



Mobile Data Strategy

Statement

Publication date:

28 May 2014

About this document

This document is our long term strategy to address the increasing use of data by mobile devices like smartphones, tablets and laptops. UK citizens and consumers already benefit considerably from use of mobile devices and the data traffic consumed by those devices is expected to grow significantly in the future.

There are a number of ways to increase the capacity of mobile networks to deal with this growth, such as more efficient technology and greater use of small cells, but use of additional spectrum is likely to be part of the solution. We are already preparing to award suitable spectrum in the 2.3 GHz and 3.4 GHz bands and are today consulting on a proposal to release the 700 MHz band for mobile use. However, the potential scale of the future challenge, the potential benefits that could be achieved by meeting it, and the long lead times normally associated with changing spectrum use, mean that developing a long term strategy is important.

This document therefore identifies additional spectrum bands for potential mobile use and prioritises our efforts on these. It describes what we plan to do to better understand the possibilities for each band, and, where appropriate, ensure there is an option for future mobile use.

We will take forward the band-specific actions identified in this document and continue to develop our understanding of future demand and technology trends. We will update and refine our strategy periodically as necessary.

There are links between this work and two other documents that we are publishing today:

- our consultation on a change of use of the [700MHz band](#); and
- a discussion document on the [future of free to view TV](#).

Contents

Section		Page
1	Executive Summary	3
2	Introduction	7
3	Context	11
4	Prioritisation of bands	17
5	Implementation	27
Annex		Page
1	Summary of consultation responses	33
2	Glossary of terms	52

Section 1

Executive Summary

Overview

1.1 This document is our long term strategy to address the increasing use of data by mobile devices such as smartphones, tablets and laptops. It identifies and prioritises a number of bands where we will undertake further work to consider their future use and sets out what we plan to do next.

Addressing future mobile demands is one of our priorities for the coming 10 years

1.2 Use of mobile data services brings considerable benefits to UK citizens and consumers and demand for these services is likely to increase significantly in the future. One estimate is that demand for mobile data in 2030 could be 45 times higher than today, with the traffic carried on mobile networks (after allowing for traffic offloaded to Wi-Fi networks) increasing 25 times¹. Addressing this demand is a priority area for our work over the coming 10 years².

1.3 There are a range of potential solutions to meeting the likely growth in demand, including greater deployment of small cells and use of more efficient technologies, but making additional spectrum available is also likely to be part of the solution. Ofcom has a duty to secure optimal use of spectrum. To do this, we rely on market mechanisms where possible and effective, but also take regulatory action where necessary.

1.4 We are already planning to award additional spectrum for mobile data services in the 2.3 GHz and 3.4 GHz bands and today (28 May 2014) set out our proposals for enabling the 700 MHz band to be used for mobile services. Beyond these bands, it is possible that there will be limited benefit in making more spectrum available for mobile data services if demand can be met at lower cost through technology and network improvements.

1.5 However, if further major changes to spectrum use *do* turn out to be beneficial, they can require several years of preparation, for example to secure the necessary international agreements. A key part of this preparatory work is to ensure that we take account of the interests of all spectrum users, including assessing the potential for, and if necessary mitigating, harmful interference. Therefore, it is important for us to start preparatory work now in order to maintain options for the future.

1.6 Our work on spectrum is complemented by:

- Our work to support improvements in mobile coverage, including monitoring compliance with the 4G coverage obligation, working with third parties to provide better consumer information on coverage and mobile broadband speeds, and

¹ See Analysys Mason Study <http://stakeholders.ofcom.org.uk/consultations/700MHz/>

² See Spectrum Management Strategy

<http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/statement/statement.pdf>

exploring other options to further extend geographical coverage (including on roads and railways).

- Our regulation of the fixed communication networks that underpin provision of mobile data services, including leased lines and superfast broadband. We review competition in relevant fixed communications markets and apply appropriate regulatory remedies to address any competition issues that we may find³.

Our strategy comprises prioritised actions on specific bands and a range of cross cutting work

1.7 We have identified a number of frequency bands where we plan to undertake further work in the coming years and our priorities for future work on each band are set out in Table 1 below.

Table 1: Summary of our work to prepare for future growth in mobile data services
(band priorities changed since consultation document shown in *italics*)

Prioritisation and high level aims for band specific work	Bands
Current priorities <ul style="list-style-type: none"> • Continue existing work to enable mobile use 	<ul style="list-style-type: none"> • 700 MHz • 2.3 GHz*, 3.4 GHz • UHF white space (shared)
High <ul style="list-style-type: none"> • Enable cleared bands to be brought into use as demand emerges • Establish feasibility / conditions for sharing as soon as possible • Secure relevant international agreements as appropriate 	<ul style="list-style-type: none"> • 1452-1492 MHz • 1980-2010 / 2170-2200 MHz ('2GHz MSS') • 3.6-3.8 GHz (shared) • 5-6 GHz Wi-Fi (5350-5470 MHz, 5725-5925 MHz) (shared)
Medium-High <ul style="list-style-type: none"> • Establish viability of shared access • Promote international support 	<ul style="list-style-type: none"> • 1427-1452 MHz (<i>shared</i>) • 3.8-4.2 GHz (<i>shared</i>)
Medium <ul style="list-style-type: none"> • Further develop our understanding of longer term use scenarios 	<ul style="list-style-type: none"> • 470-694 MHz (very long term) • 1492-1518 MHz • 2.7-2.9 GHz • 5.925 – 6.425 GHz (<i>shared</i>)
Low <ul style="list-style-type: none"> • No pro-active action at this stage 	All other bands

³ For example, our [review of the UK's Fixed Access Markets](#), covering the access connections used to provide telephone and broadband internet services (including superfast broadband) to residential and business consumers.

Cross cutting and ongoing work

- Maintaining a long term UK perspective on changing demand and supply options
- Understanding future technology developments and their implications for spectrum
- International engagement including WRC-15
- Progressing our work on mobile coverage
- Appropriate incentives and information
- Keeping our priorities under review

* As discussed in our spectrum sharing statement we will also (in addition to the award of cleared spectrum) further consider the feasibility of sharing in the retained parts of the 2.3 GHz band, based on a better understanding of existing users' requirements

- 1.8 Our prioritisation takes account of how important the various bands could become in the event that there is significant future mobile data demand, and also reflects likely timescales for each band.
- 1.9 The prospects for mobile data use vary widely from band to band. For example, a high priority band for future work such as 1452-1492 MHz could be available for mobile data use within a year or two. In contrast, and as we explain in more detail in our consultation document on the Future of Free to View Television (also published today) we expect the 470-694 MHz band, which is currently used for DTT, to remain important for that purpose for many years. However, its medium priority reflects our work on potential long term scenarios for its use. This work will inform our international engagement, and may also inform future implementation options for 700 MHz release, if we go ahead with our proposals in that area.
- 1.10 Another important area of future work, that may be relevant to several bands, is to promote improvements to equipment radio performance standards so as to help reduce the risk of harmful interference if and when mobile data services are introduced. In addition, we have identified a range of cross cutting and ongoing work areas that will help us refine and update our strategy going forward and ensure consistency (see Table 1). This is particularly important given the rate of growth in the use of mobile data and the high level of technological innovation in its provision.

Benefits for consumers

- 1.11 Even without the potential spectrum changes identified in this strategy, consumers will benefit from faster and higher capacity mobile data services in the future as a result of recent and planned awards, network and technology improvements and re-farming of existing spectrum. They will also benefit from improved coverage as a result of the 4G coverage obligation and other initiatives, including better consumer information.
- 1.12 If the spectrum identified in this strategy were available for mobile data in the future (see Table 1) then this would boost capacity even further, perhaps up to 17 times higher by 2030 compared to today (see Figure 1). This would support an even higher growth in the amount of traffic carried by mobile networks compared to 2014 because some of the spectrum currently available for mobile networks is not yet fully utilised⁴. The extra capacity will help improve the quality of service that consumers get when they are in areas with coverage. Although the spectrum identified will not, on its own, extend coverage, we will continue to support improved mobile data services for all

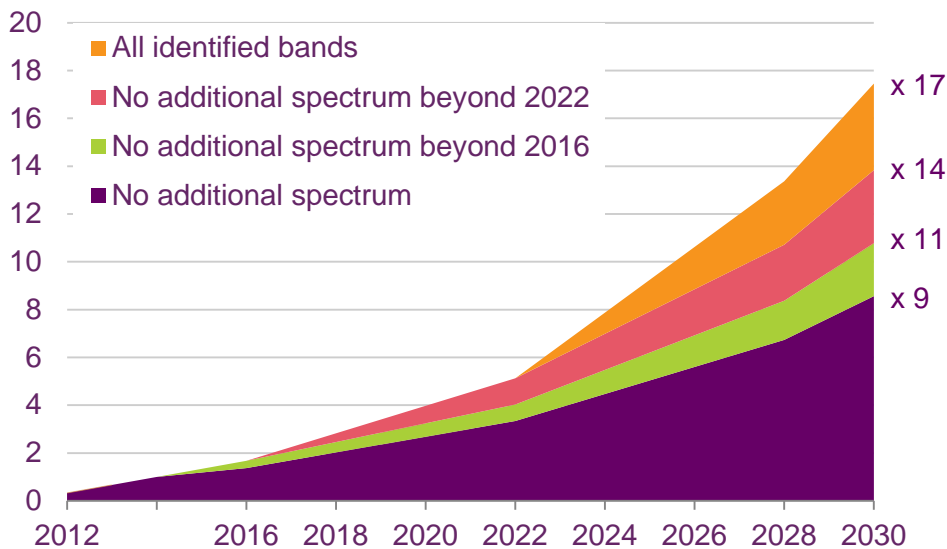
⁴ For example, operators are currently in the process of deploying networks using the spectrum released in the 4G auction and only a proportion of consumers have taken up 4G services to date. The growth in data demand suggests that this position will change rapidly.

consumers, and as further spectrum is made available for mobile use, we may consider including further coverage obligations.

Table 2: Illustrative implications for spectrum availability

Scenario	Bands available for mobile data	Total MHz available for mobile data (downlink estimate)
2012	<ul style="list-style-type: none"> • 900 MHz, 1800MHz • 2.1 GHz 	162 MHz
2014	<i>As 2012 plus:</i> <ul style="list-style-type: none"> • 800 MHz • 2.6 GHz 	290 MHz
2016	<i>As 2014 plus:</i> <ul style="list-style-type: none"> • 2.3 GHz, 3.4 GHz • 1452–1492 MHz 	491 MHz
2022	<i>As 2016 plus:</i> <ul style="list-style-type: none"> • 700 MHz • 2 GHz MSS • 3.6-3.8 GHz • 1427-1452 MHz 	671 MHz
2028	<i>As 2022 plus:</i> <ul style="list-style-type: none"> • 2.7-2.9 GHz • 3.8-4.2 GHz • 1492-1518 MHz 	941 MHz

Figure 1: Illustrative increase in mobile data capacity relative to 2014 capacity



Next steps

1.13 We will take forward the band specific and cross cutting work outlined in Table 1 above and keep our strategy under review.

Section 2

Introduction

- 2.1 This document sets out 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 Our strategy identifies bands where we will undertake further work, for example analysis of coexistence issues. In addition, we have identified a range of cross cutting, ongoing work areas to support delivery and continued development of our strategy.

Background

- 2.3 Mobile data services, and the applications they support, already deliver substantial benefits to UK citizens and consumers. These services include provision of mobile broadband to consumer devices such as smart phones and laptops as well as emerging machine-to-machine (M2M) communications.
- 2.4 The demand for mobile data is growing rapidly and there is a significant likelihood that it could continue to grow materially in the future. In light of the challenges that continued growth could bring, we published a consultation on our Mobile Data Strategy⁵ on 21 November 2013 (our 'Consultation Document'). This set out our analysis and proposals to facilitate the continued long term growth of consumer and citizen benefits from increasing use of mobile data services. In particular, it reviewed a number of specific bands and considered their long term potential for mobile data use.
- 2.5 The consultation closed on 30 January 2014. We received 31 responses, of which eight were confidential. We have published the 23 non-confidential responses on our website⁶. This statement sets out our conclusions on our strategy in light of stakeholder responses and other developments since the consultation.
- 2.6 In addition, we have recently published our Spectrum Management Strategy Statement which provides the strategic context and rationale for developing a mobile data strategy. It outlines six sector-focussed priorities for the next 10 years, one of which is to address future mobile data demands, recognising the importance of improving mobile coverage and the availability of new mobile services.

