The future role of spectrum sharing for mobile and wireless data services

Licensed sharing, Wi-Fi, and dynamic spectrum access

Statement

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Contents

About this document

This document sets out the steps that Ofcom intends to take to help spectrum sharing play a complementary role alongside dedicated spectrum bands in meeting the significant growth in demand for mobile and wireless data.

It identifies three key areas where spectrum sharing can play an important role in delivering future benefits to citizens and consumers. These are:

- For indoor use: ensuring that Wi-Fi based on shared spectrum can continue to provide high speed wireless network connectivity
- For outdoor use: increasing access to spectrum for use in a growing number of small mobile broadband cells
- For internet of things use: helping provide the spectrum needed to support innovation in services requiring wireless interconnections between devices

Previously, the benefits of spectrum sharing have been constrained by the difficulty associated with managing interference between different users. This document also examines whether the emergence of new developments in technology could change this by providing more intelligent and efficient ways of sharing spectrum.

Section 1

Executive summary

1.1 In August 2013 we published a consultation and technical research studies which explored the potential role that spectrum accessed on a shared basis could play in meeting the significant growth in demand for mobile broadband and wireless data capacity[1].

1.2 Based on stakeholder responses and our own analysis, we have identified three key areas where spectrum sharing can play an important role in delivering future benefits to citizens and consumers:

- *For indoor use*: ensuring that Wi-Fi based on shared spectrum can continue to provide high speed wireless network connectivity, so that consumers can fully benefit from the increasing availability of superfast broadband;
- *For outdoor use*: increasing access to spectrum for use in a growing number of small mobile broadband cells, which we anticipate will be deployed to help meet the growth in demand for mobile data capacity driven by the increasing use of smartphones and tablet PCs; and
- *For internet of things (IoT) use*: helping provide the spectrum needed to support growth and innovation in the emerging IoT sector, which is set to see hundreds of millions of devices become wirelessly interconnected by the end of the decade. These new services have the potential to provide benefits across a wide range of sectors, including healthcare, energy distribution, transport and agriculture.

1.3 In addition, our Spectrum Management Strategy, also published today, sets out the wider important role that spectrum sharing is set to play in helping meet the future competing demands for spectrum across a broad range of sectors and applications[2].

Spectrum sharing can provide important complementary benefits to dedicated spectrum

1.4 Spectrum is a scarce and valuable resource which is subject to demand from a wide range of wireless services including mobile broadband, broadcasting, programme making and special events (PMSE), satellite, radar, emergency services, military and the IoT. Some of these sectors already share spectrum, such as PMSE services which share spectrum on a geographic basis in the UHF TV bands.

1.5 Much of the spectrum in use today has been allocated on dedicated basis. This has the advantage that it makes it easier for services to operate at higher power without causing inference, enabling wide area coverage to be achieved with a good quality of service. However, as the demand for spectrum grows from an expanding range of wireless services, it is becoming increasingly difficult to accommodate new services in their own dedicated spectrum bands.

1.6 An alternative approach is to share spectrum between different users. Spectrum accessed on a shared basis can provide a complementary approach to the use of

[1] http://stakeholders.ofcom.org.uk/consultations/spectrum-sharing/
[2] http://stakeholders.ofcom.org.uk/consultations/spectrum-management-strategy/statement/

dedicated spectrum bands. Sharing can occur geographically, where spectrum is unused in a particular location, or on a temporal basis, where spectrum is only being used at certain times. Under both approaches, the same spectrum band is accessed by more than one service, which can provide a number of benefits:

1.6.1 It can increase access to spectrum for use by new services;

1.6.2 It can reduce barriers to spectrum access, acting as enabler for growth and innovation in new wireless services; and

1.6.3 It can allow consumers and businesses to more easily access spectrum and deploy their own wireless infrastructure where it is needed.

1.7 The focus of this document is on the role that spectrum accessed on a shared basis, either authorised on a licensed or licence exempt basis, can play to meet demand from mobile and wireless data services. In particular this is considered in the context of related advances in dynamic spectrum access technologies that can support a better sharing of spectrum between different spectrum users.

Advances in technology are increasing the benefits that spectrum sharing can provide

1.8 Spectrum sharing is not a new concept and is already used in a number of different forms, for example, sharing by licensed PMSE services in the UHF TV bands and by licence exempt Wi-Fi devices in the 2.4 and 5GHz bands.

1.9 Previously, the benefits of spectrum sharing have been constrained by the difficulty associated with managing interference between services, which can limit the overall range and quality of service that can be achieved.

1.10 We are currently facing a significant challenge to meet the rapid growth in demand for mobile and wireless data. However, new developments in technology are emerging which have the potential to enable more intelligent and efficient ways of sharing spectrum. These include:

- **Geolocation database technologies** are making it easier for devices to identify spectrum that is available for sharing while protecting the operation of existing services. This will be an important enabler for access to shared spectrum. While the current focus is on the use of databases to manage access to TV white spaces (i.e. within the frequency range 470 – 790MHz), the fundamental principle is not frequency specific. The database concept could be extended to manage access to spectrum across a broader range of frequencies. This could enable a tiered access model, where licensed and licence exempt use could be permitted in the same band to meet the needs of different spectrum users.

- **Dynamic Spectrum Access** (DSA) technologies are enabling devices sharing the same spectrum band to dynamically select a frequency and/or time slot to use to avoid causing interference to other nearby devices. Devices can gather the information needed to avoid causing interference using approaches including:

  - Database control: an extension of the geolocation database approach to provide devices with information on not only what spectrum is available, but also on how spectrum can be used to prevent interference to other devices; and

- o <u>Sensing</u>: here devices detect and avoid using the radio frequencies emitted by other devices.

1.11 Responses to our consultation indicated that there was strong support for the use of these technologies, to both increase access to spectrum by extending the geolocation approach to other frequency bands and support better sharing using DSA approaches. In addition, stakeholders identified the opportunity to extend their use to enable tiered access to spectrum to better meet the needs of different spectrum users.

Spectrum sharing will play an important role in delivering benefits to citizens and consumers in three key areas

1.12 We have identified three key areas where spectrum sharing will play an important role in delivering benefits to citizens and consumers:

1.12.1 Providing high speed indoor wireless connectivity using Wi-Fi;

1.12.2 Meeting the increased demand for spectrum for use in small outdoor cells; and

1.12.3 Helping meet the future demand for spectrum by Internet of things (IoT) and machine-to-machine (M2M) applications.

Indoor wireless connectivity

1.13 The complementary role shared spectrum can play in making additional spectrum available for wireless broadband use is being clearly demonstrated by the increasing use of the 2.4 and 5GHz bands by Wi-Fi.

1.14 In addition to helping provide additional capacity in high demand locations, Wi-Fi's licence exempt use of shared spectrum, which has been adopted on a global basis, has delivered some additional benefits. These include:

1.14.1 Creating very large economies of scale and lower prices for Wi-Fi enabled consumer equipment;

1.14.2 Reducing barriers to spectrum access and enabling innovation in Wi-Fi services and equipment across a wide range of different industry sectors; and

1.14.3 Enabling end users to install their own Wi-Fi network infrastructure where it is needed, which they can then use at low incremental cost.

1.15 Wi-Fi has become the preferred means of extending fixed broadband connections to internet enabled devices in the home and is used in over 89% of all broadband connected households.

1.16 As the speed of fixed broadband connections has progressively increased over the last decade, newer generations of Wi-Fi standards and equipment have been developed to support these higher speeds. Without these complementary increases in Wi-Fi speeds, the indoor Wi-Fi distribution network could become a *hold-up factor* to the wider benefits that could be delivered through the rollout of higher speed fixed broadband infrastructure. This is because:

1.16.1 Higher speed services delivered to UK households and businesses over superfast broadband could not be supported by indoor Wi-Fi networks; and

1.16.2 There is currently no substitute technology to Wi-Fi in providing high speed multi-room wireless connectivity. For example, the new WiGig standard and emerging Li-Fi technologies are limited to single room operation.

1.17 One way to provide faster Wi-Fi connections is to use wider frequency channels. Additional contiguous spectrum is likely to be needed to accommodate these wider channels and prevent interference occurring between adjacent households. To help meet this demand a potential extension of the 5 GHz licence exempt band used by Wi-Fi will be discussed in preparation for the forthcoming World Radiocommunication Conference in 2015 (WRC15).

1.18 However, there are important services currently operating in the 5GHz band which also provide significant benefits for society. For example, we are aware of the value of the remote sensing services and applications used by the space science industry in the 5350 – 5470MHz band. We are also aware of the concerns of these stakeholders that their services should be protected from interference. Therefore, we have to balance the need for increased spectrum for Wi-Fi against the risk of existing users, including the space science industry, experiencing harmful interference as a result of extending this band for licence exempt use.

1.19 Given the balance between the benefits that an extension of the 5GHz band for Wi-Fi use could provide and the risk that an extension could undermine the benefits provided by existing spectrum users, we will continue to undertake detailed technical co-existence studies.

Outdoor wireless connectivity

1.20 Wi-Fi connectivity is increasingly being used outdoors by small cells on a licence exempt basis to help meet high concentrations of demand for mobile broadband capacity. This is set to increase further with developments such as Passpoint, which will allow mobile users to more easily connect to Wi-Fi hot spots and seamlessly roam between them.

1.21 However, as Wi-Fi use continues to increase there is a risk of a tragedy of the commons occurring, where increasing numbers of Wi-Fi users and devices at a given location cause a reduction in the quality service and throughput that can be achieved. This is because interference is harder to manage outdoors, in particular between Wi-Fi hotspots deployed by different providers. The problem may be averted by future technology improvements, although some additional steps may be required to better manage how Wi-Fi uses spectrum outdoors.

1.22 Given the increasing consumer benefits of outdoor Wi-Fi coverage and the risk of a future tragedy of the commons occurring, Ofcom will continue to monitor levels of Wi-Fi use and congestion to provide an early indication of whether industry led improvements in Wi-Fi access technologies and standards are likely to be sufficient.

1.23 The use of mobile data over both public and private networks is set to see significant growth over the next ten years and there is a growing consumer expectation that mobile and wireless connectivity will become increasingly accessible everywhere. One particularly attractive potential use of shared spectrum is for low power smaller sized cells in areas of concentrated demand in cities and towns alongside cleared spectrum. Small cells reduce the number of users accessing the spectrum available in each cell, effectively increasing the capacity available to each user. The reduced coverage range also makes it easier to manage interference with other small cells sharing access to the same spectrum band.

1.24 Our complementary Mobile Data Strategy is assessing the long-term options to support the anticipated future growth in mobile data use. The bands under consideration for that strategy include some which could also be made available on a shared basis in the future.

