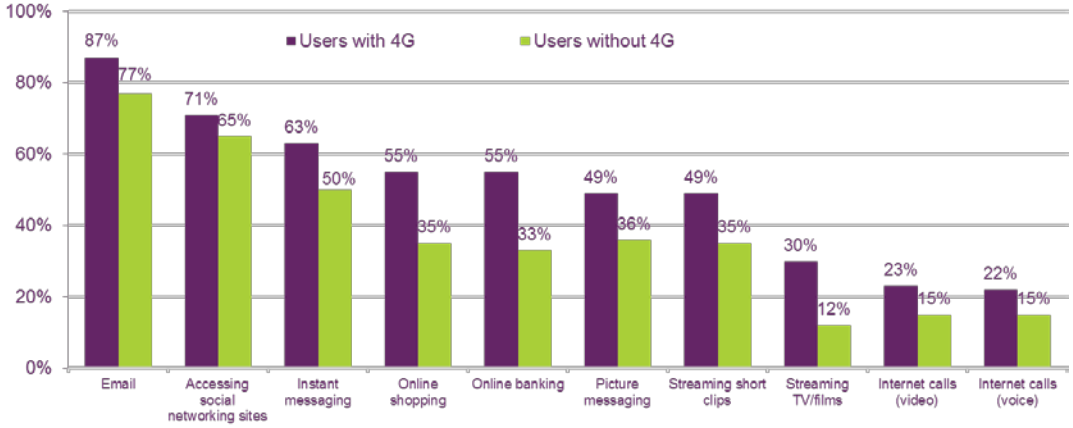
grows: providing capacity and coverage. We discuss our plans to address both of these challenges in this section.

We believe data traffic will continue to grow

3.10 There are a number of underlying factors that suggest that a trend of growth may continue for some time:

- Consumer enthusiasm for devices and applications that use mobile data continues to be very high. The proportion of connections using data services has increased from 39% in 2012 to 66% today. And smartphone users on average spend almost two hours daily online[26].
- Many of today's teenagers and young adults grew up with smartphones and tablets and nine in ten now own a smartphone[27]. As this "digital native" generation grows up, behaviours that consume more data (for example mobile video) become embedded in the general population.
- A large and diverse number of companies around the world are making huge investments into improving every aspect of mobile technology including new and better devices, applications, and networks.
- As mentioned earlier in this section, there is also potential for growth in the total number of data connections, because devices other than mobile phones and tablets are increasingly using mobile data - the "Internet of Things".
- New technologies such as 4G provide greater capacity and quality of services also encourages greater mobile data use. Figure 3 below shows that the proportion of 4G users using any data service is higher than non 4G users. 4G adoption is growing fast with 23.6m 4G subscriptions by the end of 2014, and the proportion of 4G users streaming TV or films on their phones is 2.5 times greater than that of non 4G users.

Figure 3 – Mobile data usage, 4G users versus non 4G users.



[26] *The Communications Market Report*, August 2015 http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr15/CMR_UK_2015.pdf, page 6.
[27] We define "teenagers and young adults" here as 16-24 year olds. See *The Communications Market Report*, August 2015 http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr15/CMR_UK_2015.pdf, page 65

3.11 We believe a similar effect will happen again with future mobile technologies, such as 5G. The technology improvement will make new use cases possible and make existing use cases work better and faster. This will encourage greater data use.

3.12 We have summarised in Table 2 some of the future 5G mobile use cases in discussion in the industry. We have selected these from a larger set of use cases from several industry discussion documents because they form a sufficient set to illustrate a pattern. Table 2 also indicates whether a use case has a specific quality requirement, in terms of throughput, latency or mobility.