Planning ahead

- 2.7 The mobile sector is highly innovative and dynamic with new devices and applications creating new consumer demands that cannot easily be predicted a long time in advance. As a result, the long term demand for mobile data – in say 10-15 years' time - is uncertain and there are varying forecasts of its level. Nonetheless the potential benefits of enabling growth in mobile data could be considerable.
- 2.8 There are a range of potential solutions to meeting the growth in demand and industry is leading on several of these, such as the use of more efficient

⁵ See <http://stakeholders.ofcom.org.uk/consultations/mobile-data-strategy/>.

⁶ See <http://stakeholders.ofcom.org.uk/consultations/mobile-data-strategy/?showResponses=true>.

technologies, greater use of small cells and offloading of mobile data onto Wi-Fi networks. However, use of additional spectrum is also likely to be part of the solution.

- 2.9 Ofcom has a duty to secure optimal use of spectrum. As part of our work to secure that duty we already have activities in place to make more spectrum available for mobile data services over the coming years. We are preparing to award the 2.3 GHz and 3.4 GHz bands, have proposed the release of the 700 MHz band and are working to enable access to UHF whitespaces (for which provision of data to mobile devices is one possible application).
- 2.10 The existing opportunities for expanding capacity may mean that only modest additional changes in spectrum use become necessary over the coming 10-15 years. However, given the high degree of uncertainty in long term demand forecasts, and the potential for disruptive innovations to create a step change in demand, it is also possible that more extensive changes could be needed.
- 2.11 If it were possible to respond very quickly to changing spectrum demands, then it might be possible to consider these issues nearer the time. However major changes in spectrum use can take many years to bring about for a number of reasons, including:
- The necessary international agreements can take many years to negotiate.
 - Any changes necessary to manage interference between spectrum users (and sometimes clearance of existing users from a band altogether) can be complex and take several years to implement, particularly if cost and disruption are to be minimised.
 - Existing users may have made long term investments in use of the band (and neighbouring bands) and it can be beneficial to provide early information to inform their future investments. This includes taking account of the potential for future mobile use of neighbouring bands when specifying the performance of new radio equipment.
- 2.12 Therefore, given the potential importance of the mobile data challenge and the long lead times associated with major changes in spectrum use, the aim of our mobile data strategy is to prepare for future increases in the use of mobile data services while taking account of other users of spectrum.
- 2.13 An important aspect of our preparation is our engagement with the international processes that will influence future harmonisation of mobile data spectrum. In particular, important decisions in relation to potential future bands for mobile data use will be taken at an upcoming international conference, the World Radiocommunication Conference in 2015 ('WRC-15'). Our strategy informs our preparations for that.

Related work

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

- a) our **Spectrum Management Strategy**⁷, which sets our overarching approach to managing spectrum over the next 10 years, with a key objective of delivering the greatest value to UK citizens and consumers. As discussed above, it provides the context and rationale for our mobile data strategy;
- b) our **statement on spectrum sharing**⁸. This work highlighted the steps we will take to encourage wider use of spectrum sharing in the mobile broadband, Wi-Fi and Internet of Things sectors. These include ensuring Wi-Fi can continue to provide high speed wireless connectivity; increasing access to spectrum for use in small mobile broadband cells; and helping provide the spectrum needed to support innovation in the emerging Internet of Things sector. It also explored how spectrum can be shared more effectively between different spectrum users through advances in dynamic spectrum access technologies. These are likely to be at least part of the solution to meeting the growth in demand for mobile data services.
- c) the **proposed release of 700 MHz spectrum**⁹. Our consultation published today (28 May 2014) sets out proposals for a change of use and award of spectrum in the 700 MHz band (694–790 MHz). If we go ahead with our proposals, this spectrum would be available for mobile data use from early in the 2020s.
- d) analysis of the **future of Free to View TV**¹⁰. We have also published a discussion document today which considers how current Free to View TV platforms might need to develop in the future in order to remain competitive and relevant to viewers. The document considers the potential long term options for delivering Free to View TV, including over broadband networks, and is relevant to the long term future of spectrum at 470-694 MHz.
- e) the **Public Sector Spectrum Release Programme (PSSRP)**¹¹. We are working with Government to support its aim of releasing 500 MHz of public sector spectrum into civil use by 2020. This is relevant to our Mobile Data Strategy as a future potential source of spectrum for mobile data use.
- f) our forthcoming **WRC-15 Consultation**. Agenda Item 1.1 of WRC-15 deals with future mobile and wireless broadband spectrum and is highly relevant for our mobile data strategy. We will be publishing a separate consultation on WRC-15 to give stakeholders further opportunity to contribute to our preparations for the conference.

Structure of this document

2.15 The rest of this document is structured as follows:

- **section 3** provides the context for our mobile data strategy;

⁷ See <http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/statement/statement.pdf>

⁸ See http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-sharing/statement/spectrum_sharing.pdf

⁹ See <http://stakeholders.ofcom.org.uk/consultations/700MHz/>

¹⁰ See <http://stakeholders.ofcom.org.uk/consultations/700MHz/ftv/>

¹¹ See https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287992/PSSRP_update_5_March_2014_Final.pdf

- **section 4** sets out our revised prioritisation of bands and explains our rationale where we have changed the ranking of bands since publication of the consultation document taking account of stakeholder responses and other developments;
- **section 5** explains how we plan to implement our strategy.

2.16 Ofcom's response to individual stakeholder comments can be found in Annex 1.

Section 3

Context

Overview

3.1 This section summarises the context for our strategy covering:

- Ofcom's role in relation to mobile data spectrum including our duties and strategic approach to managing spectrum;
- the international context for spectrum use in the UK;
- technology trends and developments that could help satisfy growing demand for mobile data and shape future spectrum demand; and
- the public sector spectrum release programme.

3.2 Additional detail is provided in our Consultation Document and its annexes.

Ofcom's role

Ofcom's specific duties and powers related to spectrum management

3.3 The European Common Regulatory Framework for electronic communications¹² (in particular, the Framework Directive and the Authorisation Directive) sets the broad legal framework for how spectrum use should be authorised and managed in the UK and aims to harmonise the regulation of electronic communications networks and services throughout the European Union. The UK's responsibilities for spectrum management under these Directives are given effect in UK law primarily through two Acts of Parliament which confer on Ofcom specific duties and powers in respect of spectrum (and the other sectors we regulate): the Communications Act 2003 (the '2003 Act') and the Wireless Telegraphy Act 2006 (the 'WT Act').

3.4 Our principal duties under the 2003 Act are to further the interests of citizens and consumers, where appropriate by promoting competition. In doing so, we are also required (among other things) to secure the optimal use of spectrum, as well as to have regard to the desirability of securing the availability and use of high speed data transfer services through the United Kingdom, the desirability of encouraging investment and innovation, and the interests of consumers in respect of choice, price, quality of services and value for money.

3.5 In carrying out our spectrum functions, we have a duty under section 3 of the WT Act to have regard in particular to: (i) the extent to which the spectrum is available for use or further use for wireless telegraphy, (ii) the demand for use of that spectrum for wireless telegraphy and (iii) the demand that is likely to arise in future for the use of that spectrum for wireless telegraphy. We also have a duty to have regard, in

¹² The Common Regulatory Framework comprises the Framework Directive (Directive 2002/21/EC), the Authorisation Directive (Directive 2002/20/EC), the Access Directive (Directive 2002/19/EC), the Universal Service Directive (Directive 2002/22/EC) and the Directive on privacy and electronic communications (Directive 2002/58/EC), as amended by the Better Regulation Directive (Directive 2009/140/EC). See <http://ec.europa.eu/digital-agenda/en/telecoms-rules>.

particular, to the desirability of promoting: (i) the efficient management and use of the spectrum for wireless telegraphy, (ii) the economic and other benefits that may arise from the use of wireless telegraphy, (iii) the development of innovative services and (iv) competition in the provision of electronic communications services.

- 3.6 In addition to our functions under the Common Regulatory Framework, we have also been directed by Government to represent UK interests in negotiations within the main spectrum related international institutions, including the International Telecommunications Union (ITU), the European Conference of Postal and Telecommunications Administrations (CEPT), and spectrum committees of the European Union.

Our spectrum management strategy and the role of regulatory intervention

- 3.7 In exercising our discretion regarding how we can best fulfil our duties as they relate to spectrum, it is important that we take a strategic approach to managing this scarce and valuable resource. Ofcom's Spectrum Management Strategy statement¹³ sets out our strategic approach, which is, in summary: to rely on market mechanisms where possible and effective, but also take regulatory action where necessary.

- 3.8 For example, companies wishing to provide new or additional mobile data services could acquire spectrum from other (non-mobile) users. The difficulty, however, is that bringing about a major change of use of spectrum is not a straightforward process and, without Ofcom's involvement, might not occur even if it is in the interests of citizens and consumers, or might be subject to unnecessary costs or delays. Some of the reasons for this are:

- A major change of use typically requires international engagement because international harmonisation of spectrum use enables economies of scale, e.g. in the production of handsets and other devices.
- New high power uses need to be co-ordinated across borders to avoid harmful interference.
- A major change of use will normally involve vacation of the band by incumbent users, and changes to the interference environment that could have negative effects on users of adjacent spectrum. These processes can be complex, making it hard for the market to reach a coordinated solution.

- 3.9 In many cases, the market can overcome these challenges. However, in others, we may need to take action to *enable* a change in use, for example:

- undertaking international engagement to support appropriate international agreements at ITU and European level (see below);
- developing mitigation solutions to limit the impact on existing and/or adjacent users; and
- providing appropriate incentives or conditions for the market to lead to a change of use e.g. through spectrum pricing, clarification or liberalisation of existing rights, or possibly through the use of auctions.

¹³ See <http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/statement/statement.pdf>

- 3.10 In some cases enabling actions such as these may be sufficient for the market to reach a socially optimal outcome. However in other situations it may be necessary for Ofcom to take further action. The additional actions we may take, sometimes in combination with Government, could include an assessment of the economic viability of change; making a decision to clear spectrum of existing users (with any decisions on funding the costs of clearance ahead of an award being a matter for Government); implementing the clearance of incumbent users and managing the implementation of measures to mitigate potential harmful interference between users.

International context

- 3.11 International harmonisation is particularly important in relation to mobile services because there are large economies of scale in equipment manufacture. Mass market mobile devices are typically produced at the largest global scale possible and ideally the number of regional variants is kept as small as possible. In addition, harmonisation can allow consumers to use their mobile devices in other countries without modification.
- 3.12 The international processes that are most relevant to the development of our mobile data strategy in the UK are Agenda Item 1.1 of WRC-15 and EU processes (including RSP and RSPG). Further details on both are set out in our Consultation Document. We will also publish a consultation document on our preparations for WRC-15 in the next few days.

ITU World Radiocommunication Conference 2015

- 3.13 The ITU is a specialised agency of the United Nations, which harmonises the allocation of spectrum internationally. It does so through the ITU Radio Regulations, which are amended approximately every four years by World Radiocommunication Conferences (WRCs). Ofcom takes the lead for the United Kingdom (UK) in WRC negotiations under direction from the Government. We are therefore actively engaged in UK, European and international preparations for the next WRC in 2015 (WRC-15).
- 3.14 WRC-15 Agenda Item 1.1 concerns the availability of spectrum for mobile broadband applications over the next 10-15 years. It will consider options for new frequency allocations suitable for mobile broadband (including Wi-Fi) and identification of frequency ranges as suitable for International Mobile Telecommunications (IMT), the ITU term that encompasses 3G, 4G and future wireless broadband systems.
- 3.15 If WRC-15 identifies spectrum for IMT this does not necessarily mean that it will be used for that purpose in the future in the UK. Ofcom will make any policy decisions in this regard taking account of any relevant harmonisation measures, such as non-binding CEPT ECC Decisions or legally binding European Commission decisions (see below); Ofcom's statutory duties; applicable EU law; and the relevant factual context at the time. On the other hand, if WRC-15 does not identify a given spectrum band for IMT then it is reasonably unlikely that that band will be used for IMT in the UK because of the economies of scale in equipment manufacture noted above.
- 3.16 A related agenda item at WRC-15 is 1.2 which concerns the introduction of a mobile allocation and IMT identification in 694-790 MHz (the '700 MHz band'). Its primary focus is on adjacent band compatibility between mobile and digital terrestrial television (DTT), and on the band plan for IMT use in ITU-R Region 1 (Europe, the Middle East and Africa).

European Union

- 3.17 Within the European Union, the Radio Spectrum Policy Programme (RSPP) has set out a series of policy objectives, including an obligation on member states to make every effort to identify at least 1200 MHz of spectrum for wireless data traffic (to consumer devices) by 2015. European member states and the Commission are currently implementing the provisions set out in the RSPP. To date a total of 990 MHz for wireless broadband has been harmonised through Commission Decisions¹⁴.
- 3.18 The European Radio Spectrum Policy Group (RSPG) – which provides strategic advice to the European Commission (EC) on matters of spectrum policy – is also undertaking work in this area. Of most relevance is the RSPG Opinion on strategic challenges facing Europe in addressing the growing spectrum demand for wireless broadband¹⁵, which was adopted in June 2013. This includes an analysis of bands between 400 MHz and 6 GHz which are currently available, or more significantly could become available in future, for wireless broadband.