1.25 Stakeholder responses identified that only new spectrum sharing opportunities in frequency bands which meet the following criteria are likely to be attractive for mobile broadband use:

1.25.1 They should be internationally harmonised or have a realistic prospect of harmonisation in short-medium term;

1.25.2 Sharing on a geographical or temporal basis should be feasible with existing users; and

1.25.3 The frequency and propagation characteristics of the spectrum band should be favourable for use by mobile broadband

1.26 Based on these requirements, many stakeholders identified that the part of the 2.3GHz band that will be not be fully cleared by Government users represented the most attractive band for shared access, in particular for use by small cells. In particular, respondents highlighted the importance of current European Commission activities aimed at enabling Licensed Shared Access (LSA) in the 2.3GHz band on a pan-European basis.

1.27 The 2.3GHz band is currently in a period of transition, while government users redeploy their equipment to other frequencies, and it is not currently possible to accurately determine whether sharing is possible. However, given the level of stakeholder interest and the potential for benefits from access to harmonised spectrum, we think this will be a key band to consider for sharing in the longer term. We therefore intend to work with the various public sector bodies to better understand current usage and the potential for future sharing opportunities.

Internet of Things and M2M

1.28 The number of wireless machine-to-machine (M2M) connections in the UK is predicted to rise from 30m today to more than 360m by 2022[3]. These connections are expected to span a wide range of sectors that will form the Internet of Things (IoT), including intelligent buildings, utilities, automotive, healthcare, consumer electronics and many more.

1.29 The benefits that these IoT connections could provide are potentially significant. For example, the more efficient management of energy supplies and public transport systems, or better monitoring of patients at home after they have left hospital.

1.30 Many IoT applications require the transmission of only a small amount of data over relatively short distances on an infrequent basis making them well suited to a shared

[3] "M2M Application Characteristics and Their Implications for Spectrum", technical study by Aegis and Machina Research, April 2014, http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2014/M2MSpectrum

spectrum approach. This approach is already being pursued in the 870-876MHz and 915-921 MHz bands to support smart metering and other applications.

1.31 Stakeholder responses to our consultation also highlighted the need for access to additional lower frequency narrowband spectrum below 1 GHz to provide wider area coverage using low transmitted power levels. We have already commissioned some technical work to inform our understanding of spectrum requirements and will undertake further studies as we develop our broader thinking on the IoT. Given the potentially significant benefits M2M and IoT developments can provide, we will continue to pro-actively explore new spectrum sharing opportunities to support further growth and innovation in this sector.

We will take steps to encourage the wider use of spectrum sharing in these areas

1.32 Stakeholder responses to our consultation highlighted the important future role that spectrum accessed on a shared basis could play in the mobile, Wi-Fi and Internet of Things sectors by increasing access to spectrum and enabling innovation in new services by reducing barriers to spectrum access. In this statement we identify a number of steps based on our current analysis and understanding that we now intend to take to support the wider use of shared spectrum in these sectors and help secure the benefits it can deliver. These include:

1.32.1 We will undertake further technical studies into the risk that a future extension of the 5GHz band for licence exempt Wi-Fi use could cause new co-existence issues with existing users, to inform our international activities;

1.32.2 We will continue to periodically monitor spectrum usage by Wi-Fi devices to provide an early warning of potential congestion;

1.32.3 We will investigate further the feasibility of making new shared spectrum bands available for mobile broadband use, including the retained parts of the 2.3GHz band, based on a better understanding of existing users' requirements;

1.32.4 We will investigate further the feasibility of making additional narrowband shared spectrum available below 1GHz to help meet the spectrum requirements for the emerging IoT sector; and

1.32.5 We will seek to extend the application of the geolocation database approach beyond TV white spaces and consider enabling tiered spectrum access.

1.32.6 We will also introduce a pilot of measures to pre-agree arrangements for research and development access for bands of particular interest for innovation. As part of this work we are investigating the feasibility and benefits of using an online system to manage such requests for access.

Section 2

Introduction and document structure

Overview

2.1 Enabling different users to share access to the same frequency band can deliver three important benefits:

2.1.1 It can extend spectrum access to a wider range of services;

2.1.2 It can increase spectrum efficiency by allowing spectrum to be more fully utilised; and

2.1.3 It can reduce barriers to spectrum access, which can act as an enabler for innovation in new wireless services.

2.2 Spectrum sharing is not a new concept and is already used, for example, to provide:

2.2.1 Licensed spectrum for PMSE services on a shared geographical basis in the UHF TV bands; and

2.2.2 Licence Exempt (LE) spectrum for Wi-Fi use in the 2.4 and 5GHz bands.

2.3 Previously, the benefits provided by spectrum sharing have been limited by the difficulty associated with managing interference between different users than with a dedicated spectrum band. This can constrain the range and quality of service that can be achieved. Two key advances in technology are allowing this to be addressed which is extending the benefits that spectrum sharing can provide. These include:

2.3.1 *Geo-location database technology:* this can make it easier for devices to identify spectrum that can be accessed on a shared basis in a given location without causing interference to other spectrum users. This approach is being used to enable white space access to the UHF TV bands and can also be applied in other frequency bands; and

2.3.2 *Dynamic spectrum access (DSA) technology:* this can allow devices sharing spectrum to identify the presence of other devices operating in their vicinity so they can avoid causing interference to them. At a simple level, this approach is already used by some Wi-Fi equipment to help select the least congested frequencies.

2.4 These advances in technology are driving an increased level of interest in the wider and more extensive use of spectrum sharing, both to help support innovation in new services and meet future demands for spectrum from a growing number of wireless services. This interest is particularly strong in the mobile and wireless data sectors because:

2.4.1 *There is a demand for more spectrum, some of which could be provided by spectrum sharing*: the consumer demand for mobile and wireless indoor data capacity is growing rapidly, and for these services to be accessible in all locations. This is placing an increasing demand for spectrum for use in combination with other capacity and coverage enhancing techniques.

2.4.2 *Wi-Fi is already playing an important role*: shared spectrum access in the 2.4 and 5 GHz bands is demonstrating the important role that spectrum sharing is able play in these sectors. For example, Wi-Fi is being extensively used to provide high speed indoor wireless connections and is also used in an increasing number of outdoor Wi-Fi hot spots;

2.4.3 *There is significant scope for innovation in new services such as the Internet of Things (IoT)*: the reduced barriers to spectrum access that spectrum sharing is able to provide could play an important role in enabling cross-sector innovation in new wireless services such as the IoT; and

2.4.4 *Heterogeneous networks*: networks operating with dedicated spectrum such as mobile networks are being combined with networks operating with shared spectrum such as Wi-Fi. For example, the Passpoint standard aims to simplify roaming between mobile and Wi-Fi networks[4].

2.5 The factors listed above are driving an increasing level of international interest in the use of spectrum sharing in the mobile broadband and wireless data sectors:

2.5.1 *In Europe:* A Licensed Shared Access (LSA) approach is being considered to enable mobile broadband services to share access with incumbent spectrum users, with a particular focus on using this approach in the 2.3GHz band;

2.5.2 *In the US:* The Federal Communications Commission is taking steps to enable shared access to the 3.5GHz military band for use by small cells.

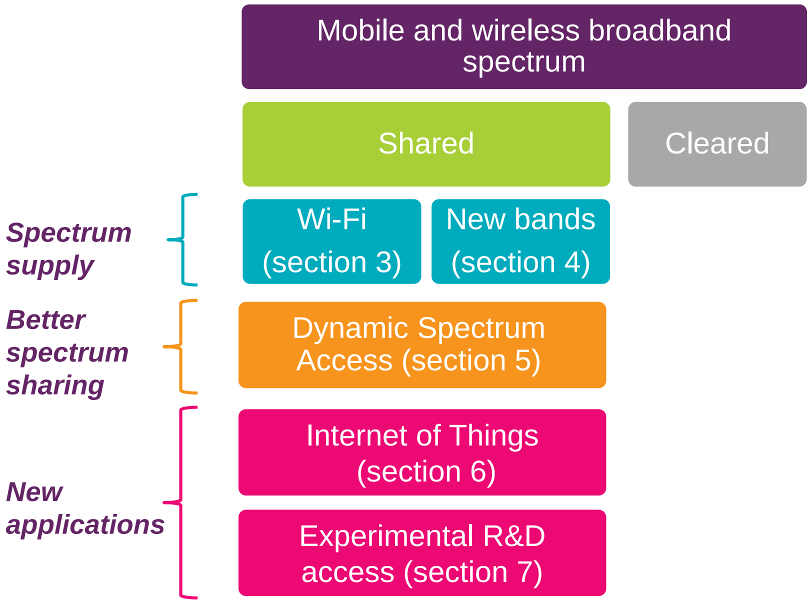
2.5.3 *At the World Radiocommunication Conference 2015:* A potential extension of the 5GHz licence exempt band used by Wi-Fi may be considered.

2.6 Given these developments this statement sets out, based on consultation responses and our own analysis, the steps Ofcom intends to take to help enable spectrum sharing to play a greater future role in the indoor wireless and mobile data sectors. It is envisaged that many of these steps will also help support the wider adoption of spectrum sharing to meet the demand for spectrum in other sectors.

2.7 Figure 1 provides an overview of the structure of this document.

[4] http://www.wi-fi.org/discover-wi-fi/wi-fi-certified-passpoint

Figure 1: Overview of statement sections



2.8 **Section 3** considers the future role that spectrum sharing in the 2.4 and 5GHz bands could play in meeting the future demand for mobile and indoor wireless capacity. It identifies that more contiguous spectrum in the 5GHz band is likely to be needed if indoor Wi-Fi networks are to support future connection speeds that match those provided by fixed superfast broadband networks. It also identifies a need to balance any benefits to Wi-Fi that a future extension of the 5GHz band could provide against a risk of this causing significant harmful interference to other spectrum users such as satellite systems. Given this, we set out Ofcom's intention to commission further technical research to better understand any new co-existence issues that could be created by an extension of the 5GHz band for Wi-Fi use.

2.9 **Section 4** considers the role that spectrum sharing could play alongside new cleared spectrum bands in providing additional spectrum to help meet the increasing demand for mobile data capacity. It identifies that spectrum sharing is likely to have greatest utility in smaller sized cells deployed in indoor locations and areas of concentrated demand in cities and towns.

2.10 It also identifies, based on consultation responses, the characteristics that any new shared spectrum band would most likely need to meet in order to be attractive for mobile broadband and indoor wireless use. These place requirements for new shared spectrum bands that are: below 6 GHz, internationally harmonised for mobile broadband use, and can be easily used without causing interference to other spectrum users. Given these requirements many respondents identified the parts of public sector bands that will not be fully cleared, such as the 2.3GHz band, as leading candidates for spectrum sharing for small cell applications. In section 4 we set out Ofcom's intention to explore the feasibility of spectrum sharing in these bands based on a fuller understanding of the current existing spectrum users' needs.