Table 2 – Illustrative use cases

Use cases (where services are needed) and network requirements	High throughput	Low latency	Full mobility / consistent coverage	
Very high speed internet browsing at home/office	✓			Nomadic
HD Video conferencing "in every room" (A large amount of concurrent video streams)	✓	✓		
Smart Office	✓	✓		
Nomadic online gaming / VR	✓	✓✓		
Smart buildings / homes (including sensors / home surveillance)				
Cloud services along transport routes	✓	✓	✓	Mobile
High quality cloud services everywhere	✓	✓	✓	
High speed internet browsing while out and about*			✓	

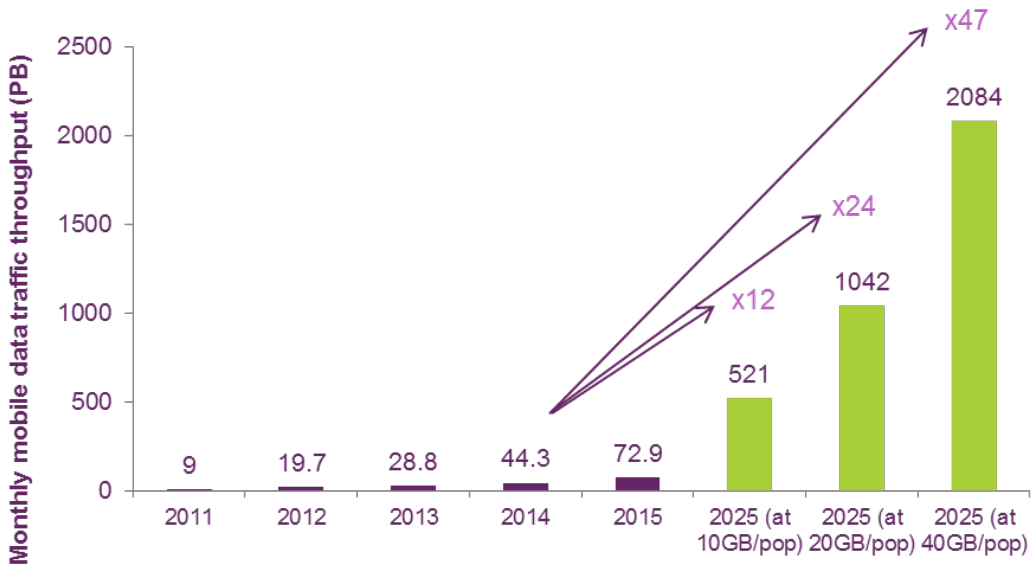
3.13 Many of the use cases we have identified require high throughput/bandwidth. Adoption of high bandwidth applications will drive growth in data traffic, as consumers time online is likely to move from mostly browsing and email to higher bandwidth applications, as we are starting to see with 4G users and video streaming.

3.14 Today data traffic is 0.8GB per connection per month; this equates to 1.3GB per adult population per month[28]. We have considered various potential scenarios of traffic per pop of 10GB, 20GB and 40GB per month. These 3 scenarios imply an annual growth rate of 25%, 33% and 42% between 2014 and 2025. These figures are higher than the forecast we quoted in our 2014 statement (22% annual growth rate between 2014 and 2030)[29]. This is to reflect the new use cases and the impact they may have on mobile data traffic, as 4G penetration and use increases and we start seeing early adoption of 5G services. Figure 4 below provides an overview of the total traffic and the relevant growth these scenarios would imply.

[28] Monthly mobile data throughput in 2015 was 72.9PB. This equates to 0.8GB usage per active connection based on a total of 83.7m active connections, and 1.4GB usage per person based on the UK population over 15 years old of 52.1m as per the UK 2011 census

[29] In *Mobile Data Strategy Statement*, May 2014, http://stakeholders.ofcom.org.uk/consultations/mobile-data-strategy/ paragraph 4.43, we quoted a forecast that predicted mobile data traffic to grow 25 times between 2014 and 2030, this is equivalent to 22% annual growth.

Figure 4 – Future data traffic scenarios



3.15 Spectrum availability, and how it is deployed across the networks will be critical to address the challenges in terms of capacity and coverage and therefore quality of experience across the UK to ensure citizens and consumers can benefit from the latest technologies wherever they are.

Spectrum is not the only way to meet growing demand, but is likely to be part of the solution

3.16 Network capacity to meet demand for mobile data is delivered by a combination of number of sites and spectrum and is impacted by the technology and spectrum used at each site. Mobile Network Operators (MNOs) have not typically deployed all of the spectrum they hold in all locations, and increased rollout of existing spectrum may allow capacity to grow further in the short term and address part of the potential growth in demand. Beyond that, to meet any additional growth, the options include technology improvements, building additional sites and deploying more spectrum.