Technology developments that could help satisfy growing demand for mobile data

- 3.19 The capacity of networks to carry mobile data traffic depends on the amount of spectrum available and how efficiently that spectrum is used. The latter depends on the efficiency of the technology adopted and the number of sites on which that spectrum is deployed. Hence spectrum users can help satisfy increasing demand for mobile data services by:
- Deploying networks and devices based on technologies that are more efficient; and
 - Deploying additional sites, including network architectures that use spectrum more efficiently or facilitate access to a broader set of access networks.
- 3.20 These trends may also affect what sort of spectrum can be used to provide mobile data services most effectively and the relative demand for different types of spectrum. Relevant developments in technology and network topology that we are currently aware of include:
- a) **Spectrum sharing:** we expect to see an increase in shared access to spectrum amongst different uses as the opportunities to clear spectrum (particularly on a nationwide basis) become ever more challenging and as technical and regulatory developments, such as dynamic shared access, enable more efficient re-use of spectrum where and when it is really needed. Our ongoing work to enable white space devices in the frequencies used for DTT is a demonstration of innovative deployment of geo-location database technology to enable spectrum sharing.
 - b) **Support for wider channel bandwidths:** demand for spectrum where wider channel bandwidths can be supported is likely to increase. This may need to be at higher frequencies where wider bandwidths in contiguous frequency blocks

¹⁴ See <http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1399300944635&uri=CELEX:52014DC0228>

¹⁵ See <http://rspg-spectrum.eu/rspg-opinions-main-deliverables/>

tend to be more readily available, although techniques such as carrier aggregation across multiple bands, may mitigate this demand.

- c) **Advanced antenna techniques:** Multiple Input Multiple Output (MIMO) antenna techniques are commonly deployed by current 3G, 4G and Wi-Fi networks. Recent advances have seen the emergence of more sophisticated multiple antenna techniques such as beam-forming based on 'massive MIMO' systems. These systems may allow the exploitation of higher frequency bands so far unused by current mobile broadband technologies by overcoming some of the associated propagation constraints.
- d) **Development of technologies that can deal with traffic asymmetry (between uplink and downlink):** The delivery of services using paired spectrum with equal quantities of uplink and downlink spectrum may not be optimal in all cases. Technologies based on time division duplex (TDD) rather than frequency division duplex (FDD) may help to address this as the amount of uplink and downlink capacity can be more easily adjusted to better match demand. Other technology developments such as supplemental downlink (SDL) may also help by adding additional downlink spectrum capacity to existing paired FDD arrangements.
- e) **Co-ordination between base stations:** Advanced co-ordination techniques between different cell types and base stations can allow more efficient utilisation of network resources and a reduction of interference in the network.
- f) **Development of broadcast capability for mobile terminals:** Video content is an important component of the overall demand for mobile data. A converged mobile/broadcast standard - known as eMBMS - could make use of LTE technology to deliver live broadcast services to both mobile handsets and TV sets in the home. While at this stage the commercial viability of such a service is unclear, these developments present a theoretical opportunity to achieve significant spectral efficiencies.
- g) **Mobile device support for multiple bands:** Mobile devices need to support multiple bands and up to three mobile technology generations (2G, 3G and 4G), Wi-Fi and Bluetooth. It is likely to be easier (particularly in small devices) and less expensive to integrate new bands in a device if they are closer in frequency to bands already in use as it is more likely that components can be shared. In order to understand better this complex issue we have commissioned an external study on the implications of supporting an increased number of frequency bands and wireless technologies in mobile devices.
- h) **Smaller cells:** Demand in a mobile network can be highly localised with traffic hotspots developing in predictable locations. It can be more efficient and cheaper to cover these areas with small (micro and pico) cells than by a traditional large (macro) base station. While small cells can be deployed in any frequency band, the lower power and coverage requirements of small cells mean that they can take advantage of higher frequencies that are otherwise challenging to use for the provision of more ubiquitous coverage from macro sites.
- i) **Automatic switching between cellular and Wi-Fi networks:** Wi-Fi offload currently plays an important role in the delivery of services to mobile devices. There are a number of initiatives currently looking to facilitate automatic switching including Hotspot 2.0 from the Wi-Fi Alliance, Access Network Discovery and Selection Function (ANDSF) from 3GPP and Next Generation Hotspot (NGH)

from the Wireless Broadband Alliance. These developments could lead to a greater proportion of mobile data traffic being offloaded onto Wi-Fi in the future.

- 3.21 Other technology developments might help slow the growth of mobile data traffic over wide area networks. For example better compression technologies and greater storage capacity in mobile devices can allow users to store data locally that they might otherwise have to access over a wide area network -, although the data might still be uploaded onto the device over a wireless Wi-Fi network.
- 3.22 In addition, mobile networks and devices are the subject of continued and very significant research efforts. It is therefore likely that other innovations will emerge in the coming years that will influence how efficiently spectrum is used (and what sort of spectrum). Consequently an important part of our forward work will be to monitor and consider the implications of these developments (see section 5).

Public sector spectrum

- 3.23 The release of public sector holdings could make a significant contribution to future spectrum availability for mobile broadband. The Government plans to release 500MHz of spectrum from public sector use by 2020. A number of the bands discussed in this document are used by the public sector and therefore it is important to take a co-ordinated approach across civil and public sector holdings. Government is leading on this issue through its strategic plans set out in an overarching UK Spectrum Strategy published in March 2014¹⁶.
- 3.24 The first release of spectrum suitable for mobile data services will take place in 2015/16 with the award by Ofcom of 190 MHz of spectrum previously used by the Ministry of Defence (MoD) in the 2.3 GHz and 3.4 GHz spectrum bands. In addition, spectrum sharing is an important mechanism for the public sector to provide access to spectrum. We are currently working with the MoD to assess the prospects for sharing military spectrum by studying the potential for coexistence with civil uses.

¹⁶ The UK Spectrum Strategy - https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287994/UK_Spectrum_Strategy_FINAL.pdf

Section 4

Prioritisation of bands

4.1 This section sets out our strategic prioritisation of bands and explains the changes compared to our proposed prioritisation in the Consultation Document.

Purpose of prioritisation

4.2 The purpose of our prioritisation exercise is to inform, at a high level, the work that Ofcom will undertake to prepare for long term growth in mobile data services. The actions that we may take to understand the feasibility of mobile data use, and where appropriate, enable its use, include:

- Analysis of potential long term scenarios for use including, for example, trends in demand for incumbent or other alternative users, and technology developments that could influence how the band might be used.
- Investigation of the potential for harmful interference between mobile data services and the incumbent users (in the case of sharing) and the adjacent users (in the case of clearance and sharing). In some cases we may help to develop solutions to mitigate the impact on existing and/or adjacent users.
- Promotion of improvements in radio frequency performance, e.g. in equipment standards, so as to help reduce the risk of harmful interference.
- International engagement at the ITU and European level to support the potential harmonisation of additional bands for future mobile data use.
- Implementation of appropriate incentives or conditions to support market-led change of use, e.g. spectrum pricing, clarification of existing rights, liberalisation or possibly through the use of auctions.

4.3 Prioritisation of bands therefore helps to ensure our efforts on these actions are as effective as possible. It should also help spectrum users to take account of possible future changes in their investment decisions and in the design of their equipment, for example to ensure that receivers are suitably selective in the frequencies to which they listen.

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. In general:

- **High priority bands:** If a band is already clear, i.e. not currently in use, then our aim is to enable it to be brought into use as demand emerges – for example by helping to resolve coexistence issues (i.e. potential for interference to/from users in neighbouring bands) or ensuring there are appropriate market incentives for efficient use. If a band is being considered for sharing with incumbent users, then our aim is to establish the feasibility and conditions for sharing as soon as possible. In both cases we may also need to secure relevant international agreements if appropriate (for example at WRC-15).

- **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. The scenarios may take account, for example, of trends in incumbent demand and technological developments.
- **Low priority bands:** At this stage we do not plan to undertake any pro-active action in relation to mobile data use for bands ranked as low priority. This covers all bands not explicitly identified as higher priority.

4.5 We may review the prioritisation of bands periodically as necessary, for example to take account of international decisions at WRC-15. So, ranking a band low now does not mean that it will never be considered for mobile data use, although we would expect to engage with affected stakeholders if and when that changed. Nor will a high priority band necessarily remain so. For example, further technical sharing analysis may provide strong evidence that the opportunities for mobile data use are very limited.

Prioritisation of efforts of specific bands

4.6 Our methodology for prioritising bands was detailed in our consultation document and takes account of the potential benefits, costs and the extent of (or potential for) international harmonisation. We have reviewed each band in light of stakeholders' responses to the consultation (see Annex 1) and other relevant developments since then. Our revised prioritisation is set out in Table 3 below, with changed priorities compared to our consultation marked in italics.

Table 3: Prioritisation of band specific work to prepare for growth in mobile data services

Priority for further work	Bands
Current priorities	<ul style="list-style-type: none"> • 700 MHz • 2.3 GHz*, 3.4 GHz • UHF white space (shared)
High	<ul style="list-style-type: none"> • 1452-1492 MHz • 1980-2010 / 2170-2200 MHz ('2 GHz MSS') • 3.6-3.8 GHz (shared) • 5-6 GHz Wi-Fi (5350-5470 MHz, 5725-5925 MHz) (shared)
Medium-High	<ul style="list-style-type: none"> • 1427-1452 MHz (shared) • 3.8-4.2 GHz (shared)
Medium	<ul style="list-style-type: none"> • 470-694 MHz (very long term) • 1492-1518 MHz • 2.7-2.9 GHz • 5.925 – 6.425 GHz

* As discussed in our spectrum sharing statement we will also (in addition to the award of cleared spectrum) further consider the feasibility of sharing in the retained parts of the 2.3 GHz band, based on a better understanding of existing users' requirements.

- 4.7 For many bands, we will be focusing on the potential for shared use between existing uses and mobile data services. Shared use is becoming an increasingly important option, both because of the challenges of making nationally cleared spectrum available, and because the demand for mobile data is geographically concentrated.
- 4.8 In addition, we will undertake further work on bands above 6 GHz. The issue is at a very early stage and further consideration will be necessary to understand which bands or which ranges of bands it will make sense to focus upon. The UK has submitted a preliminary proposal for a WRC-18 agenda item on IMT identification for bands above 6 GHz while also investigating the most appropriate way to safeguard applications that currently use these bands.
- 4.9 For most bands, our prioritisation is unchanged compared to our original proposals. The following paragraphs provide a brief summary of those bands where the prioritisation is unchanged (with additional detail provided in our consultation), followed by a more detailed explanation of where we have made changes.

Spectrum bands where our priorities are unchanged

470–694 MHz

- 4.10 The band remains a **medium** priority. It is widely used for broadcasting DTT services delivering significant benefits to UK citizens and consumers, and is important for supporting a range of PMSE applications. Several international discussions on the future of this band are taking place, especially within Europe, through RSPG, CEPT and further work sponsored by the European Commission. This band, or parts of it,

could also be considered for co-primary allocation and identification of IMT at WRC-15.

- 4.11 As we discuss in two other documents we are publishing today on the potential release of the 700 MHz band and of the future of Free to View TV, we consider that the ongoing importance of DTT and barriers associated with IPTV, including availability and take-up of suitable broadband connectivity, mean that we would only expect any switch off of DTT to occur post 2030. This is consistent with the view we took in our UHF Strategy Statement of November 2012¹⁷, which forms the basis of our position for international engagement.
- 4.12 As we continue to play an active role in international discussions, it will remain important for us to consider potential scenarios for use of this band over the very long term. These could also be relevant to the implementation of potential changes at 700 MHz, as we would seek to give DTT multiplex operators flexibility to react quickly and efficiently to any future changes in the DTT frequency plan.

1452–1492 MHz

- 4.13 The band remains a **high** priority for us. The band, which is a single block of 40 MHz, is licensed to Qualcomm in the UK, which has been proactive in promoting the band to be used for supplemental downlink (SDL). The proposal is supported internationally through a CEPT Decision and is likely to be considered for IMT identification at WRC-15. The band is unused and we are currently considering a licence variation request to enable it to be used for SDL. An important aspect of this work relates to the adjacent band technical compatibility issues.