2.11 **Section 5** considers the role that advances DSA technologies could play in increasing the future benefits spectrum sharing can provide. In particular it explores the role that DSA might play in:

2.11.1 Reducing interference between an increasing number of outdoor Wi-Fi hotspots;

2.11.2 Improving the quality of service that can be achieved in shared spectrum bands; and

2.11.3 Enabling tiered access to shared spectrum bands to best meet the needs of different services.

2.12 This section also identifies a need to ensure that the current regulatory framework does not present a barrier to realising the benefits that DSA can provide.

2.13 **Section 6** considers the role that spectrum sharing could play both increasing the supply of spectrum for the emerging IoT sector and reducing barriers to spectrum access to encourage cross sector innovation by large and small scale players.

2.14 There are likely to be a very wide range of different IoT applications spanning different industry sectors including for example: agriculture, energy, transport, medical and home automation. These are likely to have a wide range of different spectrum access requirements in terms of range, throughput, quality of service etc. However, it is also likely that the requirements of many IoT services can be met in shared spectrum bands, in particular those services requiring only small amounts of data to be transmitted on an infrequent basis.

2.15 For example the 870 - 876MHz band is being made available on a LE basis for use by low duty cycle applications such as smart metering and we plan to actively explore further the requirement for complementary shared licensing approaches and frequency bands to support further growth and innovation in IoT services.

2.16 Finally, **section 7** considers the role that faster short term access to spectrum for R&D purposes could play in supporting growth and innovation in the mobile, wireless and IoT sectors. Here we set out our intention to establish a pilot giving access to a limited number of spectrum bands through an online database to develop a better understanding of the benefits such an approach could provide.

The demand for mobile data capacity and coverage is increasing

2.17 As the use of mobile devices becomes an increasingly important part of our everyday lives, it is creating an increasing demand for mobile capacity and coverage. In addition, the increasing penetration and use of larger screen smartphones to access high capacity data and video services is placing an increasing demand on the capacity of mobile networks.

2.18 Meeting these increasing capacity and coverage requirements is likely to deliver significant future benefits by:

2.18.1 Providing consumers with access to a wider range of high capacity mobile video and data services;

2.18.2 Enabling the UK’s communications infrastructure to support wider growth and innovation in the economy.

2.19 There is a range of capacity enhancing techniques that can be adopted by mobile broadband network operators, including the use of:

2.19.1 *More spectrum:* here more spectrum is used at existing mobile sites to increase their capacity. The use of lower frequency spectrum below 1GHz is beneficial in increasing coverage in difficult to reach indoor and outdoor locations whilst relatively plentiful higher frequency spectrum above 1 GHz is beneficial in increasing capacity in high demand locations;

2.19.2 *Smaller sized cells:* here smaller sized cells are used to reduce the number of mobile users accessing the capacity of each cell. This allows more capacity to be made available to each user. A drawback of this approach is that it requires the deployment of new mobile sites;

2.19.3 *More efficient mobile technology:* here more efficient mobile technologies such as LTE are used at existing sites to increase their capacity; and

2.19.4 *Offloading of mobile capacity onto Wi-Fi:* here some mobile data connections are made using a Wi-Fi hot spot as opposed to a connection to mobile network. This can reduce the demand for mobile network capacity in high demand indoor locations such as homes, offices and shops as well as locations outdoors, such as tourist destinations and railway stations. However, because Wi-Fi has limited range it cannot be used throughout the whole of the mobile coverage area. Wi-Fi also uses limited spectrum resources creating a risk that it too could become capacity constrained as demand increases.

2.20 Research commissioned by Ofcom has identified that it is likely that all of these approaches will need to be used in combination to cost effectively meet the future demand for mobile data capacity[5].

The demand for indoor wireless data capacity is also increasing

2.21 There is also an increasing demand for indoor wireless connectivity beyond that needed by smartphones. This is being used to wirelessly distribute services delivered over fixed broadband around homes and other commercial buildings. This connectivity is being provided by Wi-Fi operating in the 2.4 and 5GHz bands in an increasing number of homes, as can be seen in Figure 2.

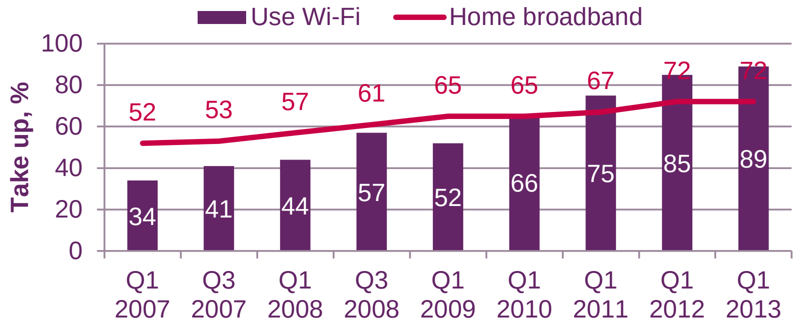
2.22 The demand for higher speed increased capacity indoor Wi-Fi connectivity is being driven by a number of factors including:

2.22.1 The rollout of superfast broadband which is placing an increasing demand for higher speed indoor wireless connections. Whilst new Wi-Fi standards are being developed to provide these higher speeds, they are providing only modest improvements in transmission efficiency. This means that wider channels will be needed to support these higher speed Wi-Fi connections; and

2.22.2 The integration of Wi-Fi in an expanding range of consumer equipment including PCs, printers, TVs, radios, games consoles, tablets and the increasing use of these devices.

[5] "Techniques for increasing the capacity of wireless broadband networks: UK, 2012 – 2030", technical study for Ofcom, http://www.ofcom.org.uk/static/uhf/real-wireless-report.pdf

Figure 2: Home broadband take-up and Wi-Fi router use, 2007-2013



Source: Ofcom Communications Market Report 2013

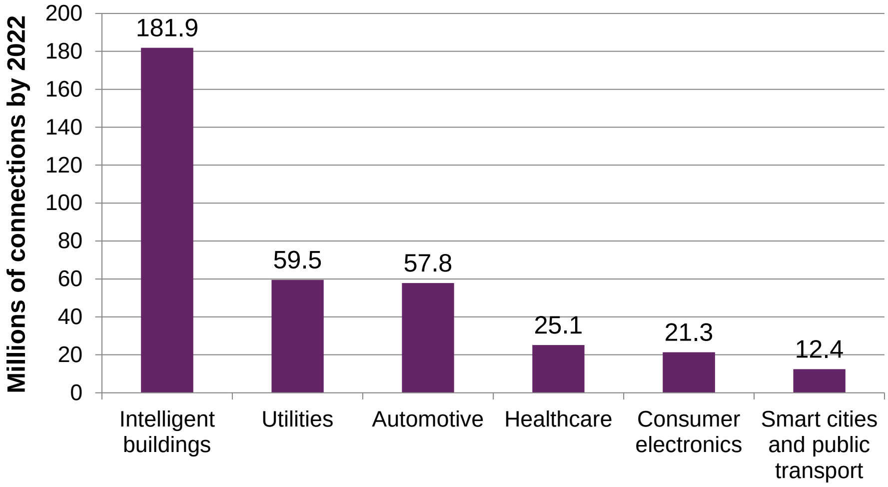
2.23 Wi-Fi operates on a LE basis and research conducted by Ofcom indicates that more spectrum will be needed by 2020 to support the demand for higher speed Wi-Fi connectivity[6]. Research also indicated that additional steps beyond more spectrum, such as improved spectrum sharing access protocols, may be needed to prevent this occurring for outdoor hot spot use in high demand locations[7] [8]. This is because, for outdoor applications, building walls cannot be relied upon to provide some isolation between different Wi-Fi devices.

There is also new demand for emerging services such as the IoT

2.24 The IoT is an emerging area and the range of possible applications is large and growing. One recent study[9] estimated that the number of IoT connections across a range of sectors could grow to over 360 million by 2022, as illustrated in Figure 3. IoT applications are likely to have different characteristics to conventional mobile or wireless broadband applications. Some of these characteristics, such as the need to transmit only small amounts of data at specific locations or at certain times, could make IoT applications particularly suited to delivery using shared access to spectrum.

[6] “Study on the future UK spectrum demand for terrestrial mobile broadband applications”, available at http://stakeholders.ofcom.org.uk/binaries/consultations/cfi-mobile-bb/annexes/RW_report.pdf
[7] “Study on the use of Wi-Fi for Metropolitan Area Applications”, August 2013, available at http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2013/wifi-met-area/
[8] “Technologies and approaches for meeting the demand for wireless data using licence exempt spectrum”, August 2013, available at http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2013/demand-wireless/
[9] “M2M Application Characteristics and Their Implications for Spectrum”, technical study by Aegis and Machina Research, April 2014, http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2014/M2MSpectrum

Figure 3: Estimation of the number of IoT connections across a range of sectors by 2022



Source: Data from Aegis Systems/Machina Research for Ofcom

Technology evolution will facilitate the improved sharing of spectrum

2.25 Previously, the benefits of spectrum sharing have been constrained by the difficulty associated with managing interference between services, which can limit the overall range and quality of service that can be achieved. The projected increases in demand for mobile and wireless data are likely to pose a significant challenge.

2.26 However, new developments in technology are emerging which have the potential to enable more intelligent and efficient ways of sharing spectrum. This document sets out our position on the role that spectrum sharing can play in the mobile and wireless broadband sectors and outlines our next steps.

Section 3

Ensuring sufficient spectrum is available for use by Wi-Fi devices

3.1 The consumer use of W-Fi enabled devices continues to grow and is now playing a central role in both:

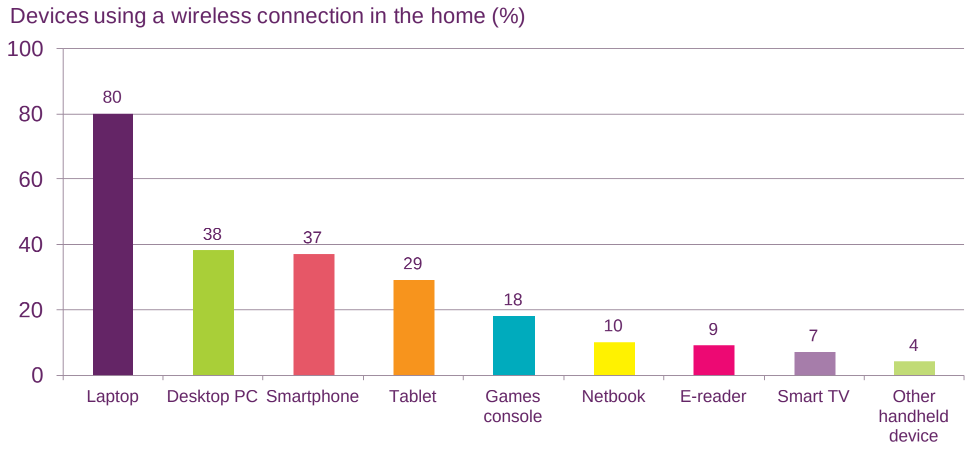
3.1.1 Connecting devices such as smartphones and tablet PCs to the internet in localised, high demand indoor and outdoor locations; and

3.1.2 Enabling consumers to install and use their own indoor networking solutions at zero incremental cost.

3.2 Wi-Fi[10] equipment operates in the 2.4 and 5GHz spectrum bands on a licence exempt basis. Exempting Wi-Fi equipment from licensing has reduced barriers to spectrum access, enabling use across a wide range of different industry sectors. This, coupled with the use of internationally-harmonised frequency bands, has created a platform for innovation similar to that of the internet, in which a diverse range of applications and devices benefit from connectivity with low access barriers.