3.17 With regards to technology improvements, mobile networks are already increasing capacity by deploying more efficient technology, including moving from 3G to 4G, and to more advanced versions of 4G. However, current evidence suggests that this may not be sufficient, to meet future growth, on its own. One estimate of the rate at which mobile networks may become more spectrally efficient was 18.5%[30] per year.

3.18 With regards to network deployments in terms of sites and spectrum, the concentrated distribution of traffic we discussed above will inform how to respond to potential growth in demand. Different geographical areas will have different challenges which will need to be met with a different combination of spectrum and sites.

[30] Real Wireless, 4G Capacity Gains Final Report, 2011, p 13 http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2011/4G-Capacity-Gains/

3.19 Improving capacity by building additional sites presents some challenges, including costs and site availability. Spectrum is therefore a key enabler of growth and both low frequency and high frequency spectrum will be required to deliver improved capacity, quality of consumer experience and coverage and ensure the availability of new applications and technologies to all UK citizen and consumers.

3.20 Currently we have licensed a total of 741 MHz of spectrum which is or could be used for mobile[31]. We are planning to make available an additional 446 MHz below mmWave[32] frequencies. In addition, mmWave frequencies may provide around 1 to 5 GHz.

We aim to ensure new services will reach everyone, but technology solutions will vary from cities to suburban and rural areas

3.21 As mentioned earlier in this document geographic clustering of population leads to different challenges: providing coverage and capacity. Typically mobile operators will deploy larger cells in areas with lower population density, where the challenge is coverage, and smaller cells in areas with higher population density, where the challenge is sufficient spectrum to serve all users (capacity). Figure 5 below illustrates two contrasting types of deployment, where each hexagon represents coverage from one mobile site.

Figure 5 – Mobile network simplified architecture

High density deployment **Low density deployment**

3.22 As demand continues to grow, the densely populated areas that have a capacity challenge will need a combination of more sites and more spectrum. All of the spectrum in our current and high priority list should help operators meet this demand.

3.23 As mentioned earlier, the development of 5G may lead to new services that require very high speeds and high bandwidths. These services will be provided using different solutions in different areas of the country.

3.24 In rural or suburban areas, mobile networks typically deploy a lower density site grid, because of the costs of rolling out a large number of cells to serve a relatively small number of users.

[31] This includes all the mobile spectrum held by the MNOs, and spectrum held by UK Broadband in the 3.4-3.8 GHz band and used for their Relish broadband service.
[32] This includes our current priorities and high priority bands: the remaining spectrum in the 3.4-3.8 GHz band, the 700 MHz spectrum including its centre gap, the upper 2.3 GHz spectrum and the remainder of the 1.4 GHz band.

Figure 6 – Heterogeneous deployment: actual deployments will be a mix of large and small cells

3.25 In these areas, it will be possible to provide very high speed services using a heterogeneous deployment shown in Figure 6 above. This type of deployment combines a seamless low density deployment with small cells that provides high bandwidth bands in the places where consumers congregate - homes, offices and village centres.

3.26 This already happens today to some extent as many consumers use data most intensely at home using their Wi-Fi connections. Some mobile networks already deploy some small cells – either inside the home, or increasingly, outside the home[33].

3.27 Our view is that most of the services we discussed earlier in this document above can be covered by heterogeneous deployments with macrocells and small cells, because they allow very fast "nomadic" services along a coverage layer that provide a consistent minimum quality of service.

3.28 The economic constraints described here are not specific to the UK, and other countries around the world will have to deal with similar issues. For this reason, some of the future applications that would require very high mobility are being designed with less dense deployments in mind – for example, a cross-industry group is specifying future automotive applications based on wide area network deployment at frequencies lower than mmWave, combined with short range communications including vehicle to vehicle[34]. Wide area applications may include, for example, download of high resolution map updates. Short range applications include low latency automated cooperation between cars, such as automatic manoeuvring.

3.29 As we mentioned, the pace of development of new applications is fast moving, and the type of analysis above can only be indicative. We cannot anticipate all the future major applications and will keep monitoring the technology horizons, ready to adapt our plans if necessary.