1980–2010/2170–2200 MHz

- 4.14 The band remains a **high** priority for us. It comprises 2 x 30 MHz of spectrum and is adjacent to bands which are already in use for mobile services at 1920–1980 MHz and 2110–2170 MHz. The band has been allocated on a pan European basis for providing mobile satellite services (MSS) and so can already be used by the current licensees for provision of mobile data services via satellite and a Complementary Ground Component (CGC)¹⁸. If services are not provided by the current licensees then this spectrum might in the future become available for (dedicated) terrestrial mobile data services, depending on enforcement action and agreement at EU level.

3.6–3.8 GHz and 3.8–4.2 GHz

- 4.15 The 3.6-3.8 GHz band remains a **high** priority and 3.8-4.2 GHz remains a **medium-high** priority. Spectrum in these ranges potentially offers a large amount of contiguous bandwidth and is adjacent to spectrum at 3.4–3.6 GHz, part of which is being prepared for award under the PSSR programme. In the UK the band is used for satellite downlinks, fixed links and 2 x 84 MHz is licensed to UK Broadband. This band is being considered for potential sharing with incumbent users.
- 4.16 3.8-4.2 GHz ranks lower than 3.6-3.8 GHz even though it potentially offers twice as much bandwidth because:

¹⁷ <http://stakeholders.ofcom.org.uk/consultations/uhf-strategy/statement/>

¹⁸ Complementary Ground Component (CGC) is ground based infrastructure in a satellite network that uses terrestrial base stations to provide connectivity in weak signal areas

- Internationally there is support for 3.6-3.8 GHz in the CEPT Conference Preparatory Group for consideration of a primary mobile allocation at WRC-15, and there is already a European Commission Decision supporting harmonised use. In contrast, 3.8-4.2 GHz is not harmonised for mobile use and there is opposition from a number of countries to consideration of a co-primary mobile allocation.
- There is a greater density of satellite downlinks in the 3.8-4.2 GHz part of the band compared to 3.6-3.8 GHz, so the capacity available for sharing may be less.

5 GHz (5350–5470 MHz, 5725–5925 MHz) – potential Wi-Fi extension

- 4.17 These bands remain a **high** priority for us. As discussed in our spectrum sharing statement, Wi-Fi operating in the 2.4 and 5 GHz bands plays a vital role in the UK's broadband infrastructure, delivering high speed connectivity to consumers in homes, offices and outdoor hotspots. This connectivity is used by mobile devices for 'offload' of mobile data onto fixed networks as well as a range of non-mobile devices in the home (such as desktop PCs and Smart TVs). To ensure indoor Wi-Fi networks can support increasing superfast broadband speeds, additional contiguous spectrum is likely to be needed to accommodate wider channels and prevent interference occurring between adjacent households. To help meet this demand, a potential extension of the 5 GHz licence exempt band is being discussed in preparation for WRC-15.
- 4.18 There are important services currently operating in the 5GHz bands which also provide significant benefits for society, such as remote sensing services and applications in the 5350–5470 MHz band. Therefore, it is important to assess the risk of existing users, including the space science industry, experiencing harmful interference if these bands were to be made available for Wi-Fi use. We are continuing to undertake detailed technical coexistence studies on this issue.

Spectrum bands where our priorities changed

- 4.19 In the following paragraphs, we set out our rationale in relation to those bands where our review resulted in a changed prioritisation for the spectrum band.

450–470 MHz

- 4.20 We previously assessed this band as a **medium** priority; we have now re-assessed it as a **low** priority.
- 4.21 Around one third of the capacity available in the 450–470 MHz band is currently heavily used by business radio users (over 25,000 assignments), ranging from utilities to hospitals, industrial sites and taxi firms. Other users of this band include emergency services, scanning telemetry used by the utilities, PMSE 'talk-back', and licence exempt devices. Our Consultation Document, as well as the Spectrum Management Strategy consultation, noted the deployment of LTE services in Brazil in this band (although wider deployment has not materialised) and the potential benefits it could bring for extending coverage to areas which are difficult to reach.
- 4.22 However, in response to both consultations there was relatively limited interest expressed by stakeholders in the prospect of using this band for LTE for public mobile networks in the long term. Consequently the Spectrum Management Strategy statement clarified that while we will continue to take forward important work on this band, we are likely to place greater emphasis on the changing requirements of

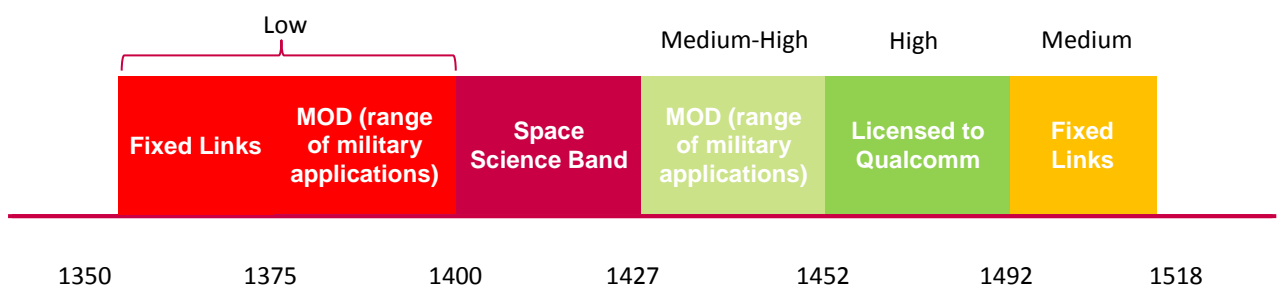
incumbent users, and addressing potential increases in interference from the continent, rather than the prospects for mobile data use.

- 4.23 We also previously noted that the use of larger antennae sizes at this frequency may pose challenges for integration into mobile handsets. Therefore, taken together with the constraints and high costs associated with re-planning, we have decided that reducing the band to **low** priority for consideration of mobile data use is appropriate, although the wider review of incumbent use of this band will continue.
- 4.24 Nonetheless, the low frequency of the band means that it might become beneficial in providing a near ubiquitous coverage layer for applications that do not depend on mass market mobile handsets, e.g. possibly for some future M2M applications. In our Spectrum Management Strategy statement we identified enabling growth and innovation in M2M applications as an area for further priority work. We will therefore keep potential mobile use of this band under review as our work on M2M and incumbent use of the band progresses.

1350–1518 MHz

- 4.25 In our consultation, this frequency range was ranked as **medium** priority, with the exception of 1452–1492 MHz which was ranked a **high** priority, and 1400-1427 MHz (a space science band) which is not available for alternative uses.
- 4.26 Since our consultation, international interest has continued to develop in bands directly adjacent to the 1452-1492 MHz band (which is supported for supplemental downlink use), i.e. 1427-1452 MHz and 1492-1518 MHz, with the prospect that a wider band for mobile data use might be created.
- 4.27 A wider contiguous band for mobile data use could offer greater benefits than several smaller blocks. Wider blocks of spectrum offer higher capacity and are better able to deliver high data rate services. In addition, given that mobile devices support a limited number of bands and there is a cost to adding new ones, the availability of a wider block of spectrum could further encourage manufacturers to develop equipment to support it.
- 4.28 Stakeholders held different views in relation to the different sub-bands in this range, and there are different issues with regard to incumbent users. It therefore seems more helpful to assess the sub-bands individually rather than in aggregate. The figure below (Figure 2) illustrates the revised prioritisation for the spectrum range and the paragraphs below explain our rationale.

Figure 2: Prioritisation of spectrum in the 1350 – 1518 MHz spectrum range



- 4.29 PMSE stakeholders have separately highlighted 1427-1518 MHz as a possible future sharing option for audio PMSE. We have included this amongst the future spectrum

options for PMSE we are studying as part of our PMSE strategy, but we do not consider this band meets our objective of a long term solution for audio PMSE given the possibility of future mobile use.

1350–1375, 1375-1400 MHz

- 4.30 We have re-assessed these sub-bands as **low** priorities. There is less international support for these bands than those between 1427 and 1518 MHz, and less opportunity to create a wide block of spectrum. Military use in the 1375–1400 MHz band is wide-ranging and includes NATO military operations which may make release of the spectrum challenging, as well as costly. There are also extensive fixed wireless links in 1350-1375 MHz sub-band. This band is paired with 1492-1518 MHz, and so any clearance of fixed links would clear both bands, but it is much less attractive for mobile data use for the reasons given above.

1427–1452 MHz

- 4.31 We have re-assessed this sub-band up to a **medium-high** priority. The sub-band is used by the MoD and is being considered for sharing as part of the Government's Public Sector Spectrum Release (PSSR) programme. Initial research into the sharing possibilities for the band suggests that MoD use is concentrated in rural areas and therefore shared access to this band could have synergies with SDL use in 1452-1492 MHz (as discussed above). The band is also supported by European administrations within CEPT.

1492–1518 MHz

- 4.32 We have assessed that this sub-band should remain a **medium** priority. There is some international interest due to its proximity to the 1427–1452 MHz and 1452–1492 MHz bands (as discussed above). 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. So, if the band were to be supported at CEPT level we would need to be satisfied that our fixed link use could continue.
- 4.33 If we did retain fixed links in this band (and did not license it for mobile data), then mobile devices designed to operate across an internationally harmonised 1427-1518 MHz band could still be used in the UK. They would not have access to the full band, but UK consumers would still benefit from the economies of scale in these devices.

2.7–2.9 GHz

- 4.34 We have re-assessed this band down to a **medium** priority. In the UK this spectrum is used to provide primary radar services for both civil and military purposes and is under consideration within the Government's PSSR programme. With estimates of a potential release of up to 100 MHz of spectrum, one aspect of the Government's PSSR work is to investigate the possibility of re-planning the radar system and establishing how much spectrum might potentially be released.
- 4.35 The status in part reflects the priority for Ofcom work and resources (rather than that of Government). While the Civil Aviation Authority (CAA) is still in the early stages of understanding the feasibility of any release, we also now have a greater understanding of the military use and appreciate that considerable work is required in order to understand and balance the estimated cost of a remediation programme with the geographical extent of any release. Internationally, only a few countries in Europe are supporting the band and we have seen no evidence of support outside Europe. In

recognition of the limited international support, a recent meeting of the European preparation meeting for WRC-15 (CPG) agreed to move this band into the category of “band not supported for mobile broadband”. Our downward revision reflects this position.

5.925–6.425 GHz

- 4.36 In our consultation this band was ranked as a **low** priority as there was very limited international support for it, although we noted the potential for this to change. It was not subject to detailed review. In light of more recent developments we have re-assessed the band as a **medium** priority, although this could change over the coming months
- 4.37 The band is being supported for action (to add to an IMT identification) at WRC-15 by Russia for small cell indoor LTE use. It is currently used for fixed links and fixed satellite services. Very recent studies undertaken by the ITU indicate that, although sharing and compatibility between fixed links and fixed satellite stations and indoor mobile broadband small cells in this band is difficult in the same geographical area, the potential for sharing could be increased through detailed planning of mobile systems.
- 4.38 If sharing is shown to be feasible (and noting that there is already a world-wide co-primary allocation to the mobile service) identifying this band for either IMT or RLAN use may be beneficial. The band could potentially be used for Wi-Fi services in addition to or as an alternative to the Wi-Fi extension bands currently under consideration (5.350-5.470 GHz and 5.725-5.925 GHz). We intend therefore to seek views from stakeholders about the identification of this frequency band for either IMT or RLAN use when we consult on our position and strategy for WRC-15.

Potential implications for capacity

- 4.39 We have estimated what the potential increase in capacity of mobile networks could be in coming years if some or all of the bands we have identified were made available. Table 4 and Figure 3 below show the estimated potential increase in capacity compared to 2014 for different spectrum scenarios.
- 4.40 The estimates¹⁹ measure the potential increase in total mobile network downlink capacity (peak hour throughput in Mbit/s). The additional capacity will enable more people to use mobile data services, at faster speeds and using more data hungry applications.
- 4.41 As discussed in the introduction to this document, making additional spectrum available is just one way in which capacity on mobile networks can be increased. The estimates therefore use assumptions about technological improvements and deployment of additional mobile sites (both macro and small cell sites) which means that capacity will increase significantly even in scenarios where no additional spectrum is released. In addition, there is also likely to be greater use of mobile data offload to Wi-Fi networks, and the speed of connectivity to Wi-Fi networks could benefit from use of additional spectrum at 5-6 GHz if this were made available.

¹⁹ The model and assumptions used for our capacity estimates were detailed in our consultation. We now use slightly different assumptions for spectral efficiency to align with more recent work on 700 MHz.