3.3 Wi-Fi is also an example of how shared access to spectrum can generate significant benefits to citizens and consumers. In contrast to the frequency bands used by 3G or 4G mobile networks, which are dedicated to that single use, the bands used by Wi-Fi are shared by a number of different users and technologies.

Figure 4: Consumer use of wireless devices in the home, 2013



Source: Ofcom Technology Tracker, Q1 2013

3.4 Wi-Fi has evolved from a niche product for the professional market into a vital component of the UK's mobile broadband infrastructure, delivering high speed connectivity to consumers in homes, offices and outdoor hotspots. Wi-Fi has proved

[10] We use the term Wi-Fi to refer to the range of technologies detailed in the 802.11 standards prepared by the Institute of Electrical and Electronics Engineers (IEEE) and certified by the Wi-Fi Alliance.

to be a huge global market success, with estimated shipments[11] of over 1.5 billion Wi-Fi enabled devices during 2012 and over 9 billion in total since 2009. These very high volumes have reduced prices, enabling Wi-Fi functionality to be offered as standard in a growing range of consumer devices, as shown in Figure 4. The range of devices featuring Wi-Fi is likely to grow further in the future.

3.5 For consumers, the benefits of Wi-Fi can be linked to wider access to broadband services in the home and, in particular, to the increasing take-up of superfast broadband services. Wi-Fi enabled routers are frequently offered to consumers as part of their home broadband service, with 89% of homes with a broadband service making use of Wi-Fi[12]. Given the proliferation of wireless devices in the home, Wi-Fi has become a vital extension of the fixed line broadband service and the demand for higher speed indoor Wi-Fi connectivity is set to increase.

3.6 Over the past few years, significant public and private investment has underpinned the deployment of superfast broadband networks, which are expected to be available to around 95% of households by 2018[13]. Recent figures suggest that almost 18% of all broadband connections are now superfast[14] and it is predicted that this will grow to 51% by 2018[15]. Since the speed of every part of the internet distribution chain will need to support these speeds it will be vital for Wi-Fi to continue to match these increasing broadband speeds, if the benefits of investments in superfast broadband are to be delivered to consumers,

3.7 Successive generations of Wi-Fi standards have supported higher speed connections to match those provided higher speed broadband connectivity. The maximum theoretical speeds of successive Wi-Fi standards are shown in Figure 5; actual speeds achieved in real-world deployments will be lower, due to signal losses through walls and the need to share capacity with multiple users. The emerging Wi-Fi standard, known as 802.11ac, supports data rates well in excess of 100Mbps, through improved MIMO[16] support and operation in bandwidths of up to 160MHz.

[11] "Wireless Connectivity Chipsets Revenues to Exceed $10 Billion in 2012, Wi-Fi Chipsets Account for 40% of the Market", ABI Research, http://www.abiresearch.com/press/wireless-connectivity-chipsets-revenues-to-exceed-

[12] As of Q1 2013, from the Communications Market Report 2013, http://stakeholders.ofcom.org.uk/market-data-research/market-data/communications-market-reports/cmr13/

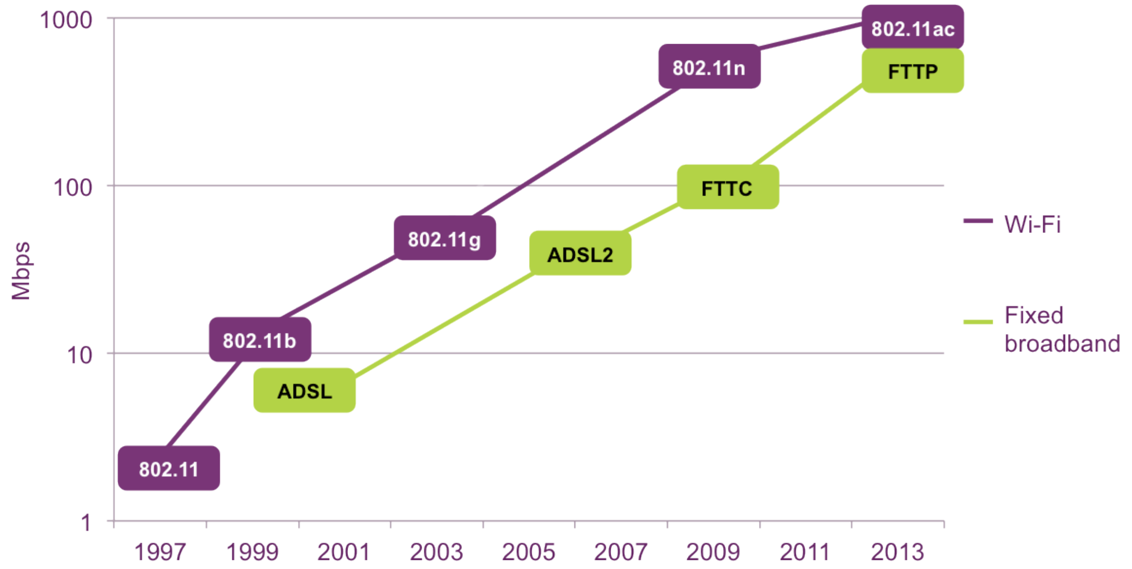
[13] "International benchmark of superfast broadband", Analysys Mason, Dec 2013, http://www.analysysmason.com/UK-broadband-2013

[14] As of Q1 2013, superfast broadband connections make up 17.5% of all broadband connections, from the Communications Market Report 2013.

[15] "International benchmark of superfast broadband", Analysys Mason, Dec 2013, http://www.analysysmason.com/UK-broadband-2013

[16] Multiple Input Multiple Output, or MIMO, refers to advanced antenna and signal processing techniques which allow more data to be sent in the same bandwidth.

Figure 5: Evolution of Wi-Fi standards compared to fixed broadband technologies



Source: Ofcom / Plum consulting

3.8 However, these enhancements can only help Wi-Fi keep pace with higher fixed broadband speeds provided there continues to be sufficient spectrum to support the wider channel bandwidths needed to provide high speed Wi-Fi connectivity throughout the home. In particular, support for broader bandwidths of 80 or 160MHz is likely to be important for achieving a combination of high data rates and good in-building coverage. This represents an increase in demand for spectrum over the 20 or 40MHz channels commonly used today and may lead to increased pressure for the supply of additional Wi-Fi spectrum.

3.9 The technologies that underpin Wi-Fi are designed to share spectrum politely and be robust to interference. However, as wider channel widths are used it becomes harder to ensure that Wi-Fi interference does not occur between households. Additional spectrum can help address this by increasing the number of channels that Wi-Fi can use in different households.

3.10 Alternative technologies which operate outside the 2.4 and 5GHz bands are emerging for high speed indoor wireless networking, including:

3.10.1 WiGig, which is a variant of Wi-Fi that operates at 60GHz, based on the IEEE802.11ad standard and;

3.10.2 Li-Fi, which is an emerging technology that uses visible light as opposed to radio frequencies.

3.11 These technologies are generally only suited for short-range, single room use and hence are not a direct substitute for Wi-Fi as they cannot provide coverage between rooms. Other home networking technologies are also available based on wired solutions. These include:

3.11.1 Ethernet cabling, which, whilst capable of supporting superfast broadband connection speeds, can be disruptive and expensive to install in existing buildings; and

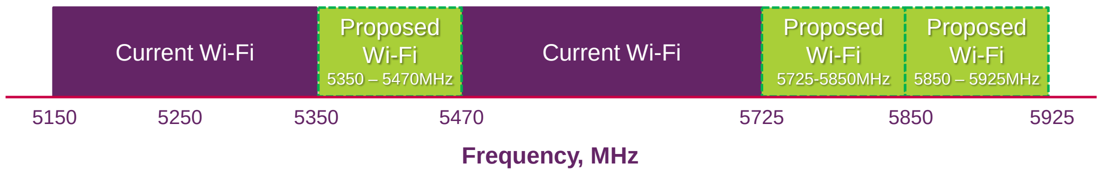
3.11.2 Powerline technology, which sends data over the existing electrical wiring within a building. Whilst this approach can theoretically provide connection speeds that match those provided by superfast broadband, speeds may be lower in practice and dependent on the quality, age and type of in-building wiring used.

3.12 In addition, these wired solutions would need to be attached to Wi-Fi access points to provide a connection to wireless devices. Given the limitations of other alternative wireless and wired in-home networking solutions, we are of the view that Wi-Fi is likely to be the only viable technology for providing high speed wireless connectivity throughout a home or other building for the foreseeable future.

Additional spectrum may be required to support future growth in the use of Wi-Fi indoors

3.13 There is insufficient bandwidth in the 2.4GHz band to accommodate the wide channel bandwidths required to support the emerging higher speed 802.11ac standard. As a result, 802.11ac equipment will only work in the 5GHz band. The current allocation of spectrum at 5GHz for Wi-Fi is illustrated in Figure 6, along with proposals to extend the Wi-Fi band, which are currently being considered as part of the preparation for the forthcoming World Radiocommunication Conference in 2015.

Figure 6: Current and proposed future allocation of 5GHz spectrum for Wi-Fi



3.14 The potential need for additional spectrum for Wi-Fi has been identified by a number of studies, both independently and conducted on behalf of Ofcom. One study[17] concluded that the full benefits of Wi-Fi would only be realised with additional spectrum, noting that, without this additional bandwidth, supported speeds may fall below the 100Mbps Digital Agenda for Europe target. Another study, commissioned by Ofcom[18], found that the current spectrum allocation for Wi-Fi at 2.4 and 5GHz is likely to be under pressure by 2020 and that additional spectrum may be required to continue to meet expected demand.

3.15 In our consultation we asked a number of questions intended to gauge views on likely future demand for spectrum for Wi-Fi devices. We summarise responses in the following sub-sections.

3.16 There was broad agreement from respondents that Wi-Fi is playing an important role in delivering services to citizens, consumers and businesses and that demand would continue to grow in the future. Many respondents noted that Wi-Fi was becoming integrated into a growing number and variety of devices, moving beyond its original use as an office networking technology.