Lower frequency bands, coverage obligations, and improved backhaul will help ensure new services will reach everyone

3.30 Our priorities will deliver spectrum that can enable the different types of deployments explained above. First, our plans include release of a new lower frequency band, 700 MHz, which can cover large areas. We will seek to include a coverage obligation as

[33] See for example: *Vodafone rolls out mini masts to improve 4G coverage*, Financial Times, 29 May 2016, http://www.ft.com/cms/s/0/645294dc-25b6-11e6-8ba3-cdd781d02d89.; *EE's not-spot-busting small cell trial delights Cumbrian villagers*, The Register, 3 December 2014; http://www.theregister.co.uk/2014/12/03/cumbrian_village_gets_experimental_ee_network/

[34] 5G Automotive Vision, 5GPPP https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-White-Paper-on-Automotive-Vertical-Sectors.pdf

one of the conditions of using one or more licences in the 700 MHz spectrum and will consult on its inclusion and form when we consult on conditions for that award.

3.31 While the rest of this document focus on bands that provide the connection between mobile devices and a base station (or home router), improvements in backhaul are also required for delivery of future services, and to allow mobile networks to extend their reach by deploying additional sites. Backhaul is the connection between a mobile site back to a core network. We outline below our plan to lower this barrier.

3.32 Fibre and fixed wireless links complement each other in the provision of backhaul. Fixed wireless links are typically use if a fibre connection is not available, or is not economically viable for that particular site. This includes some sites in urban areas, and also sites in harder to reach locations in rural areas. In homes, consumers can use their own fixed broadband connection to provide backhaul to their Wi-Fi connection or to a small cell (e.g. Vodafone's "sure signal" product[35]).

3.33 We have announced initiatives which will help improve reach, cost and availability of fibre and copper and help improve backhaul. These include new rules to improve BT's performance in installing high speed business lines as part of our Business Connectivity Market Review[36]; and our Strategic Review of Digital Communications[37], which includes measures to improve fixed broadband to consumers' homes.

3.34 On wireless backhaul, we are currently working on the following initiatives:

- We will consider backhaul for mobile in our upcoming strategic review of fixed wireless services;
- Some frequencies that we plan to authorise for mobile access in the future may also be useful for backhaul. It is possible that in some cases a network operator may want to use the same frequencies for mobile access in some places, and for backhaul in other places. This type of deployment already happens today, and we will continue to work to ensure sufficient flexibility in the future.
- Satellites can also be used to provide backhaul in locations which are hard to serve using purely terrestrial networks[38]. We are currently consulting on our strategy for the use of spectrum by satellite and space science services.

Higher frequency bands provide an opportunity for a step change in capacity

3.35 All other things being equal, adding spectrum to a cell site grows its data capacity roughly in direct proportion with the number of MHz available. To meet a large increase in demand as described earlier, and to enable new services with very high speeds, a large increase in total bandwidth is likely to be required.