Figure 3: Illustrative increase in mobile network capacity relative to 2014 capacity

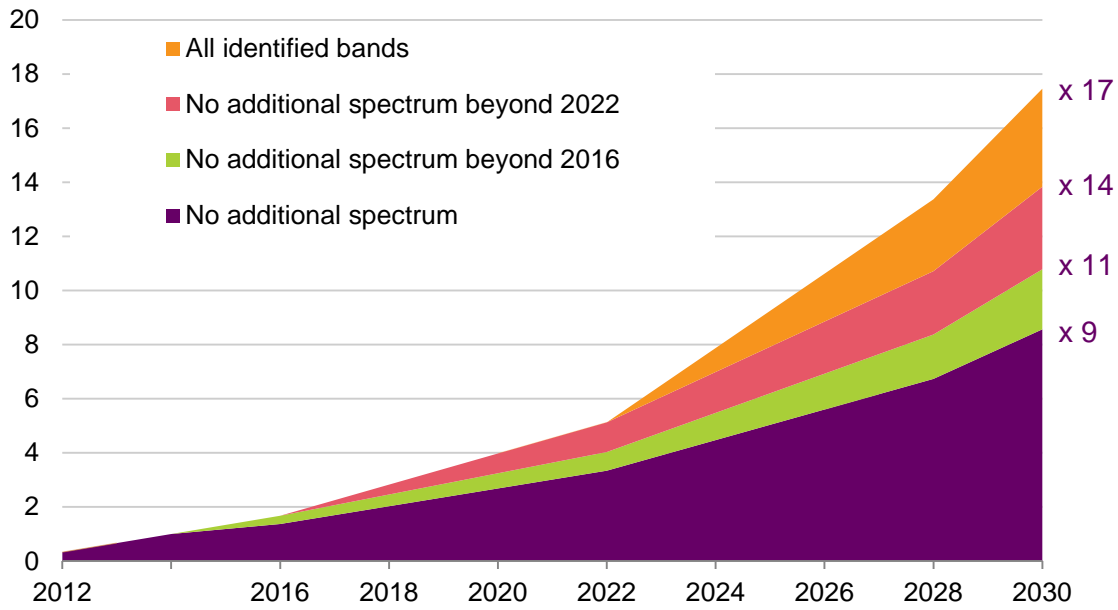


Table 4: Illustrative implications for spectrum availability and mobile network capacity

Scenario	Bands available for mobile data	Total MHz available for mobile data (downlink)	% of total spectrum < 1 GHz	Spectrum increase over 2014? (downlink)	Total potential capacity increase over 2014
2012	900 MHz, 1800MHz 2.1 GHz	162 MHz	19%	-	-
2014	As 2012 plus: • 800 & 2600 MHz	290 MHz	21%	-	-
2016	As 2014 plus: • 2.3, 3.4 GHz • 1452–1492 MHz	491 MHz	12%	x 1.7	x 1.7
2022	As 2016 plus: 700 MHz • 2 GHz MSS • 3.6-3.8 GHz • 1427-1452 MHz	671 MHz	13%	x 2.3	x 5.1
2028	As 2022 plus: • 2.7-2.9 GHz • 3.8-4.2 GHz • 1492-1518 MHz	941 MHz	10%	x 3.2	x 13.4

4.42 The relative increases in capacity of mobile networks are lower than the illustrative numbers outlined in our Consultation Document for a number of reasons:

- a) In the consultation we estimated capacity increases relative to capacity in 2012, but we now estimate capacity increases relative to 2014. Capacity between 2012 and 2013 approximately tripled, partly as a result of the 4G auction.
 - b) We have adjusted the prioritisation of potential bands that could be made available for mobile. In particular, we have excluded the 470–694 MHz band (currently used for DTT and PMSE) from our capacity estimates to 2030. As discussed above, we consider that the ongoing importance of DTT and barriers associated with IPTV, including availability and take-up of suitable broadband connectivity, mean that we would only expect any switch off for DTT to occur post 2030.
 - c) We have updated our forecast of spectral efficiency so that it is consistent with the forecast we have used in our 700 MHz cost benefit analysis. This slightly reduces the forecast growth in spectral efficiency compared to the figures used in the mobile data strategy consultation. However, the overall impact of this on capacity growth is limited.
- 4.43 In our consultation on the potential future release of the 700 MHz band we highlight forecasts from Analysys Mason that estimate that demand for mobile data in 2030 could be 45 times higher than today, with the traffic carried on mobile networks (after allowing for traffic off-loaded to Wi-Fi networks) increasing 25 times.
- 4.44 Our estimates above are for increases in mobile network capacity compared to *capacity* (not the amount of traffic) in 2014. Therefore a 17 times increase in capacity would support an even higher growth in the amount of traffic carried by mobile networks compared to 2014 because some of the spectrum currently available for mobile networks is not yet fully utilised. For example, operators are currently in the process of deploying networks using the spectrum released in the 4G auction and only a proportion of consumers have taken up 4G services to date.
- 4.45 As discussed in section 5, one aspect of our ongoing work will be to further develop our analysis of mobile data demand and supply, taking into account geographic variations in demand.

Section 5

Implementation

Introduction

5.1 This section describes how we plan to implement our strategy in the coming months and years. Our work will cover three areas:

- band-specific actions;
- international engagement; and
- cross cutting work.

Band specific actions and international engagement

5.2 Table 5 below sets out our planned actions for further analysis of specific bands and our current aims for international engagement on those bands. In time we may consider additional bands in more detail in response to international and/or technology developments (see below). For example, if particular bands or ranges of bands are identified as potentially relevant for future 5G services we may need to carry out more detailed work on those.

Table 5: Band specific work to prepare for future growth in mobile data services

	Band	Specific actions	International aims
Current priorities <ul style="list-style-type: none"> Continue existing work to enable mobile use 	700 MHz	<ul style="list-style-type: none"> Proposal for release published May 2014 Statement on future of the band– late 2014 / early 2015 	<ul style="list-style-type: none"> Continue to support harmonisation (including work on a CEPT band plan)
	2.3 GHz, 3.4 GHz	<ul style="list-style-type: none"> Publish auction design consultation - Summer 2014 	<ul style="list-style-type: none"> Continue to support further harmonisation
	UHF white space (shared)	<ul style="list-style-type: none"> Complete pilot implementation of access to white spaces in the UHF band in 2014 	<ul style="list-style-type: none"> Continue to support harmonisation
High <ul style="list-style-type: none"> Enable cleared bands to be brought into use as demand emerges Establish feasibility / conditions for sharing as soon as possible Secure relevant international agreements as appropriate 	1452-1492 MHz	<ul style="list-style-type: none"> Currently considering licence variation request from existing licensee (Qualcomm) to enable the use of this band for supplementary downlink (SDL) Develop wider strategy on 1427-1518 MHz 	<ul style="list-style-type: none"> Continue to support harmonisation in CEPT while retaining flexibility at a national level to resolve coexistence issues with adjacent services Support as a potential candidate band for WRC-15 (IMT designation)
	1980-2010 / 2170-2200 MHz ("2 GHz MSS")	<ul style="list-style-type: none"> Assess compliance by existing licensees with licence conditions 	<ul style="list-style-type: none"> Continue to engage with the European Commission and other Member States to secure the efficient use of this spectrum
	3.6-3.8 GHz (shared)	<ul style="list-style-type: none"> Analyse feasibility and costs of mobile broadband sharing with earth stations across 3.6-4.2 GHz 	<ul style="list-style-type: none"> Continue to support further harmonisation in CEPT/EU Continue to support as a potential candidate band for WRC-15.
	5350-5470 MHz / 5725-5925 MHz (shared)	<ul style="list-style-type: none"> Sharing and compatibility studies to understand the conditions under which Wi-Fi sharing with incumbent services would be feasible and enforceable. 	<ul style="list-style-type: none"> Continue to support studies on potential for harmonised Wi-Fi use while seeking to ensure protection of existing uses

	Band	Specific actions	International aims
Medium-High <ul style="list-style-type: none"> Establish viability of shared access Promote international support 	1427-1452 MHz (shared)	<ul style="list-style-type: none"> Support MoD in the assessment of sharing opportunities for mobile data services (inc. supplemental downlink) in this band Take into account wider strategy on 1427-1518 MHz 	<ul style="list-style-type: none"> Continue to support as a potential candidate band for WRC-15
	3.8-4.2 GHz (shared)	<ul style="list-style-type: none"> Analyse feasibility and costs of mobile broadband sharing with earth stations across 3.6-4.2 GHz 	<ul style="list-style-type: none"> Support longer term consideration of this band for potential mobile broadband use in CEPT/EU (e.g. sometime after WRC-15)
Medium <ul style="list-style-type: none"> Further develop understanding of longer term use scenarios 	470-694 MHz (long term)	<ul style="list-style-type: none"> Understand potential longer term scenarios for this band in order to inform international engagement and possibly 700 MHz implementation options 	<ul style="list-style-type: none"> Seek to ensure that consumers and citizens can continue to enjoy benefits delivered by DTT and PMSE use of the band in the UK.
	1492-1518 MHz	<ul style="list-style-type: none"> Analyse feasibility and costs of mobile data services sharing and impact of migrating fixed links from this band. 	<ul style="list-style-type: none"> For further consideration following our forthcoming WRC-15 consultation
	2.7-2.9 GHz	<ul style="list-style-type: none"> Government is leading a programme to consider the options for re-planning radars in order to potentially release spectrum 	<ul style="list-style-type: none"> Continue to support as a potential candidate band for WRC-15, but to keep under review in the run-up to the conference in light of the level of international support
	5.925 – 6.425 GHz (shared)	<ul style="list-style-type: none"> Potentially analyse sharing conditions for Wi-Fi and/or IMT use taking account of further evidence of demand and international developments 	<ul style="list-style-type: none"> For further consideration following our forthcoming WRC-15 consultation
Low <ul style="list-style-type: none"> No pro-active action at this stage 	All other bands	<ul style="list-style-type: none"> No action 	<ul style="list-style-type: none"> Our general approach is not to oppose international study of other bands and we may wish to encourage study on specific bands in response to 5G developments

Cross cutting activities

5.3 To ensure our strategy continues to be refined and kept up to date we have identified a range of cross cutting and ongoing activities.

Understanding future technology developments and implications for spectrum

- 5.4 Technology developments will continue to shape future demand for spectrum in a number of ways:
- by stimulating demand for mobile data through device and application innovation;
 - by expanding network capacity and so acting as a substitute for additional spectrum; and
 - by influencing the demand for different types of spectrum - for example by enabling the use of higher frequencies or shared spectrum.
- 5.5 On the other hand, technology developments also respond to expectations of future spectrum availability. Therefore we will continue to monitor relevant technology developments and develop our thinking on their spectrum implications.
- 5.6 To date there has been a focus on the potential for new technologies (e.g. 5G) to open the use of much higher frequencies, and this is clearly an area we will consider further. However, there may be a range of disruptive innovations over coming years which could have implications for spectrum use. Going forward we will continue to build a forward view on these implications by:
- Engaging with industry and the research community to understand the direction of their work and consider the long term spectrum implications of innovation. Our membership of 5GIC is one current example of this.
 - Undertaking targeted technology research to provide more detailed insight where appropriate. One example of this is research we have commissioned on the implications of supporting multiple frequency bands and technologies in mobile devices (we expect to publish the results of this work in summer 2014).

Monitoring and developing our understanding of mobile data demand and its spectrum implications

- 5.7 The long term demand for mobile data services is subject to a high degree of uncertainty and there are a wide range of forecasts both in terms of traffic levels and the subsequent implications for future spectrum requirements. Consequently, at this stage, it is uncertain how much of the spectrum we have identified for further work might ultimately be made available for mobile data use.
- 5.8 We will therefore continue to develop our view of future growth in mobile data demand, taking account of a range of factors including consumer demand and willingness to pay for mobile data, technology developments (eg new devices) that may stimulate demand, the geographic distribution of traffic and international trends. We will also consider further what the implications of this demand might be in terms of future changes in spectrum use and/or sharing. One aim is to provide greater insight into how much (if any) additional spectrum it might be beneficial to make available for mobile data in the future - recognising the high degree of uncertainty of this type of analysis.

- 5.9 In addition, international comparisons of UK demand may inform our international engagement (see below), for example if we identify significant differences in the quantity or type of spectrum that the UK needs compared to other countries.

International engagement including WRC-15

- 5.10 We will continue to engage with a number of international processes that are considering the potential for additional spectrum for mobile services, including preparations for WRC-15 Agenda Item 1.1 and 1.2 and the EU Radio Spectrum Policy Group (RSPG). Our overall aim is to ensure that international decisions give the UK the ability to respond to future growth in mobile data if and when needed.
- 5.11 Our current international aims for specific bands are detailed in Table 5 above. In addition, we will shortly be publishing a consultation on WRC-15 which will provide stakeholders further opportunity to contribute to our preparations for the conference.