3.17 Given the expected increase in Wi-Fi devices and the demand to support higher data rates to match those supplied by superfast broadband services, many stakeholders

[17] "Future proofing Wi-Fi – the case for more spectrum", Plum Consulting, January 2013, http://www.plumconsulting.co.uk/pdfs/Plum_Jan2013_Future_proofing_Wi-Fi.pdf
[18] "Study on the future UK spectrum demand for terrestrial mobile broadband applications", available at http://stakeholders.ofcom.org.uk/binaries/consultations/cfi-mobile-bb/annexes/RW_report.pdf

supported the need for additional spectrum for Wi-Fi. Several manufacturers of networking equipment noted the importance of proposals to increase the amount of spectrum available for Wi-Fi at 5GHz, as illustrated in Figure 6 above.

3.18 These respondents expressed a view that the proposed extensions will be necessary to create a single, contiguous band of spectrum, able to accommodate the wider bandwidths (i.e. 80 and 160MHz) required to achieve the highest data rates supported by the current Wi-Fi standard. This will be particularly important for indoor use of Wi-Fi, where the highest data rates are expected, driven by the continued take-up of networked laptops, smartphones, tablets and other multimedia devices.

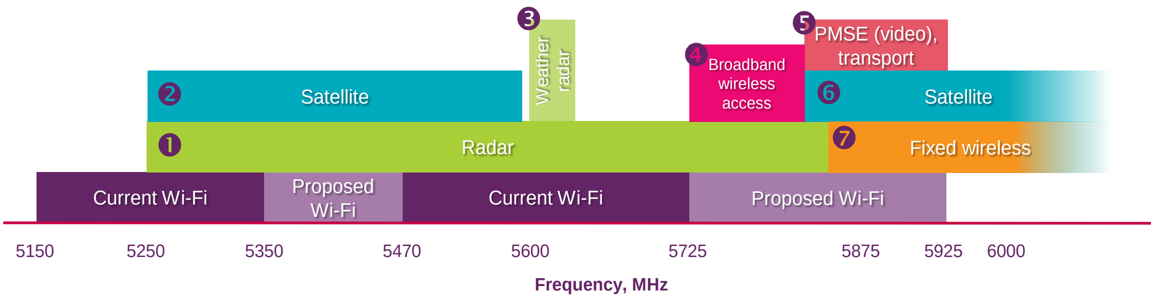
3.19 While there was broad agreement that demand for Wi-Fi will increase, several respondents sounded a more cautionary note. One respondent predicted that more Wi-Fi traffic will migrate from the 2.4GHz band to the 5GHz band, and that the case for additional spectrum at 5GHz was not yet proven. Others highlighted that the 5GHz band is shared between a number of users creating a risk of interference, as discussed in subsequent sections.

3.20 Some respondents noted the emergence of WiGig and Li-Fi technologies and suggested that these technologies will have an increasingly important role in the distribution of multimedia content within a single room, acting as a short-range complement to Wi-Fi.

Any allocation of additional spectrum for Wi-Fi needs to be balanced by the need to protect incumbent users

3.21 The 5GHz band is shared between a number of military and civilian users, including aeronautical and weather radar, earth exploration satellite services (EESS) and fixed satellite services. As shown in Figure 7 these users are spread over the whole of the 5GHz band, including within the current and potential future allocations for Wi-Fi.

Figure 7: Illustration of spectrum use 5-6 GHz



Use	Description
❶	MOD radar band
❷	Satellite-based transmission to measure ground-level (or below) features for mapping or scientific purposes
❸	Radar to predict heavy rainfall and flooding
❹	Light licensed use for CCTV or broadband access networks
❺	Licence exempt for video applications and intelligent transport systems
❻	Ground-to-satellite uplinks
❼	Wireless fixed links

3.22 The services are important and valuable and hence their continuing operation needs to be protected. Wi-Fi devices are currently allowed to operate in the 5GHz band on the basis that they do not cause interference to these services and various mitigation techniques have been employed to ensure coexistence.

3.23 Any future decision to extend the allocation for Wi-Fi at 5GHz will need to be taken internationally, given the importance of harmonisation to the international Wi-Fi equipment market, and will be subject to suitable coexistence measures continuing to be in place to protect incumbent services. Technical work is on-going to determine whether, and under what circumstances, sharing is possible in the proposed extension bands at 5GHz. Mitigation techniques may include:

3.23.1 *Dynamic frequency selection:* An access point listens for incumbent users and automatically selects a frequency that is not in use;

3.23.2 *Transmit power control:* Wi-Fi devices reduce their transmit power to the lowest level to maintain communication;

3.23.3 *Restriction to indoor use:* Transmission at particular frequencies may be restricted to indoor use, where the shielding afforded by walls, ceilings and roofs offers protection to incumbents that operate outdoors; and

3.23.4 *Geolocation database:* The database assigns transmit frequencies and powers to Wi-Fi equipment that have been calculated not to cause interference to incumbent users. This is a similar approach to that being developed for access to TV white spaces.

3.24 While noting the increasing demand for Wi-Fi, several respondents indicated that they did not support an increased allocation for Wi-Fi at 5GHz. These respondents typically operate equipment or use services in the 5GHz band and emphasised the need for protection from interference from increased use of Wi-Fi. Some of these services rely on detecting low level signals and many, such as EESS, have been subject to a significant level of investment, using equipment that cannot be easily modified once deployed.

3.25 As part of the preparations for World Radiocommunication Conference 2015 (WRC15) a number of technical studies have been undertaken to determine whether, and under what circumstances, Wi-Fi is able to coexist with incumbent services in the proposed extension at 5GHz. Our view is that technical studies are necessary to provide the evidence of whether Wi-Fi can operate in the proposed extension without causing harmful interference.

3.26 At the time of writing some of these studies are still on-going and we believe that it is too early to form a view on whether to support the proposed extension. In particular, we believe additional work is required to establish a more detailed view of the activity factor of Wi-Fi networks (i.e. how frequently, and for how long, their transmitters are active) and on the efficacy of mitigation techniques.

Other factors, in addition to more spectrum, may be important for outdoor use

3.27 As we noted in our consultation document, using Wi-Fi indoors effectively limits the amount of interference that can be caused to neighbouring spectrum users, as the signals are reduced or blocked by walls. When used outdoors, the Wi-Fi signals can travel further, increasing the possibility of interference between spectrum users and potentially reducing the performance of neighbouring Wi-Fi access points.

3.28 In addition to providing high speed wireless networks indoors, Wi-Fi is increasingly being used outdoors or in public spaces. This can be in the form of discrete hotspots or as a network of interconnected Wi-Fi access points to provide wider area coverage in for example shopping centres and sports stadia.

3.29 This type of Wi-Fi use is increasingly being used as a complement to wide area, cellular networks, providing low-cost or free connectivity in a range of public places. New Wi-Fi standards such as Passpoint are also making it easier to automatically connect to these networks and public Wi-Fi usage more than doubled last year to represent over 6% of total data traffic carried on wireless and mobile networks[19]. Many respondents noted the important role that Wi-Fi is playing in both supporting these services and in offloading data traffic that would otherwise need to be carried over cellular networks. One respondent (an operator of Wi-Fi networks) noted a pronounced increase in the number of devices capable of operating at 5GHz on their networks, indicating that this band will be increasingly important given the relatively congested nature of the 2.4GHz band.

3.30 While many respondents acknowledged the importance of additional spectrum in meeting demand for Wi-Fi use indoors, there were a number of views that additional steps beyond using more spectrum would be needed to support increased and enduring use of Wi-Fi outdoors. These steps included:

3.30.1 *Technical solutions – co-ordination:* Many large-scale deployments of Wi-Fi equipment, such as those in offices or stadia, are centrally managed to ensure interference between access points is avoided. At the simplest level, this involves planning of access point positions and frequencies. The Wi-Fi family of standards include provision for co-ordination between devices, yet many managed deployments rely on the use of equipment from a single vendor. Some respondents took the view that the more widespread adoption of management tools based on standardised protocols would lead to better performance of outdoor access points, as would improved co-ordination between network operators. There was a divergence of views, however, on the practical difficulties associated with achieving these improvements when equipment is sourced from multiple vendors.

3.30.2 *Technical solutions – efficiency:* A number of respondents expressed a view that new technologies would play a role in improving the performance of Wi-Fi outdoors. The Institute of Electrical and Electronic Engineers (IEEE), the organisation responsible for developing Wi-Fi standards, has recently announced the creation of a group to study ways in which to improve Wi-Fi performance in environments where there are large numbers of access points. The so-called 802.11 High Efficiency WLAN (HEW) study group is in the process of defining its scope, but it is likely to examine ways in which to improve the average data rate for a Wi-Fi device by up to 4 times, whilst maintaining or improving power efficiency. This work could lead to a new standard for Wi-Fi devices within 5 years, with equipment widely available early in the next decade. Widespread adoption of a more efficient variant of Wi-Fi may, in the longer term, help to offset the need for additional spectrum but it is too early to determine the impact of this.

[19] Ofcom Infrastructure Report: 2013 Update, October 2013, http://stakeholders.ofcom.org.uk/market-data-research/other/telecoms-research/broadband-speeds/infrastructure-report-2013/

3.30.3 *Restrictions on use:* An operator of Wi-Fi networks expressed a view that the additional allocation of spectrum at 5GHz would be necessary to meet the demand for outdoor, as well as indoor, use. To get the most efficient use out of this spectrum, the respondent noted the need for planning and co-ordination between Wi-Fi operators. They suggested that this could be facilitated by mandating that Wi-Fi equipment used outdoors or in public places should use channel bandwidths of no more than 40MHz. This would effectively increase the number of non-overlapping channels available for use, at the expense of limiting the maximum data rates achievable.

3.31 A number of respondents emphasised the need for detailed studies to understand the potential for interference into incumbent services operating in the proposed extended allocation at 5GHz band caused by outdoor use of Wi-Fi.

There is a need for further work to determine whether Wi-Fi could co-exist with other spectrum users in the proposed extension at 5GHz

3.32 We are aware that a number of technical studies have been undertaken to understand whether Wi-Fi could co-exist with other spectrum users in the proposed extended allocation at 5GHz (i.e. at 5350 – 5450MHz, 5725 – 5850MHz and 5850 – 5925MHz). We ourselves have undertaken studies to examine the future demand for spectrum for Wi-Fi services and, at the time of writing, are concluding a study on co-existence of Wi-Fi with other services. This study will be published on our website in due course.

3.33 At this stage, we believe that the evidence suggests that there is the **potential** for Wi-Fi to operate in the proposed extended allocation at 5GHz without causing interference to incumbent services, subject to certain mitigation approaches being in place. However, further, more detailed work is required before we can adopt a definite position on the matter. We believe that this approach is appropriate, given the importance and value of 5GHz spectrum for both Wi-Fi and the incumbent services.