3.36 We will continue to prioritise work to make available bands that could provide such a large step increase:

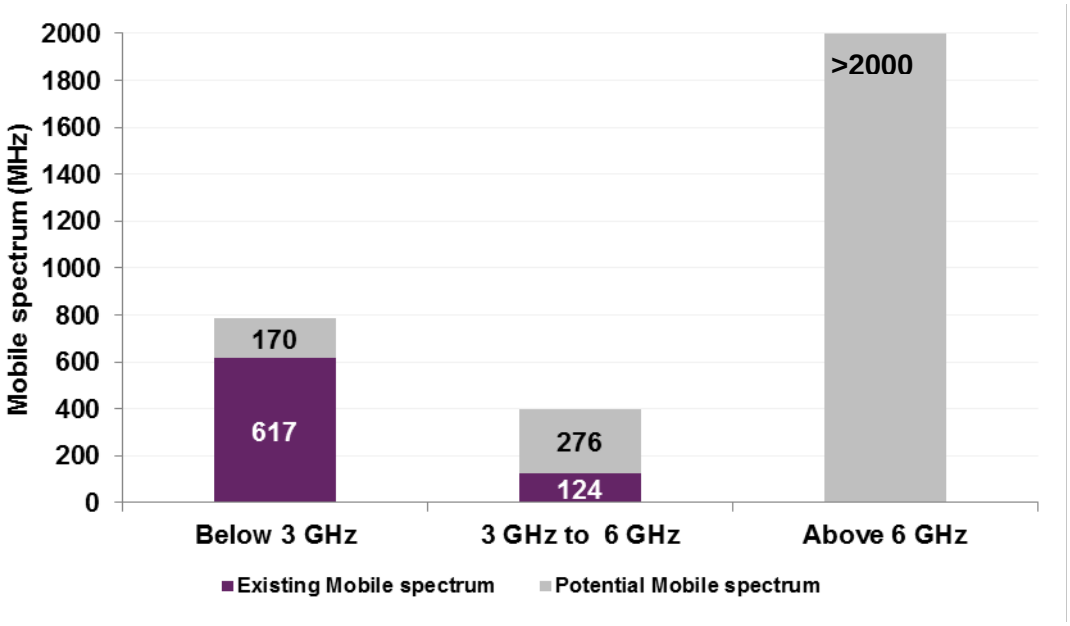
[35] http://shop.vodafone.co.uk/shop/mobile-phone/accessories/SKU75375-white
[36] See *Ofcom demands better business services from BT*, March 2016, http://media.ofcom.org.uk/news/2016/bcmr-2016/
[37] http://stakeholders.ofcom.org.uk/telecoms/policy/digital-comms-review/dcr-feb-16/
[38] For example, see *Avanti Communications wins backhaul contract from EE*, telecompaper, 9 May 2016.

- **Frequencies from 3.4 to 3.8 GHz.** These comprise 400 MHz in total. Some of this spectrum is already being used to provide data services to consumers, via the Relish broadband service, but not directly to mobile handsets. This is a band likely to be available for mobile in Europe within the next four years that could support the large bandwidth envisaged for 5G high throughput services. For this reason, the RSPG is currently consulting on its identification as an early 5G band for Europe.

- **Frequencies above 24 GHz**. These are called millimetre wave, or mmWave. These bands could offer around 1 - 5 GHz in a single band.

3.37 Figure 7 below shows the additional capacity we foresee could be made available in the next 5 – 10 years. This is a snapshot of our current and high priority bands. The "existing mobile spectrum" numbers includes spectrum in the hands of MNOs, and spectrum currently used by the Relish service for provision of fixed wireless broadband, but that will be included in future handsets. The "potential mobile spectrum" numbers include our current and high priority bands. The picture does not include current and future spectrum for Wi-Fi.

Figure 7 – Current and potential future bands in handsets (excludes Wi-Fi)[39]



3.38 The next section in this document provides more detail about the specific bands in our work programme.

[39] Existing mobile spectrum includes all the mobile spectrum held by the MNOs, and spectrum held by UK Broadband in the 3.4-3.8 GHz band and used for their Relish broadband service. Potential mobile spectrum includes current priorities and high priority bands: the remaining spectrum in the 3.4-3.8 GHz band, the 700 MHz spectrum including its centre gap, the upper 2.3 GHz spectrum and the remainder of the 1.4 GHz band.

Section 4

Priority bands

4.1 This section refines the list of spectrum bands which may be suitable for carrying mobile data traffic, in light of the market technology and international developments covered in section 3.

We will focus our efforts on bands where benefits from mobile use are likely large and achievable

4.2 In order to transform our strategic vision into a set of coherent actions, we maintain a priority list of bands. This provides clarity about where we will focus our effort over the next years. It should also help spectrum users to take account of possible future changes in their investments.

4.3 We take into account how likely it is that our efforts will result in actual mobile use in this band. This relates to prospects for international harmonisation, the current utilisation of the band, and the benefits that a band would provide, such as the amount of bandwidth available.

4.4 The specific actions on which we are likely to focus our efforts will vary widely between different bands, taking account of their prioritisation and their specific circumstances. Based on our 2014 statement, we have defined the following priority levels:

- **High priority bands:** Bands we expect to make available for mobile, through full release or sharing, assuming any coexistence issues (i.e. potential for interference to/or from users in neighbouring bands) can be addressed. If a band is being considered for sharing with incumbent users, our aim is to establish the feasibility and conditions for sharing as soon as possible. We may consider some intervention to change use of the band. We may also need to secure relevant international agreements if appropriate.