Progressing our work on mobile coverage

- 5.12 As set out in our Spectrum Management Strategy, over the next few years we will continue to investigate how to support improvements in the provision of mobile coverage and in the quality of experience for end users. This will include:
- Monitoring compliance with the 4G coverage obligation and considering whether it would be appropriate to take any further action.
 - Exploring options to support further improvements in geographical coverage of mobile voice and data services, including road and rail coverage.
 - Working with third parties to provide better consumer information on coverage levels provided by operators, as well as additional information relevant to the quality of experience of mobile end-users, such as voice calls reliability and mobile data speeds.
 - Conducting research on the role of device performance affecting the consumer mobile coverage experience and on the effectiveness of technical solutions to addressing instances of poor signals inside buildings or cars.

Appropriate incentives and information

- 5.13 We will continue to put appropriate incentives in place and make information available to enable market mechanisms to work where possible and effective, in line with our strategic approach to spectrum management. The work includes:
- Improving the quality and quantity of information we make available on spectrum use. Our aims for this work are detailed in our Spectrum Management Strategy.
 - Reviews of spectrum pricing for incumbents services, taking account of the potential value of bands for mobile data services as appropriate.
 - Licensing and policy changes that facilitate and/or create incentives for market driven change of use, such as liberalisation, trading and indefinite licence terms.

Keeping our priorities under review

- 5.14 We have identified our current priorities and what we plan to do next to implement our strategy, but our strategy will not remain static. We will review and update our views in light of ongoing regulatory, market, technological and international developments, building on the work areas identified above.

Annex 1

Summary of consultation responses

- A1.1 This annex provides a summary of comments received from stakeholders in response to our Mobile Data Strategy consultation published on 21 November 2013, together with our responses to these comments. A total of 31 responses were received to the consultation, of which 8 were confidential.
- A1.2 Where stakeholders have made the same, or very similar, comments to multiple questions in their response we have included the comment only once under the question to which the comment has greatest relevance. In addition, we have combined the responses to questions 9, 11 and 12 as these covered very similar issues. We have limited this summary to comments received that are directly relevant to our Mobile Data Strategy. This Annex does not summarise comments received in relation to other spectrum matters.
- A1.3 Organisations from whom we received non-confidential responses are listed below:

<ul style="list-style-type: none"> • ARM Holdings • Arqiva • BBC • BEIRG • BT • DUK • Dynamic Spectrum Alliance (DSA) • European Satellite Operators Association (ESOA) 	<ul style="list-style-type: none"> • Freeview • Global VSAT Forum • Hauwei • High Speed Two (HS2) Ltd • Inmarsat Ventures • Met Office • NATS • O3b Ltd 	<ul style="list-style-type: none"> • Phonak UK • Qualcomm • Samsung Electronics UK • Scottish Government • Solaris Mobile & Echostar • Vodafone • Wi-Fi Alliance
---	---	---

Question 1: Have we correctly identified the future characteristics of mobile data demand?

Stakeholder comments	Ofcom response
<p>Stakeholders broadly agreed that we had correctly identified the characteristics of mobile data demand. Vodafone commented that compelling applications were driving demand and Huawei commented that consumer expectations and the requirements of new applications (e.g. ultra high data rates, or reliability of data for mobile health applications) would be key factors in characterising mobile data demand.</p> <p>Global VSat Forum argued that our characterisation of Wi-Fi transfer as predominantly intra-building was incorrect; other stakeholders considered that the importance of Wi-Fi to help meet the growing demand for mobile data should not be underestimated.</p> <p>Several stakeholders noted the emergence of M2M applications and commented on the need for the availability of appropriate spectrum to support its development.</p> <p>HS2 Ltd commented that our analysis should have made more reference to the increase of data demand by people in transit.</p>	<p>We agree that the significant factor driving demand is consumers' expectation of data connectivity to access new applications through increasingly advanced devices.</p> <p>We also agree that Wi-Fi plays an important role in delivering mobile data traffic. It is used in over 89% of all broadband connected households to extend the fixed broadband connections to in-home devices as well as mobile devices. In recognition of this we are considering the feasibility of the extension of the 5 GHz band to enable more shared access of the spectrum with Wi-Fi services (see our Spectrum Sharing statement²⁰ for more details)</p> <p>In relation to M2M applications, we continue to improve our understanding of requirements across a range of applications and sectors. Our <i>Spectrum Management Strategy</i> statement²¹ has identified enabling growth and innovation in M2M applications as an additional priority work area for Ofcom. In implementing our mobile data strategy we have confirmed that we will continue to progress our work to support improvements in geographical coverage of mobile voice and data services, including road and rail coverage.</p> <p>As set out in our <i>Spectrum Management Strategy</i>, over the next few years we will continue to investigate, how to support improvements in the coverage of mobile voice and data services, including road and rail coverage as well as quality of experience of end users. Details of how we will progress this work are also set out in Section 5 of this statement.</p>

²⁰ See http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-sharing/statement/spectrum_sharing.pdf

²¹ See <http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/statement/statement.pdf>

Question 2: Do you agree that there is a prospect of significant continuing growth in demand for mobile data services?

Stakeholder comments	Ofcom response
<p>Stakeholders broadly agreed that there is a prospect of significant continuing growth in demand for mobile data services.</p> <p>However, they were not generally convinced of the reliability of long term mobile data growth forecasts and expressed caution in developing a mobile data strategy on that basis. DUK said that the rate had slowed and the focus should be on the type of demand. Vodafone also commented on the uncertainty in growth rates, recommending a balanced approach in our strategy at WRC-15 that would avoid needless disruption to incumbent users if the higher growth levels did not materialise.</p> <p>Arqiva agreed with the prospect of growth in the medium term and suggested that based on geographic concentration, local capacity enhancements might be an appropriate approach.</p> <p>ESOA was not supportive of identifying new bands at present. ESOA argued that a 30x increase could be met through new technology and new network deployments.</p>	<p>We agree that projections of demand are difficult and are subject to a large degree of uncertainty. We believe however, that as the benefits of enabling growth in mobile data could be considerable, it is important that we plan ahead. There are long lead times associated with major changes in spectrum use; our mobile data strategy enables preparation for future increases in the use of mobile data services while taking account of other spectrum users.</p> <p>We will however continue to develop our view of future growth in mobile data demand, taking account of a range of factors (as discussed in section 5) and aim to provide greater insight into how much (if any) additional spectrum it might be beneficial to make available for mobile data in the future. We think that this could go some way to address stakeholder concerns of avoiding unnecessary uncertainty for incumbent spectrum users.</p>

Question 3: Have we identified all the challenges in realising future growth in citizen and consumer benefits from use of mobile data services and do you have any comments on the nature or the scale of the challenges we have identified?

Stakeholder comments	Ofcom response
<p>Stakeholders broadly agreed that we had identified all of the challenges in realising citizen and consumer benefits.</p> <p>Samsung agreed, noting the work that it and other industry stakeholders are already undertaking to investigate use of bands above 20 GHz. Qualcomm said that innovation such as SDL and LSA would help to address the challenge and contribute to growth in consumer benefit. However ESOA argued that our consultation gave insufficient weight to opportunities for making better use of existing spectrum allocation.</p> <p>BT said that the existing network will struggle to support future enhancements especially if consumers are unwilling to pay and suggests regulatory change. A confidential respondent raised a number of challenges that it believed were not covered in our consultation including: site costs (existing and acquiring new); backhaul efficiency; application of the Electronic Communications Code (ECC); the extent of Wi-Fi offloading; sharing of spectrum by MNOs; maintaining current levels of competition; and meeting consumer expectations of ubiquitous coverage for minimal price increase.</p> <p>Another confidential stakeholder did not agree that we had identified all of the challenges, stating that the importance and level of investment in the public sector use of spectrum needed to be evaluated against the expected commercial value.</p>	<p>In our work to implement the Mobile Data Strategy we will consider, and take account of as appropriate, the various issues and factors that stakeholders have raised</p> <p>In relation to stakeholder comments on importance of public sector use, we note the recent publication of The UK Spectrum Strategy²² which outlines Governments' approach to apply the same core principles to be applied, regardless of whether the user is from the public sector or the private sector. We are working closely with Government to achieve these aims.</p>

²² UK Spectrum strategy: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287994/UK_Spectrum_Strategy_FINAL.pdf

Question 4: Have we correctly identified all the areas where Ofcom has a role in addressing the challenges of growing demand for mobile data services?

Stakeholder comments	Ofcom response
<p>There was some agreement with our analysis, however stakeholders generally offered up their own views on what Ofcom should do in order to address the challenges of the growth in demand for mobile data services.</p> <p>Stakeholders reiterated their views that Ofcom had a role to play in addressing the challenges of infrastructure development, competition and site costs. Arqiva noted that while the consultation acknowledges the challenge of network deployment, no reference is made to the Electronic Communication Code (ECC) on installing and maintaining an electronic communications network (ECN). Arqiva also mentioned the proposed EC Directive on measures to reduce the cost of deploying high-speed electronic communications network. One stakeholder argued that in order to maintain a competitive market the UK needed to improve the distribution of spectrum ownership.</p> <p>The Met Office said that Ofcom should work to ensure that markets for licence-exempt equipment act equitably (in terms of certification, compliance, enforcement and the design of spectrally efficient technology) and that Ofcom’s assessments of spectrum use should build in an evaluation of socioeconomic value. This latter point was echoed by a confidential respondent.</p> <p>Huawei commented that “active administrations” needed to define a long term strategy for spectrum use to enable longer term planning for current users.</p> <p>Vodafone said that Ofcom had a role in promoting frequency arrangements within mobile devices and ensuring co-ordinated release of spectrum across administrations.</p>	<p>A key area of response to this question was in relation to regulatory reform of network deployment specifically the ECC, the code which covers installation and maintenance of an ECN. The ECC is currently under review and Ofcom continues to work with Government to support reform of the ECC to secure best outcomes for the UK.</p> <p>We note that the EC Directive on measures to reduce the cost of deploying high-speed electronic communications networks (Directive 2014/61/EU of 15 May 2014²³) has now been adopted and Member States are required to transpose it into their national legislation by 1 January 2016. We anticipate that Ofcom will work with Government in relation to its transposition into the UK.</p> <p>In relation to our role to promote competition - our consultation confirmed that in the event that additional spectrum were to be awarded by Ofcom, we would consider whether there was a case for introducing measures to promote competition in the award. Any such decisions would be based on an assessment of the specific circumstances of the award and of the sector at the time of the award.</p>

²³ The Directive was published in the Official Journal on 23 May (OJ 2014 L155/1).
See http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2014.155.01.0001.01.ENG

Question 5: Do you agree that the main additional area that our mobile data strategy needs to address is in relation to potential future spectrum options?