Next steps

3.34 Based on the analysis set out above we intend to take the following steps to ensure that Wi-Fi can continue to share with the various services operating in the 5GHz band and can continue to deliver benefits to citizens and consumers:

3.34.1 We will periodically monitor spectrum usage by Wi-Fi devices, in particular in outdoor hot spot locations, to provide an early warning of potential congestion; and

3.34.2 We will explore the need for further technical studies into the risk that a future extension of the licence exempt allocation at 5GHz for Wi-Fi will cause new co-existence issues with existing users. This will be used to inform and develop a balanced position which recognises the interests of all stakeholders for the World Radiocommunication Conference in 2015.

Section 4

Extending sharing to other frequency bands for mobile broadband use

4.1 Many of the spectrum bands in use today have been allocated to specific users but are not always fully utilised at all locations all of the time. These gaps in spectrum usage can be potentially shared with other users to deliver additional services.

4.2 Spectrum sharing is not a new concept and is already being used, for example to support wireless microphone applications to exploit gaps in usage in the UHF TV bands. However, recent advances in technology, including geolocation databases, are extending the benefits that sharing can provide by both making it easier to identify spectrum available for sharing and allowing spectrum to be shared more efficiently between different users whilst minimising interference.

4.3 Our recent Spectrum Management Strategy identifies that spectrum sharing will become increasingly important as opportunities to clear spectrum become ever more challenging and as technical developments enable more efficient re-use of spectrum where and when it is really needed.

4.4 In our spectrum sharing consultation we identified the specific role that spectrum sharing might play in increasing the supply of spectrum for mobile broadband beyond that provided by cleared spectrum bands[20]. In particular, we highlighted how geographical sharing could be well suited to providing additional spectrum for use by small mobile broadband cells, which we anticipate will be increasingly deployed to improve the capacity and performance of mobile networks in high demand locations.

4.5 Spectrum made available on a shared basis is likely to provide a complement, as opposed to a replacement, for cleared mobile broadband spectrum. Whereas cleared spectrum can be co-ordinated and used at higher power to increase the capacity of wide area mobile broadband networks, geographically shared spectrum is more likely to need to be operated at lower power to minimise interference, lending itself more to use to provide localised increases in capacity.

4.6 As part of the spectrum sharing consultation we sought views on whether sharing spectrum on a geographical basis could be used to increase the overall supply of mobile broadband spectrum. This section summarises stakeholder responses on this issue and sets out our next steps for taking this work forwards.

Sharing will become increasingly important in the mobile data sector

4.7 Overall, respondents believed that spectrum sharing could play an important role in encouraging more efficient spectrum use and increasing the supply of spectrum for mobile broadband and other wireless services such as the Internet of Things (IoT). There was broad agreement that sharing in geographic areas or at times where spectrum would not otherwise be used will be an increasingly important tool in

[20] See Section 4, Spectrum sharing of mobile and wireless data services http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-sharing/summary/Spectrum_Sharing.pdf

enabling its efficient use. They also highlighted the benefit that shared access can bring in providing earlier access to additional spectrum for mobile broadband services compared to a fully cleared spectrum approach, because there is no need to displace existing spectrum users.

4.8 Many respondents also highlighted the increased flexibility that a shared spectrum approach can bring by providing different levels of tiered spectrum access to meet different user requirements in the same frequency band; a theme which is covered in more detail in Section 5 of this document.

The geolocation database approach should be extended to new shared spectrum bands

4.9 In our consultation we set out how advances in geolocation database technology are making it potentially easier to exploit spectrum sharing opportunities in existing frequency bands. Here a database holds information on the frequencies available for sharing in different locations, which is used by devices to select a suitable channel frequency and power to minimise the risk of causing harmful interference to the primary spectrum user(s). An important aspect of this approach is that it is not frequency dependent and can be applied in any frequency bands where geographic sharing is feasible.

4.10 Respondents acknowledged the importance of finalising our work on establishing access to TV white spaces through the geolocation database approach, to both:

4.10.1 Increase the supply of spectrum for new services in the highly sought after UHF spectrum bands; and

4.10.2 Establish an implementation framework for making spectrum available using a database approach which can then be extended to other frequency bands.

4.11 Indeed, many respondents highlighted that TV white spaces should be seen as the first step towards extending the geolocation approach to new shared frequency bands. It was suggested that this work should act as a proving ground for the geolocation concept and the associated technology and systems, which could then be applied in other bands in the future.

4.12 Respondents also called for Ofcom to work with industry to take a more proactive approach towards identifying other frequency bands where spectrum sharing could be enabled using a geolocation database approach.

Extension of the geolocation database approach beyond TV white spaces

4.13 In the UK, we are currently working to enable the first application of this geolocation approach in the digital terrestrial TV (DTT) UHF bands IV and V (470 – 790MHz). These spectrum bands have been licensed for use for DTT services and are also shared with programme making and special events (PMSE) services on a geographically licensed basis. However, the services do not make full use of all of the available frequencies in all locations. We are working with industry stakeholders to establish a number of geolocation databases which will hold information on these unused frequencies or white spaces.

4.14 We are currently focused on proving the geolocation database concept in TV white spaces, in particular ensuring that devices can identify the frequencies and power levels that can be used in their location to minimise the risk of causing harmful interference to licensed DTT and PMSE services.

4.15 Based on consultation responses, we propose to undertake work to explore the options for future extension of the geolocation database approach to other frequency bands to make additional spectrum available for mobile broadband use.

A range of factors determine the suitability and attractiveness of frequency bands for shared access

4.16 Our consultation sought views from stakeholders on the factors which might determine the attractiveness of a particular frequency band for providing geographical shared access.

4.17 When identifying the frequency bands most suitable for sharing, respondents identified a set of characteristics that new shared spectrum bands should exhibit, which broadly fell into the four categories listed below:

4.17.1 They should be internationally harmonised or have a realistic prospect of harmonisation in the short to medium term;

4.17.2 They cannot be fully cleared throughout the whole of the UK for the foreseeable future;

4.17.3 Sharing on a geographical or temporal basis should be feasible with incumbent users;

4.17.4 The frequency and propagation characteristics of the spectrum band should be favourable for use by mobile broadband

There is strong interest in access to shared spectrum for mobile broadband use in the 2.3GHz band

4.18 In terms of frequency bands that should be initially targeted for future spectrum sharing by mobile broadband services, there was strong stakeholder interest in spectrum sharing above 1GHz. Most respondents focused on the opportunity for sharing at 2.3GHz and a range of bands between 3.4-4.2 GHz which will not be fully cleared of their existing users.

4.19 Reponses to our consultation identified in particular the 2.3GHz band which forms part of the Government’s Public Sector Spectrum Release (PSSR) programme as the primary candidate for sharing on a geographic basis. Several respondents highlighted that this band would be well suited for use by small broadband cells, due to the amount of available bandwidth, the need for only relatively low power operation to achieve coverage, and that it is already harmonised for mobile broadband use in Europe with the future potential of it becoming globally harmonised. Some respondents specifically identified the retained part of the band, beyond the 40MHz currently considered for release under the Government PSSR programme, as presenting the most realistic and attractive opportunity for shared access.

4.20 There was widespread support for a Licensed Shared Access (LSA) approach[21], as currently envisaged by the European Commission. Broadly, the LSA concept aims to open up access to some spectrum bands held by Government authorities in different member states, such as that used by the military, where this spectrum cannot be fully cleared but not being used in all locations or at all times. Respondents highlighted in particular, work underway in the European Conference of Postal and Telecommunications Administrations (CEPT) to develop a regulatory framework enabling LSA in the 2.3GHz band. This approach was favoured on the basis that it could enable the band's efficient use through geographic or temporal sharing with limited disruption to existing users.

4.21 Although 2.3GHz was the primary area of interest, there was additional support for spectrum sharing within a range of bands between 3.4 - 4.2GHz, primarily to improve the capacity and performance of mobile networks in urban areas. Respondents cited a combination of relatively limited geographic use by incumbents and favourable propagation characteristics for dense, indoor use as advantages for these bands.

4.22 Respondents also expressed a strong interest for shared spectrum below 1GHz, primarily for emerging M2M applications, which is considered in more detail in Section 6.

New spectrum sharing opportunities need to take into account the feasibility of co-existence with existing users

4.23 Despite the strong interest in increasing opportunities for spectrum sharing, some respondents also noted the new co-existence issues this could create with existing services. Although many respondents supported the benefits of spectrum sharing in principle, some cautioned that sharing should not be conducted at the expense of disrupting the on-going viability of established existing services.

4.24 These respondents argued that Ofcom should only consider the application of spectrum sharing in frequency bands where there are clear benefits from shared access and there has been a full assessment of the impact on existing services.

We will investigate further opportunities for spectrum sharing, prioritising access to 2.3GHz for mobile broadband in urban areas

4.25 As set out above, stakeholder responses to our consultation identified 2.3GHz as the primary candidate for sharing on a geographic basis, noting a significant degree of interest within Europe for shared access to this band. Geographic sharing in 2.3GHz could be well suited to providing additional spectrum for the growing number of small cells that are likely to be deployed to improve the capacity and performance of mobile networks in urban areas. This is because these small cells are able to operate at low power, making it easier to protect incumbent spectrum users from interference and minimise interference between different operators.

4.26 The Ministry of Defence (MoD) is progressing plans to clear and release the upper 2.3GHz band (2350 - 2390MHz), which Ofcom will subsequently make available through an award. The MoD and other public sector users are therefore currently clearing their services from the upper 2.3GHz band, with the majority of these services redeployed into the lower 2.3GHz band. As a consequence, the band is in a

[21] Radio Spectrum Policy Group (RSPG) opinion on LSA, November 2013, https://circabc.europa.eu/d/d/workspace/SpacesStore/3958ecef-c25e-4e4f-8e3b-469d1db6bc07/RSPG13-538_RSPG-Opinion-on-LSA%20.pdf

period of transition and it is not currently possible to accurately determine whether sharing of the lower 2.3GHz band is possible.

4.27 However, for the reasons set out above, particularly related to the harmonisation of this band and availability of equipment, we think this will be a key band to consider for sharing in the longer term. We therefore intend to work with the various public sector bodies to better understand current usage and the potential for future sharing opportunities. We note that this band is extensively used (in addition to public sector users there is PMSE and amateur use) and detailed studies may be required to consider what shared use might be possible.

4.28 Beyond this, we will focus attention towards bands for where there are realistic opportunities for shared access, based upon a full consideration of the requirements of incumbent users.

Next steps

4.29 Overall, we will seek new opportunities for sharing where this is viable with existing users. Based on responses to our consultation and are own analysis, we now intend to:

4.29.1 Extend the geolocation database approach to other frequency bands beyond TV white spaces, where this is feasible and will deliver benefits to citizens and consumers; and

4.29.2 We will investigate further the feasibility of making new shared spectrum bands available for mobile broadband use, including the retained parts of the 2.3 GHz band, based on a better understanding of existing users' requirements.