- **Medium priority bands:** Prospects for use by mobile data services may be much more distant and uncertain. The focus of effort for these bands is likely to be in developing our understanding of longer term scenarios for incumbent and alternative (including mobile data) uses of the band and, where appropriate, avoiding closing off future options or making them more costly.

In the past two years, most bands have progressed to plan, with some changing priority

4.5 Different bands are in different stages in policy development or implementation. Our current priority list is as shown in Table 3:

Table 3: Our updated priorities

Priority for further work	2014	2016
Current priorities	• 700 MHz • 2.3 GHz, 3.4 GHz • UHF white space (shared)	• 700 MHz • 2.3 GHz, 3.4 GHz • Implemented
High	• 1452-1492 MHz • 1980-2010 / 2170-2200 MHz ('2 GHz MSS') • 3.6-3.8 GHz • 5-6 GHz Wi-Fi (5350-5470 MHz, 5725-5925 MHz) (shared)	• Implemented • **1427-1452 & 1492-1518 MHz (increased priority)** • **Removed** • 3.6-3.8 GHz • 5-6 GHz Wi-Fi (**emphasis now on 5725-5850 MHz**) • **mmWave bands added**
Medium-High	• 1427-1452 MHz (shared) • 3.8-4.2 GHz (shared)	• **Increased priority** • **Examining responses to a call for inputs**
Medium	• 470-694 MHz (very long term) • 2.7-2.9 GHz • 1492-1518 MHz • 5.925 – 6.425 GHz	• 470-694 MHz (very long term) • **Removed** • **Increased priority** • **Removed**

4.6 The table above is similar to the one we published in our previous Mobile Data Strategy in 2014, with a few changes. In general, we have increased our focus on fewer bands and removed from our list some of the more distant possibilities we had earlier. This greater focus should increase mobile capacity while minimising uncertainty for other industry sectors.

Changes to our table of priorities

<u>1400 MHz band (1427 – 1518 MHz)</u>

4.7 **This band is now high priority**. WRC-15 has in effect identified the entire 1400 MHz band (1427-1518) as a global mobile band. Harmonisation in this band has gained traction partly due to Ofcom's decision to make part of the band (1452-1492 MHz) available in 2008, when the licence was acquired by Qualcomm. Qualcomm

has subsequently invested in developing chipsets for this band, and has traded their license to two mobile operators, Vodafone and Three.

4.8 The 1427–1452 MHz sub-band is used by the MoD. The government has initiated studies to determine feasibility of release and cost of remediation as part of their Public Sector Spectrum Release (PSSR) programme[40].

4.9 The UK currently has a large number of fixed links in the 1492-1518 MHz band (paired with 1350-1375 MHz) supporting a range of applications. We will consider our options on whether and how to make this band available for mobile.

mmWave bands

4.10 **These bands are now high priority**. As explained in the previous sections, these bands provide a step change in capacity which will be required if mobile demand continues to grow at a pace close to current rates.

4.11 We are currently in the planning and design stages of a future 5G ecosystem. There is an opportunity to find future economies of scale by global harmonisation of one or more bands for 5G.

4.12 We have conducted last year a search for 5G candidate bands in these frequencies[41]. Many of the bands we identified have subsequently been identified for further studies at WRC-15 and will be discussed again at WRC-19.

4.13 We will continue to gather more information about worldwide usage of these bands to continue to build a global consensus. We will also perform more detailed initial assessments of any technical challenges within each frequency, engaging with the ITU, RSPG and individual countries interested in early adoption of 5G technology.

4.14 We are currently focusing our effort in considering bands with the best potential for early implementation of 5G. In particular we are examining whether either 24.5 - 27.5 GHz or 31.8-33.4 GHz could be utilised for early implementation. The RSPG is also considering these bands for early 5G implementation.[42]

1980 – 2010 / 2170 – 2200 MHz (‘2 GHz MSS’)

4.15 This band is being addressed by parallel strands of work and is not discussed further in this document[43]. We have removed it from our priority list.