Stakeholder comments	Ofcom response
<p>Stakeholders were mixed in their response to this question and largely provided a range of alternative areas that they considered the mobile data strategy consultation could address.</p> <p>Samsung, DUK and Huawei agreed that the main additional area that our mobile data strategy needed to address was in relation to potential future spectrum options, whereas GVF, Arqiva and ESOA disagreed on this point. Arqiva added that there was merit in Ofcom securing spectral efficiency including re-farming and that more should be done in relation to mobile infrastructure. BT suggested that the greatest gain would come from facilitating the introduction of small cells</p> <p>The Met Office suggested that priorities in relation to future spectrum options should not be solely driven by and dedicated to the mobile sector. Vodafone commented that we needed to assess how spectrum would be used.</p>	<p>We agree that there a range of things that industry can do, such as increasing the number of small cells to help meet the growing demand for mobile data. However Ofcom has a duty to secure optimal use of spectrum and we believe that additional spectrum is also likely to be an important part of the solution to meeting the growth in demand.</p>

Question 6: *Is Ofcom doing all that it needs to do in other areas identified as being relevant to the mobile data challenge?*

Stakeholder comments	Ofcom response
<p>Responses to this question were limited and mixed, generally reiterating views made in response to other questions in the consultation.</p> <p>Hauwei agreed that Ofcom was doing all it could.</p> <p>HS2 Ltd stated that there was a need for greater focus on mobile in relation to a range of transport modes.</p> <p>Vodafone considered that Ofcom might have a role engaging in aspects of network planning – e.g. planning, property costs and backhaul. This view was shared by a confidential respondent.</p> <p>Arqiva and DUK commented that if clearance of 700 MHz were to go ahead then the DTT platform should convert to the DVB-T2 standard.</p> <p>The BBC considered that UK support of mobile allocations at ITU level should take account of benefits for the UK by band use both within and outside of the UK.</p>	<p>In relation to mobile use on transport routes, one of our areas of future work is to explore options to support further improvements in road and rail coverage of mobile services.</p> <p>In relation to property costs, Ofcom continues to work with Government to support reform of the ECC (see response to question 4).</p> <p>In relation to 700 MHz and DVB-T2, we have now published our proposals for the release of the 700 MHz band, and a discussion document on the Future of Free to View TV. Matters in relation to the 700 MHz band and technical standards on the DTT platform are covered in these documents.</p> <p>We note the BBC comment. Ofcom works closely with Government and industry on the development of UK positions that we adopt in international discussions.</p>

Question 7: Do you agree with our high-level assessment of likely technology and topology trends and their implications for future spectrum use? We are particularly interested in views on:

- a) the potential demand for spectrum above 10 GHz;
- b) the potential impact of integrating broadcast capability into mobile networks;
- c) whether the technical and commercial challenges of supporting additional frequency bands in mobile devices drive interest towards bands close in frequency to existing bands;
- d) the relative importance of large contiguous blocks of spectrum versus aggregation of smaller blocks

Stakeholder comments	Ofcom response
<p>Most respondents who answered this question were in broad agreement with our high-level assessment of technology trends.</p> <p>a) <u>On spectrum above 10 GHz:</u> Many of the responses supported the further evaluation of frequencies in this area (including ARM Holdings, Arqiva, BT, Hauwei, Samsung), however there were concerns with the impact on existing services particularly from the satellite community (including the Met Office, ESOA, O3b Ltd).</p> <p>b) <u>On integrating broadcast capability into mobile networks:</u> There were a variety of responses with no clear consensus on the demand for this type of integration.</p> <p>c) <u>On whether technical and commercial challenges drive interest towards frequencies close to existing bands:</u> BT and Vodafone were of the view that adding bands increased cost and complexity and could degrade performance. Samsung said that bands close to existing bands offer an attractive proposition while Arqiva said that the drivers for additional frequencies should be their ability to support demand in light of existing assets. DUK highlighted 'cheaper handsets' as one of the benefits that needs to be weighed against repurposing other users of spectrum.</p> <p>d) <u>On the importance of contiguous blocks of spectrum:</u> There was general agreement (including BT, O3b Ltd, Vodafone and Samsung) that large contiguous blocks of spectrum will continue to be of value. Arqiva agreed there was merit in large contiguous blocks of spectrum but that it should not be a major driver of spectrum strategy. DUK commented on the obvious benefits to MNOs but argued that there are wasteful guard bands to enable coexistence of multiple operators, suggesting that smaller diverse blocks might be more attractive and spectrally efficient.</p>	<p>a) <u>On spectrum above 10 GHz:</u> We note that it is likely that a future WRC Agenda item will address bands above 6/10 GHz and believe that it is important to continue to study the spectrum demand for mobile broadband in this area whilst minimising the impact on existing services.</p> <p>b) <u>On integrating broadcast capability into mobile networks:</u> We note in <i>The Future of Free to View TV</i> that although these technologies present a theoretical opportunity to achieve significant spectral efficiencies, at this stage the commercial viability of such a service is unclear. We will continue to monitor developments in this area.</p> <p>c) <u>On whether challenges drive interest towards frequencies close to existing bands:</u> Recognising the complexity and importance of this issue we have commissioned an external study to consider the issues associated with adding additional bands to mobile devices. We expect to publish the report in Summer 2014.</p> <p>d) <u>On the importance of contiguous blocks of spectrum:</u> We note stakeholder views on this issue.</p>

Question 8: Are there any additional technology or topology trends that we need to consider that could have an effect on spectrum use?

Stakeholder comments	Ofcom response
<p>Respondents suggested a range of issues that they felt could affect spectrum use; there was no single identifiable theme.</p> <p>ARM Holdings said that with an explosion in wearable technology and IoT they believe there is a massive potential increase in ‘tethered’ devices.</p> <p>Samsung responded that it believes proposals for high density, high capacity systems will include aspects of convergence between back-hauling and access functions.</p> <p>BT commented on the evolution of fixed networks to deliver superfast broadband speeds and its ability to offer low cost backhaul solutions. DUK suggested investigating the merits of using TDD as opposed to FDD.</p>	<p>Our consultation provided an overview of a number of technological and network developments and their implications for spectrum, and stakeholders did not comment on any previously unidentified technologies or trends.</p> <p>However, we believe that the range of technologies illustrates the need to continue to monitor and consider the implications of technical developments as it is likely that other innovations will emerge in the coming years that will influence how efficiently spectrum is used and what sort of spectrum is required.</p>

Question 10: Do you agree with our methodology for prioritising potential bands for mobile data use?

Stakeholder comments	Ofcom response
<p>Most respondents were broadly in agreement with our methodology, although there were comments as to the completeness and emphasis within the process.</p> <p>Arqiva disagreed with the methodology commenting that priority should be given to those bands that provide highest net benefit for UK citizens and consumers. It also felt that there was no evaluation of the displaced service or the value of what each band would provide to the mobile data services. The point was shared by DUK, particularly with regard to 470 – 694 MHz. HS2 Ltd suggested that as part of the methodology we should also have considered “benefits to the country”.</p> <p>Vodafone suggested that the methodology should also have considered (1) a partial allocation of a band at WRC-15, or spectrum release in stages (2) the opportunity cost of postponing action beyond WRC-15 or (3) alternative decisions being taken at WRC-15 e.g. secondary allocation in 470 – 694 MHz. GVF did not agree with the emphasis on contiguous bandwidth as a factor in prioritising bands.</p> <p>O3b Ltd responded that prioritisation was an important strategic decision and it felt that any changes to spectrum allocation would be detrimental to the space industry. The BBC felt that the methodology was incomplete offering no evaluation of UK spectrum interests outside of the UK.</p>	<p>Our prioritisation of our future work on potential mobile data spectrum reflects our duty to secure optimal use of spectrum.</p> <p>At this stage our assessment of spectrum bands is relatively high level, for the purposes of identifying potential future options for meeting mobile data demands and thus planning Ofcom’s future work. As such this is not the stage where it is appropriate or necessary to complete a full, detailed evaluation of each band. Before any decision to make a change of use of any band would be taken, it would be subject to a more detailed evaluation in terms of technical feasibility and cost benefit analysis, including the impact that such a change would have on any incumbent user..</p> <p>We note the comments in relation to our international engagement through WRC-15. Our upcoming WRC-15 consultation will enable stakeholders an opportunity to provide direct contributions to our preparations for the conference.</p>

Question 9: Do you agree with the short list of bands we have identified for more detailed consideration?

Question 11: Do you agree with our provisional assessment and the results of our band prioritisation?

Question 12: Do you agree with the possible timelines we have identified in this section?

Stakeholder comments	Ofcom response
<p>A number of respondents broadly agreed with our shortlist of bands and prioritisation including BT, Samsung and Qualcomm and a confidential respondent. Additional band specific comments are detailed below.</p>	
<p>380–385 / 390–395 MHz: The Scottish Government noted that this public sector owned paired spectrum might become available and potentially used for mobile broadband services dedicated to the Emergency Services and urged Ofcom to consider the opportunities afforded by the band.</p>	<p>We note the potential availability of these bands and will take them into account in our work to support government in its consideration of the future wireless communication needs of Emergency Services.</p>
<p>410–430 MHz and 870–876 MHz / 915–921 MHz: The Scottish Government considered that these bands warranted further investigation for future use as a bearer for 4G technology.</p>	<p>In our consultation we noted that these bands were not supported by the RSPG Opinion on wireless broadband and ranked as a low priority for future mobile data use. However they are the subject of other Ofcom work:</p> <p>We are undertaking review of competing demands and other issues for the 420-470 MHz band</p> <p>We are making the 870-876 / 915–921 MHz bands available for short range device (SRD) use.</p>
<p>450–470 MHz: The Scottish Government commented as above. A confidential respondent agreed that the band should feature as a priority area in our work plan and considered that availability for national coverage was the preferred option as such an approach could achieve true ubiquity of coverage for consumers.</p> <p>The BBC and BEIRG were not in favour of the band being made available for mobile data services noted that there was a thriving PMSE talkback ecosystem operating in the spectrum.</p> <p>Vodafone did not consider that the consultation had given a clear explanation of the expected benefit to the UK – especially as there was potentially substantial disruption to the incumbent users. They suggested the band priority should be revised down to ‘low’.</p>	<p>Section 4 of this statement explains why we have revised our priority of this band for mobile data use down to low. However, we will still be undertaking a separate review of other competing demands for the 420-470 MHz band.</p>

<p>470–694 MHz: A number of responses were positive about further consideration of this band: ARM (specifically for IoT applications), the Scottish Government, two confidential respondents, HS2, and Vodafone. DSA and Wi-Fi Alliance specifically supported access to white spaces in this band.</p> <p>However, incumbent users of the band and organisation representing them (Arqiva, BBC, DUK, BEIRG, Freeview) were critical of the need to consider this band and highlighted the importance of the existing DTT and PMSE services provided using this spectrum.</p> <p>Sky said Ofcom should incentivise more efficient use of this band via the prices its sets for spectrum.</p>	<p>The importance of the incumbent users of this band is reflected in the documents we have published on the future of Free to View TV and the 700 MHz band.</p> <p>As discussed in section 4, as we continue to play an active role in international discussions, it will remain important for us to consider potential scenarios of use of this band over the very long term. These could also be relevant to the implementation of potential changes at 700 MHz,</p> <p>As set out in our July 2014 statement on spectrum pricing for terrestrial broadcasting²⁴ we will introduce charges for the use of spectrum for broadcasting from the end of 2014. Pricing will reflect our spectrum management costs (cost-based fees) until we have materially progressed our proposals for the future use of the UHF spectrum. We intend spectrum charges for DTT broadcasting to be adjusted to AIP, based on the true opportunity cost of the spectrum at that time, and therefore expect AIP to be in place by around 2020.</p>
<p>694–790 MHz: The Scottish Government noted the possibility of a section of the band being dedicated to enable mobile broadband for public protection and disaster relief (PPDR) and the Emergency Service community.</p> <p>A confidential respondent said that it believed that a timely release (from 2018) of the 700MHz band was required in order to support the growth in demand for mobile data and exploit the benefits of harmonisation.</p>	<p>The future of the 700 MHz band is the subject of a separate consultation document that we have now published. We explain in that document that we propose to change use of the 700 MHz band for mobile, and that as part of that process we will consider its potential for PPDR use.</p>
<p>1300–1350 MHz:</p> <p>NATS was not in favour of the inclusion of the band and argued that the consultation did not give it proper consideration. Another confidential respondent stated that it was not in favour of the band being used for mobile data purposes.</p>	<p>There was an erroneous reference to this band in our consultation. The band is a low for priority for us to consider for mobile data use and we do not plan to do future work on it in that context.</p>
<p>1350–1400 MHz:</p> <p>NATS raised concerns about the lower spectrum edge at 1350 MHz possibly causing interference with radar systems in the adjacent band below 1350 MHz. Vodafone argued for 1350–1400 MHz to be reduced to a low priority.</p>	<p>We have reduced the priority of this band to low. Therefore we do not plan to undertake proactive work to consider its potential use for mobile data.</p>

²⁴ <http://stakeholders.ofcom.org.uk/binaries/consultations/aip13/statement/statement.pdf>

<p>1427–1492 MHz:</p> <p>Vodafone and the Scottish government noted the European support for 1452-1492 MHz as a supplemental downlink band and pointed out the benefits of creating a wider band of 80 MHz. A confidential respondent supported spectrum in the range 1300– 527 MHz (as a second priority) because of its propagation characteristics and the scope to use as a supplemental downlink band</p> <p>Vodafone noted that MOD has already advertised shared access to 1427-1452 MHz and that the 1492-1518MHz is used far less in other European countries than in the UK..</p> <p>One confidential respondent raised concerns about the use of bands close to the space science band at 1400–1427 MHz and urged that we clarify in both text and any illustrations that this band is not under consideration</p>	<p>We are continuing work on 1452-1492 MHz as a high priority and will also look at the potential to create a wider band through use of neighbouring bands 1427-1452 MHz and 1592-1519 MHz.</p> <p>This work will take into account the need to protect the space science band at 1400-1427, which is not under consideration for mobile data use.</p>
<p>1980–2010 / 2170–2200 MHz:</p> <p>Vodafone said that the band was especially valuable for mobile broadband, and urged Ofcom to be proactive in the enforcement action against the currently authorised operators and the subsequent reallocation to terrestrial mobile services.</p> <p>ESOA, Global VSAT Forum, Inmarsat Ventures and Solaris did not support this band as a priority. They highlighted that priority use of these bands remains with the two selected MSS operators in the EU.</p>	<p>We recognise that the band has been allocated on a pan European basis for providing mobile satellite services (MSS) and so can already be used by the current licensees for provision of mobile data services via satellite and a Complementary Ground Component (CGC).</p> <p>We will assess compliance by existing licensees with their licence conditions and continue to engage with the European Commission and other Member States to secure the efficient use of this spectrum.</p>
<p>2.3 GHz: The Scottish Government was supportive of Ofcom considering the opportunities offered by this band for mobile broadband.</p> <p>A confidential respondent said that the release of the 2.3GHz spectrum should occur on the fastest possible timetable to align with the need to deploy existing capacity to ensure consumers have the best possible experience when using mobile broadband services.</p>	<p>Release of the 2.3 GHz band is a current priority for Government and Ofcom. We plan to publish a consultation on auction design for this award in Summer 2014.</p>
<p>2.7–2.9 GHz The Scottish Government noted the potential benefits of this band. However,</p>	<p>We have reduced the priority of this band to medium and set out our</p>