Section 5

Developing better approaches to spectrum sharing

5.1 The sharing of spectrum by multiple devices, often by different services using different delivery technologies, is not a new concept. Examples of important and valuable services that currently use spectrum on a shared basis include:

5.1.1 **Wireless microphones:** The programme-making and special events (PMSE) community share the same frequency band as digital terrestrial television (DTT) broadcasts. PMSE equipment is authorised to operate on a location-specific basis, making use of frequencies that are unused by nearby DTT transmitters;

5.1.2 **Wi-Fi:** There are two frequency bands that are currently used by Wi-Fi equipment, at 2.4 and 5GHz, that are accessed on a shared, licence exempt (LE) basis. In addition these bands are also shared with other types of services; for example the 5GHz band is shared with military radar and earth exploration satellite systems.

5.2 Spectrum sharing has the potential to both:

5.2.1 Improve the efficiency of spectrum use, by increasing access to spectrum available for use by a wider range of services; and

5.2.2 Reduce barriers to spectrum access and act as an enabler for growth and innovation in new services.

5.3 Given these benefits an increased use of spectrum sharing was widely supported by stakeholder responses. However, the delivery of these benefits is contingent on shared use not causing interference that would not unduly impair the operation of incumbent spectrum users or new services sharing spectrum.

5.4 There are a number of technical approaches or protocols for accessing shared spectrum in a way that manages or avoids interference. At their simplest, they include varying the duty cycle to reduce the probability of two neighbouring devices transmitting at the same time. Some, more complex approaches are already being implemented by Wi-Fi equipment and include:

5.4.1 *Listen before talk:* Wi-Fi devices with data to send listen for the transmissions of other devices on the network. They only transmit if no other devices can be heard, reducing the chance of lost data through multiple devices transmitting at the same time; and

5.4.2 *Detect and avoid:* Wi-Fi access points listen for other users of spectrum, such as radar services, and, if found, they tune to another, clear frequency. A variant of this approach sees Wi-Fi access points select frequencies that are less used, or not used at all, by neighbouring access points. Detect and avoid approaches can therefore be used to both protect existing spectrum users and improve the performance of Wi-Fi networks.

5.5 Looking further ahead, technology developments will include the use of databases, sensing and more intelligent data processing to help devices decide which frequencies and time slots to use, based on a better understanding of other users use of the same spectrum band in their location. These approaches, and others that may be developed in the future, have the potential to improve the quality of service that can be provided by the different services sharing spectrum and are sometimes collectively referred to as Dynamic Spectrum Access (DSA) technologies.

5.6 This section summarises respondents' views on the development and use of these and other technologies and their potential role in supporting a better sharing of spectrum between different users. It also sets out our proposed next steps in this area.

Spectrum sharing on a licensed and LE basis can deliver different complementary benefits

5.7 Respondents expressed a range of views about the value and role of spectrum sharing. Broadly, the consensus was that increasing the amount of shared spectrum is desirable, provided co-existence is managed and interference is not caused to existing spectrum users.

5.8 Respondents generally recognised that where wide area coverage is required a licensed approach is preferable. This is because it can allow licensed users to co-ordinate the higher power use of the spectrum to achieve wider area coverage without causing harmful interference to other users as the details of the other spectrum users are known.

5.9 A number of equipment manufacturers and mobile operators noted a preference for a licensed approach in the form of Licensed Shared Access (LSA) where a frequency band cannot be fully cleared, as set out in section 4. More generally, several respondents noted that a licensed approach was preferable to licence exemption, citing the difficulty in retrospectively licencing access once an exemption regime is in place.

5.10 In contrast, where only low power, short range operation is feasible, a LE may be preferable to reduce barriers to spectrum access and allow end users to install their own wireless infrastructure where it is needed. For example, a LE approach may be appropriate where shared use takes place indoors or at low transmit powers and, therefore, where interference can be more easily managed. This view was broadly shared by most respondents, who emphasised that licence exemption was a useful complement to other approaches to managing spectrum access, such as licensing.

5.11 Given the important, yet distinct, roles that licensing and licence exemption play, respondents expressed a view that any decisions that Ofcom may take on spectrum sharing should be flexible and be capable of supporting both approaches without restricting any potential future changes of use.

Evolutions in geolocation database and sensing technologies can support better sharing

Evolution in geolocation databases

5.12 The work currently being undertaken to open up access to TV white spaces is seen by many as an early example of DSA and a first step towards opening up a broader set of frequencies for shared access. The geolocation database is a key enabler, as it manages access to white spaces in a way that limits the possibility of causing harmful interference to incumbent services.

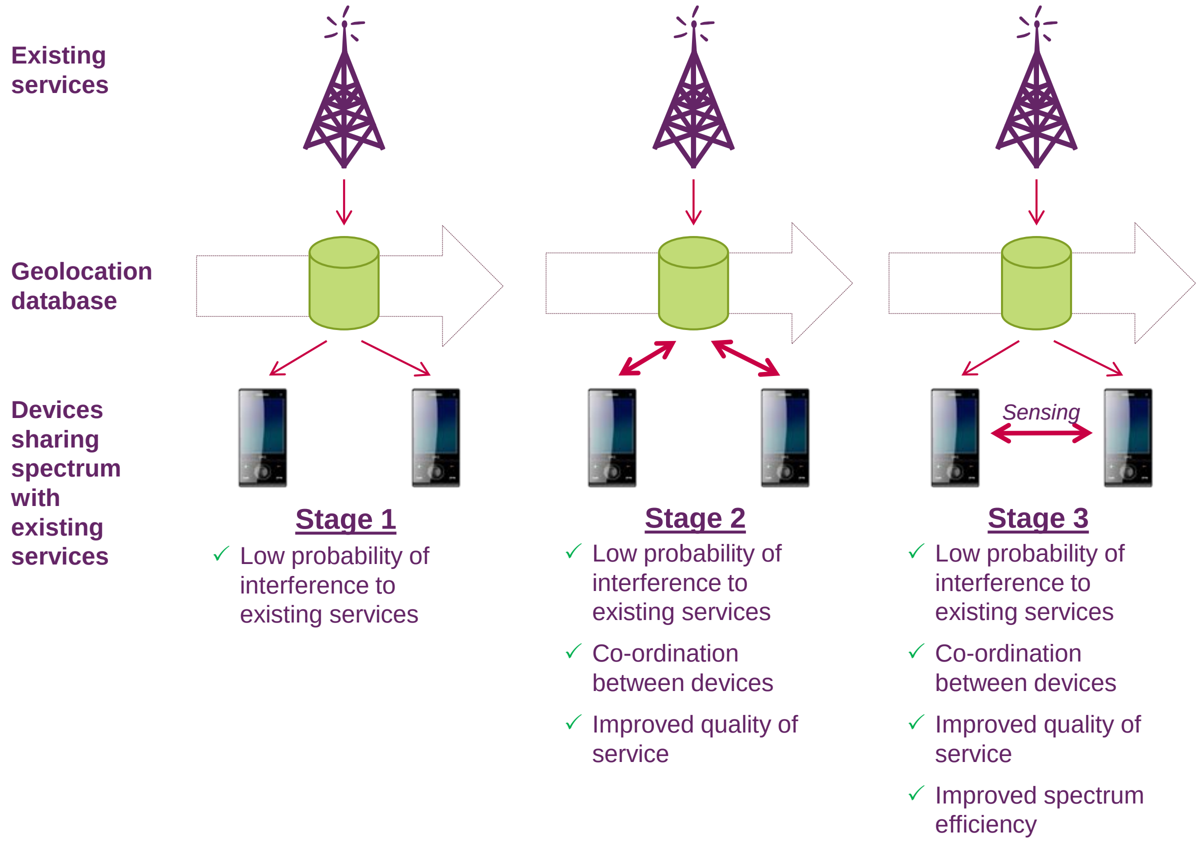
5.13 The geolocation databases currently being developed to manage access to TV white spaces feature a number of provisions to shut down devices that are found to be causing interference. Several respondents noted that this enforcement capability will continue to be important if databases are extended to manage access to a wider range of frequencies which are shared with a greater variety of incumbent users.

5.14 The current focus of Ofcom's implementation work is on the use of databases to manage access to TV white spaces (i.e. within the frequency range 470 – 790MHz) and this band is not considered further here. The fundamental principle is not, however, frequency specific and future generations of database, beyond the current TV white space implementation, could be extended to manage access across a broader range of frequencies. As set out in Section 4 a number of respondents suggested that, once access to TV white spaces has been completed, Ofcom should seek to extend the database principle to manage shared access to a broader range of bands.

5.15 In addition to extending the geolocation database approach to manage access to a wider range of frequency bands, it will also be possible in the longer term to extend the functionality of databases to better co-ordinate users of shared spectrum. This is particularly relevant where spectrum is being shared on a LE basis where it is more difficult to manage interference between different users.

5.16 The primary function of the first generation of geolocation databases is to ensure that devices are only authorised such that there is a low probability of their causing harmful interference to existing spectrum users in and adjacent to the band. With this approach, the devices which operate on a LE basis are themselves not co-ordinated to prevent interference occurring between them. In practice this means that multiple devices may choose to operate in the same frequency band subject to operational parameters provided by a database.

Figure 8: Example of a possible evolution of the geolocation database



Source: Ofcom

5.17 Figure 8 shows one example of how the functionality of the geolocation database might evolve. The current situation is shown as stage 1, with the database protecting incumbents based on information of their deployments.

5.18 Stage 2 shows the situation in which devices are also protected by a future evolution of the database. This is achieved by having the databases log (and potentially share between other databases) information relating to device assignments. Databases can then use this information to optimise existing and future assignments to improve co-ordination between devices, reduce interference or contention and improve quality of service.

Sensing technologies

5.19 The use of geolocation databases is not the only approach for managing access to white spaces. Sensing describes the ability of devices to listen for other nearby spectrum users to determine whether it is possible to transmit. In principle, an advantage of a sensing approach is that a device is able to determine autonomously whether spectrum is available for use without the need to contact a database.

5.20 During the early stages of our work on opening up TV white spaces, approaches using both geolocation databases and sensing were considered. Following consultation with stakeholders, we noted that significant technical difficulties needed to be addressed before cost effective and accurate sensing was viable. We therefore concluded that our approach to TV white spaces would be based on geolocation databases. However, the use of sensing was not ruled out and our approach is sufficiently flexible to support sensing if it becomes viable in the future.