2.7 – 2.9 GHz

4.16 Internationally, there is currently little support for harmonisation of this band for mobile. For this reason, we have removed this band from our list of priorities.

[40] *Enabling UK growth: Public Sector Spectrum Release Programme*, UK Government Investments, April 2016, https://www.gov.uk/government/publications/enabling-uk-growth-public-sector-spectrum-release-programme

[41] *Laying the foundations for next generation mobile services: Update on bands above 6 GHz*, April 2015. http://stakeholders.ofcom.org.uk/consultations/above-6ghz/update-apr15/

[42] http://rspg-spectrum.eu/2016/06/public-consultation-on-5g-launched/

[43] See *Authorisation of terrestrial mobile networks complementary to 2 GHz Mobile Satellite Service* (MSS), February 2016 http://stakeholders.ofcom.org.uk/binaries/consultations/2GHz-mobile-satellite-systems/summary/2GHz_consultation.pdf

5.925 – 6.425 GHz

4.17 We included this band in our 2014 statement as a medium priority and long term possibility. Given our more intense focus now on other bands with greater potential for future 5G use, we have removed this band from our priority list.

Bands that continue to progress according to plan

700 MHz

4.18 In November 2014 we decided to make spectrum in the 700MHz band available for mobile data as soon as practicably possible. Initial plans indicated that it would be possible to make the band available by the end of 2021. However, our analysis suggests that benefits to citizens and consumers would be greater if it was available sooner.

4.19 We consulted in March 2016 on proposals which would enable us to bring forward the point at which this spectrum is nationally available for mobile data by up to 18 months - to a target of no later than Q2 2020. In the same consultation, we also set out proposals to make 20 MHz in the centre of the band available for mobile data. This is in addition to the 60 MHz of spectrum in the same band covered by our 2014 decision. We are currently considering the responses to that consultation

2.3 GHz and 3.4 GHz

4.20 As mentioned earlier in this document, the 3.4 – 3.8 GHz band is a potential early 5G band in Europe. In the UK, we have different work programmes to address each half of this band. We discuss the lower part, 3.4 – 3.6 GHz, here and 3.6 – 3.8 GHz separately below.

4.21 In December 2015, the Ministry of Defence (MoD), formally released to Ofcom 40 MHz of spectrum in the 2.3 GHz band (2350-2390 MHz) and 150 MHz in the 3.4 GHz band (at 3410 – 3480 MHz). We plan to award these frequencies by auction.

4.22 Government is studying as high priority the lower part of the 2.3 GHz band (2300–2350 MHz) to determine feasibility of release and cost of remediation as part of their Public Sector Spectrum Release (PSSR) programme[44].

UHF White Space

4.23 We have authorised White Space Devices to operate in the UK by licence exemption in 31 December 2015. This was one of our priorities at the time of our previous MDS which we have now accomplished.

3.6 – 3.8 GHz

4.24 This band is currently used for fixed link services, satellite services, and for the Relish fixed broadband service. We are considering how spectrum can be made available for mobile use in this band. We intend to publish a consultation in the third quarter of 2016, considering whether to make spectrum in this band available for mobile broadband use in the future and how this can be achieved.

[44] *Enabling UK growth: Public Sector Spectrum Release Programme*, UK Government Investments, April 2016, https://www.gov.uk/government/publications/enabling-uk-growth-public-sector-spectrum-release-programme

5 – 6 GHz (for Wi-Fi and similar technologies)

4.25 We are currently consulting on our plans for the 5GHz band[45]. Our proposal is to open up 125 MHz of additional spectrum for Wi-Fi use in the UK, ahead of WRC-19, at 5725 MHz – 5850 MHz. This band is already used for Wi-Fi in the US and some other countries, but not in Europe. Current equipment including mobile handsets already include the capability of accessing these bands. For this reason, and unlike other bands, we do not have the need for further international harmonisation before we can benefit from economies of scale and device availability.

4.26 The changes would be subject to first establishing the correct technical parameters to ensure the appropriate protections to other users of this sub-band. The details of these technical conditions will be the subject of a further consultation.