<p>other stakeholders were less positive</p> <ul style="list-style-type: none"> • The Met Office said that the band is allocated internationally to meteorological radiolocation and represents the only suitable alternative frequency for the operation of weather radar networks. • A confidential respondent did not agree that there was sufficient justification to continue to support the band as a potential candidate for WRC-15. • NATS' view this band should at most be medium priority on the basis of information that is available publicly about the maturity of the PSSR work on the band <p>Vodafone said that we should consider reducing to a medium or low priority if international support does not increase or if less than 60 MHz can be released in UK.</p>	<p>reasoning in section 4.</p>
<p>3.6–3.8 GHz: The Scottish Government and Vodafone agreed with the potential benefits of this band. Wi-Fi Alliance commented that enabling licence-exempt use in the 3.6-3.8GHz bands will be an important catalyst to the success of small cell deployments.</p> <p>Several responses including ESOA, Global VSAT Forum, and the Met Office raised concerns with listing this band as a priority band due to the heavy use by the fixed satellite services (FSS) throughout the world.</p> <p>The BBC said that Ofcom must take account of the value to the UK of the existing use of this spectrum (both within and outside the UK) in any considerations.</p>	<p>We recognise the existing important use of the 3.6-3.8 and 3.8-4.2 GHz bands for satellite downlinks and fixed links and will take this into account in our further work on this band. In particular we will be analysing the feasibility and costs of mobile data services sharing with existing users in these bands in more detail.</p>
<p>3.8–4.2 GHz: Huawei commented that the Medium-high priority should be maintained for the 3.8–4.2 GHz range because in combination with the 3.4–3.8 GHz range it represents a unique opportunity for the evolution of mobile broadband networks.</p> <p>The BBC said that it had significant concerns that 3.8–4.2 GHz was being considered</p> <p>Other comments on this band reflected the comments on 3.6-3.8 GHz (see above)</p>	

<p>5350–5470 MHz and 5725–5928 MHz: Several respondents including DSA, Sky and Vodafone supported our proposal to prioritise making additional 5 GHz spectrum available. Sky suggested that we look to adopt a dynamic spectrum access approach in these bands, rather than the dynamic frequency selection (DFS) mechanism. Vodafone said that these bands would complete a contiguous band of nearly 800MHz, which is needed to support multiple wide channels for high speed wireless connectivity. Vodafone noted that using this band for LTE for wide bandwidth supplementary downlink channels would offer a number of significant benefits from the perspective of coexistence with existing systems:</p> <p>Regarding the 5350-5470 MHz band, concerns were raised by the Met Office and one confidential respondent about the impact to Earth Observation Satellites. The Met Office noted that considerable UK investment in satellite applications and the benefits derived could be jeopardised.</p> <p>Concerns were also raised from ESOA and the Global VSAT Forum regarding the impact to the band 5725-5925 MHz which is allocated to the FSS and is used for uplinks.</p>	<p>As discussed in our Spectrum sharing statement, and in section 4 of this document, we recognise the important services currently operating in the 5GHz bands which provide significant benefits for society. Therefore, it is important to assess the risk of existing users, including the space science industry, experiencing harmful interference if these bands are made available for Wi-Fi use. We are continuing to undertake detailed technical co-existence studies on this issue.</p>
<p>Above 10 GHz: See consideration of this issue under question 7.</p>	

Question 12: *Do you agree with the possible timelines we have identified in this section?*

Stakeholder comments	Ofcom response
<p>This question attracted a mixed response – some saying that things needed to be moved along faster, others that international agreement would determine the timeline and others commenting on a lack of consistency</p> <p>A confidential respondent said that Ofcom should do whatever it can to bring forward the availability of future spectrum capacity.</p> <p>Vodafone said that the timelines were helpful but argued that decisions on high and medium priority bands would have to take place no later than WRC-15. Qualcomm agreed with the timeline and BT considered the timeline to be a reasonable estimate but that it would need to be kept under regular review.</p> <p>A confidential respondent, ESOA and GVF commented that the timelines were not consistent with the space sector use of bands, and that satellite bands should not be made available for mobile use for the foreseeable future. The BBC felt that in relation to 3.8–4.2 GHz the timeline was very optimistic</p> <p>NATS and a confidential respondent commented that the timing would be in accordance with Government aims.</p> <p>Arqiva said that inconsistencies in relation to 470–694 could lead to the impression that the band would be available from 2025, while DUK stated that if beyond a potential clearance of 700 MHz, 470–694 MHz is still required, it would be unlikely to be released before 2030. Conversely on 470–694 MHz, Huawei commented that end user expectations towards a converged experience will translate into tangible network deployments within 2020 and 2030.</p>	<p>The timelines outlined in our consultation were illustrative and not prescriptive of future regulatory action. We agree that the timing and availability of some bands is highly uncertain at this stage.</p> <p>The capacity illustrations given in section 4 of this statement do not include 470-694 MHz in our illustrations running to 2030. In addition, our discussion document on the future of free to view TV further considers long term scenarios for the use of the 470-694 MHz band.</p>

Question 13: Do you have any comments on the capacity implications outlined in this section?

Stakeholder comments	Ofcom response
<p>Responses to this question were limited.</p> <p>Vodafone commented that our outline of capacity implications was helpful.</p> <p>GVF commented that Figure 14 suggested that a significant increase in capacity could be achieved through the deployment of bands below 1 GHz. This implies that wide-area coverage could be served in existing (or planned) bands below 1 GHz, and supports its view that wide-area coverage is not a driver for additional mobile spectrum.</p> <p>ESOA commented that a 30x increase could be met without the need for additional spectrum and that demand hotspots could be met through Wi-Fi.</p> <p>Arqiva and DUK also commented that we had overlooked the significant future contribution of Wi-Fi.</p> <p>BT commissioned its own study that looked at capacity and noted that the capacity model in our consultation differed from the approach used in its study.</p>	<p>We recognise the importance of Wi-Fi in meeting growth in mobile data traffic. As part of our illustrative modelling we estimated that offloading to Wi-Fi and femto cells could increase from around 50% of traffic today to between 70% and 90% in 2030. Despite this increase in offloading there are still likely to be benefits in making more spectrum available for wide area mobile networks in the future.</p> <p>Regarding BT’s study, we note that there are a number of possible ways of modelling mobile capacity and the approach used in the consultation represented just one option. In particular we did not attempt to look at the distribution of traffic across sites instead focussing on a high level illustrative approach to capacity modelling focussing on relative capacity levels rather than absolute levels.</p>

Question 14: Do you agree with the next steps we have identified for further domestic work based on the proposed priorities?

Stakeholder comments	Ofcom response
<p>Most respondents were in agreement with the identified next steps. Some suggested other areas of work for inclusion in our next steps, or that Ofcom review the inclusion of bands pertinent to the respondent's sector (band specific points are summarised under questions 9, 11 and 12 above).</p> <p>BT advocated regular reviews on progress and relative priorities.</p> <p>Vodafone suggested that we consider a secondary allocation to mobile in 470–694 MHz as well as the potential for consolidating fixed links in 1512–1518 / 1369–1375 MHz.</p> <p>Ob3 Ltd expressed concern that Ofcom was responding to the mobile sector's short term needs.</p>	<p>Our statement sets out the steps we plan to take to implement our strategy. However, this is not a static plan; our strategy and the activities we undertake will remain under review.</p>

Question 15: How do you think we should adjust our support for international harmonisation based on our proposed priorities?

Stakeholder comments	Ofcom response
<ul style="list-style-type: none"> • Stakeholders offered general comments on how Ofcom should represent the UK as well as their views on specific bands • General comments: • HS2 Ltd commented that Ofcom should engage at international level in relation to public transport solutions. • Vodafone argued for the need for international harmonisation as the UK's influence would be limited if Ofcom tried to act alone. It also considered that decisions at WRC-15 should inform further work. • Samsung noted that spectrum discussions would continue beyond WRC-15 and that the UK would need to review its position regularly. • BT, commenting on the difficulty to predict which band would gain traction, suggested that in order to maximise any opportunity, it would be necessary to progress bands in parallel. • Two confidential respondents commented that the UK would need to be more proactive in promoting UK priority bands. Another commented that the UK should ensure that it is in step with international developments. <p>In relation to specific bands:</p> <ul style="list-style-type: none"> • Qualcomm commented that Ofcom's strong involvement in EU and CEPT work on the future use of 470–694 MHz would be required in 2014/15. Arqiva and Inmarsat responded that Ofcom should not support co-primary allocation and identification for IMT at WRC-15 for 470–694 MHz • ESOA also commented that Ofcom should support the continued harmonisation of the 2 GHz MSS band for MSS. • Another confidential respondent said that it did not believe there was sufficient justification to continue with support for 2700 MHz as a potential WRC-15 candidate. • A confidential respondent said that Ofcom should not support international moves to change assignment of 3.8–4.2 GHz. GVF and ESOA also felt that 3.6–3.8 GHz, 3.8 GHz–4.2 GHz and 5725–5925 MHz should not be supported. 	<p>We agree that international cooperation on spectrum management will remain critical to securing increased benefits from spectrum use in the UK and that the outcome of WRC-15 will be an important milestone in this regard.</p> <p>We will be publishing a consultation on WRC-15 which will provide stakeholders a further opportunity to contribute to our preparations for WRC-15.</p>

Annex 2

Glossary of terms

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
CBA	Cost-Benefit Analysis
CEPT	The European Conference of Postal and Telecommunications Administrations
Communications Act	The Communications Act 2003, which came into force in July 2003.
CPG PTD	CEPT Conference Preparatory Group Project Team D. CPG PTD is responsible for the European coordination for WRC-15 agenda items 1.1 (additional spectrum allocations to the mobile service) and 1.2 (use of the frequency band 694-790 MHz).
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.
DVB-T	Digital Video Broadcasting – Terrestrial. A standard for terrestrial transmission of digital television developed by the DVB consortium
DVB-T2	Digital Video Broadcasting – Terrestrial 2. The latest digital terrestrial transmission technology developed by the DVB consortium.
eMBMS	Evolved Multimedia Broadcast Multicast Service is the multicast standard for Long Term Evolution (LTE) that allows multimedia content to be sent once and received by many end users.
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.
FS	Fixed Service
FSS	Fixed Satellite Service
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.
IPTV	Internet Protocol television. The term used for television and/or video signals that are delivered to subscribers or viewers using internet protocol (IP), the technology that is also used to access the internet. Typically used in the context of streamed linear and on-demand content, but also sometimes for downloaded video clips
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.
ITU-R	International Telecommunications Union Radiocommunication Sector
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
MBMS	Multimedia Broadcast Multicast Services refers a point to multi point interface specification in the 3GPP standards for efficient delivery of broadcast services e.g. TV, radio, data
MHz	Megahertz - A unit of frequency of one million cycles per second.
MNO	Mobile Network Operator
Multiplex	In digital TV broadcasting, a single signal which contains, when decoded, multiple discrete streams of digital information (including video and audio streams). Individual components of the multiplex are decoded at the receiver in order to present the desired TV service to the viewer.
PMSE	Programme-Making and Special Events. Radio applications that support a wide range of activities in entertainment, broadcasting, news gathering and community events.
PPDR	Public Protection and Disaster Relief. Includes emergency services such as the fire brigade and police.
PSSRP	Public sector spectrum release programme
QoS	Quality of Service is the overall performance of a telephone or data network, particularly the performance seen by the users of the network.
RF	Radio frequency
RSGP	Radio Spectrum Policy Group - High-level advisory group that assists the European Commission in the development of radio spectrum policy.
RSPP	The Radio Spectrum Policy Programme defines the roadmap for how Europe can translate political priorities into strategic policy objectives for radio spectrum use.
SDL	Supplemental Downlink
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.