3.8 – 4.2 GHz

4.27 We have published a call for Inputs on innovative uses for this band, sharing with existing incumbents[46]. We are currently considering the responses we received. We will publish a separate update on this band this summer.

470 – 694 MHz

4.28 We included this band in our 2014 statement as a very long term possibility. The 470-694 MHz band is widely used for broadcasting DTT services, and is important for supporting a range of PMSE applications. DTT and PMSE services deliver significant benefits to citizens and consumers. In our May 2014 Statement, we explained that we do not believe that other platforms (e.g. IPTV) will be in a position to be able fully to replicate the range of benefits DTT provides in the foreseeable future. In this light, we do not expect any DTT switch-off to occur until post-2030.

4.29 At WRC-15, we successfully argued against proposals for a co-primary allocation of the band to mobile data. This issue will not be reviewed again until 2023, when WRC-23 will examine the whole UHF band.

4.30 We continue to consider use of 470-694 MHz for mobile a very long term possibility.

[45] Improving spectrum access for consumers in the 5 GHz band http://stakeholders.ofcom.org.uk/binaries/consultations/5-GHz-Wi-Fi/summary/improving-spectrum-access-consumers-5GHz.pdf

[46] *3.8 GHz to 4.2 GHz band: Opportunities for Innovation*, call for inputs, April 2016, http://stakeholders.ofcom.org.uk/consultations/opportunities-for-spectrum-sharing-innovation/

Glossary

3GPP	The 3rd Generation Partnership Project (3GPP) is a body that develops standards for mobile technology.
4G	Fourth generation mobile phone standards and technology.
5GIC	5G Innovation Centre - the research centre at the University of Surrey that will conduct research into the next generation of mobile communication technology.
DTT	Digital Terrestrial Television - Broadcasting delivered by digital means. In the UK and Europe, DTT transmissions use the DVB-T and DVB-T2 technical standards.
EESS	Earth Exploration Satellite Service.
ES	Emergency services.
EU	European Union.
FDD	Frequency Division Duplex – a technology that deals with traffic asymmetry between uplink and downlink where separate frequency bands are used for send and receive operations.
GHz	Gigahertz. 1,000,000,000 (or 10^9) oscillations per second.
IoT	Internet of Things. There is no universally agreed definition of the Internet of Things but in general it is used (like M2M) for communications that involve communication with at least one machine.
IMT	International Mobile Telecommunications. The ITU term that encompasses 3G, 4G and 5G wireless broadband systems.
ITU	International Telecommunications Union - Part of the United Nations with a membership of 193 countries and over 700 private-sector entities and academic institutions. ITU is headquartered in Geneva, Switzerland.
LTE	Long-Term Evolution is a standard for communication of high-speed data for mobile phones and data terminals. The term 4G is generally used to refer to mobile broadband services delivered using the next generation of mobile broadband technologies, including Long Term Evolution (LTE) and WiMAX.
M2M	Machine to machine refers to technologies that allow both wireless and wired systems to communicate with other devices of the same type M2M is a broad term as it does not pinpoint specific wireless or wired networking.
MIMO	Multiple-Input Multiple-Output (MIMO) technology is a wireless technology that uses multiple transmit and receive antennas to transfer more data at the same time.
MHz	Megahertz - A unit of frequency of one million cycles per second.
mmWave	Strictly speaking, mmWave is the band between 30 GHz and 300 GHz – wavelengths at these frequencies are between 1mm and 1cm. However, the term is commonly used refer to frequencies above 24 GHz, and this is how we use it.
MNO	Mobile Network Operator.

RF	Radio frequency.
RSPG	Radio Spectrum Policy Group. A high level advisory group that assists the European Commission in the development of radio spectrum policy.
TDD	Time Division Duplex – a technology that deals with traffic asymmetry where the uplink is separated from downlink by the allocation of different time slots in the same frequency band.
Wi-Fi	Commonly used to refer to wireless local area network (WLAN) technology, specifically that conforming to the IEEE 802.11 family of standards.
WRC	World Radiocommunication Conference. The WRC reviews and revises the Radio Regulations, They are held every three to four years.
WSD	White Space Devices - which make use of transmission frequencies that are nominally allocated to other services but which are unused in the vicinity of the device.