5.21 As part of our Spectrum Sharing consultation we asked for views on whether recent developments in technology had made cost effective and accurate spectrum sensing viable. A number of respondents, including many with experience of making wireless and mobile devices, suggested that barriers still remained to achieving viable spectrum sensing. In particular, two aspects were mentioned:

5.21.1 The need for accurate and cost-effective approaches, that are able to detect, and therefore protect, a range of incumbent services; and

5.21.2 To reduce the overhead of the sensing operation, for example by scanning spectrum more quickly or sharing sensing information between nearby devices.

5.22 One respondent questioned the suitability of spectrum sensing within a technology-neutral regulatory environment, noting that many approaches to sensing require knowledge of the technologies to be detected. They felt that this could have the potential to inhibit the deployment of new communications technologies, as such developments would require sensing approaches to be updated.

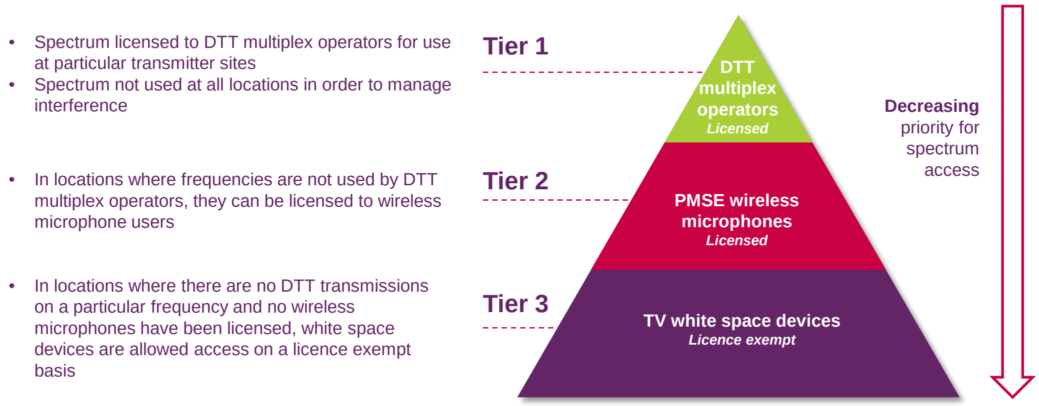
5.23 While barriers to achieving cost effective and accurate sensing remain, we understand that technical research is continuing to address these challenges. We believe that, in the longer term, sensing is likely to play a role alongside geolocation databases and is illustrated by Stage 3 in Figure 8 above. Here in addition to further potential evolution of the database to help manage interference between devices, the devices and other network equipment support spectrum sensing. This approach will protect both incumbents and devices accessing shared spectrum. Furthermore, support for sensing has the additional potential benefit of improving spectrum efficiency, as more devices may be able to operate at a given location and frequency without causing interference.

Tiered spectrum access can help better meet the needs of different spectrum users

5.24 Databases and spectrum sensing can help to identify shared spectrum for devices to use. These technologies can also be used to better manage the use of spectrum by supporting different levels of quality of service within a given frequency band.

5.25 In our consultation we described how different types, or tiers, of user can be supported within a spectrum band accessed on a shared basis. This approach is already being implemented in the UHF TV bands (see Figure 9); here the primary users are the digital terrestrial TV (DTT) multiplex operators which represent the first tier of access, Tier 1. Wireless microphones form Tier 2 and are licensed in those locations where the primary licensee is not using the spectrum. WSDs then form a third tier and can access any remaining unused spectrum in Tiers 1 and 2, which in effect increases the overall supply of spectrum for licence exempt use.

Figure 9: Example of tiered spectrum access in the UHF TV bands



Source: Ofcom

5.26 In addition to the tiered access model in TV white spaces, similar approaches are beginning to emerge in other frequency bands. In the US, geographical shared access to the 3.5GHz band, where maritime radars are the primary user, is being pursued for use by small cells[22]. The Federal Communications Commission (FCC) has proposed a tiered approach to spectrum access, with a hierarchy of users split into three groups: Incumbent Access, Protected Access and General Access. This will be managed through an extension of the geolocation database approach used in the US for TV White Spaces.

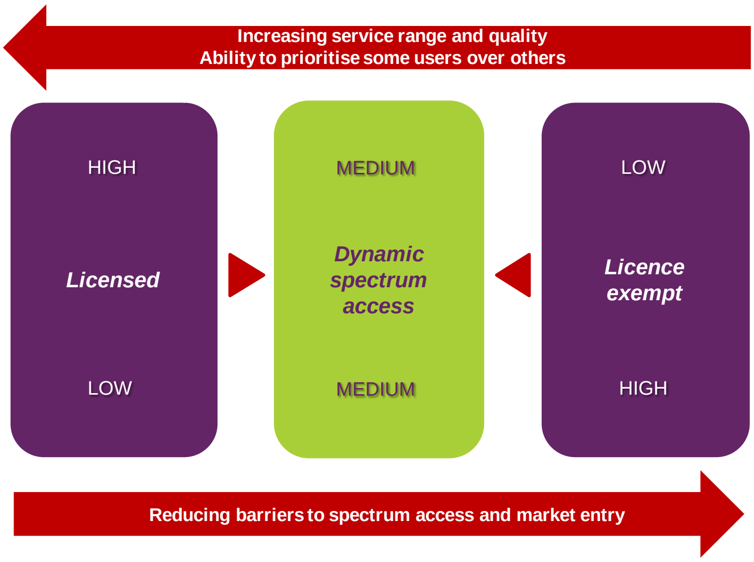
5.27 More broadly, a tiered approach to accessing shared spectrum could facilitate multiple levels of quality of service in a given band, subject to appropriate management tools being in place. In the longer term and across a wider range of frequencies, it is possible to envisage some types of devices negotiating access to spectrum that is appropriate for supporting a given service at a given time and location. For example, a device may request a change from one type of managed access to another if an improved quality of service is required.

5.28 As described above the approaches for enabling tiered access, such as geolocation databases, could evolve to also better co-ordinate spectrum use. This could lead to improved quality of service for services using different tiers of spectrum access, and in particular those operating in a licence exempt tier.

5.29 The use of novel approaches to manage spectrum use on a dynamic and highly granular scale is often referred to as dynamic spectrum access, or DSA. Figure 10 illustrates how DSA can open up a middle ground between the extremes of licensing and licence exemption, with the potential to offer some of the benefits of both. DSA has the potential to offer the low barriers to spectrum access and market entry of licence exemption whilst offering some of the quality aspects of licensing, such as improved range and the ability to prioritise users.

[22] http://www.fcc.gov/document/fcc-proposes-innovative-small-cell-use-35-ghz-band

Figure 10: Different approaches to sharing spectrum



Source: Ofcom

5.30 Respondents indicated that there was strong support for the further development of DSA principles. In particular, there was broad agreement that DSA will be an important tool for increasing the supply of spectrum, as a complement to existing licensed and licence exempt approaches, and as a means for enabling tiered access to spectrum. Respondents urged us to develop a robust yet lightweight regulatory framework for the support of DSA.

5.31 A number of themes emerged from respondents' comments which touched upon conditions or requirements for any future framework. They included:

5.31.1 *Flexible:* The framework should be sufficiently flexible to adapt to rapidly changing demand or future changes in spectrum use;

5.31.2 *Lightweight:* The framework should not impose a significant regulatory burden on equipment manufacturers or service providers; and

5.31.3 *Harmonised:* The framework should be harmonised to enable low-cost, widely-available equipment to be used in a range of countries.

5.32 While acknowledging the potential benefits of using DSA to increase the supply of spectrum, several respondents noted the importance of protecting incumbent users and that Ofcom should retain its ability to detect and resolve cases of interference. Some emphasised that geolocation databases should continue to play a role, building on databases' ability to remotely disable devices found to be causing interference.

5.33 There was a range of views of when DSA might become a commercial reality, reflecting the lack of a single, agreed definition of the term. Some felt that DSA will soon be a reality, citing the work to open up TV white spaces as an example. Others noted that a number of technical barriers still remained, such as accurate and cost-effective spectrum sensing, while others thought that the current lack of a clear commercial driver might prove a barrier. Estimates for the time to commercial reality ranged from 3 to 20 years, indicating a common view that additional technical work was still required.

5.34 We share the view of many respondents that DSA will play an important role in both increasing the supply of spectrum and getting the best use out of spectrum without the need for conventional licensing. We recognise, however, that additional work is required, both by regulators and by industry, to further develop the concepts and technologies behind DSA.

Next steps

5.35 We are proposing to explore options for the future extension of the geolocation database approach. In the first instance, this could involve approaches to protect devices accessing shared spectrum as well as incumbent users. In the longer term, this may involve exploring ways to integrate sensing functionality, subject to progress being made in addressing this technical barrier. More broadly, we will also consider commissioning additional technical research to understand the maturity of the full range of DSA approaches and technologies.

Section 6

Shared spectrum for emerging M2M and Internet of Things applications

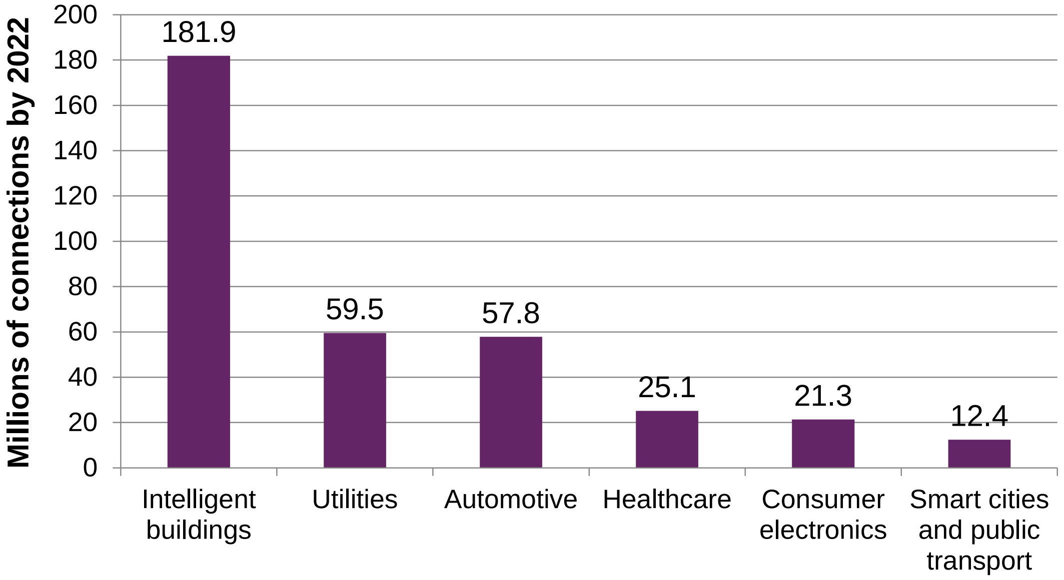
6.1 In assessing future demand for mobile and wireless data it is important to consider as many uses of spectrum as possible. Much of the focus in recent years has been on predicting future growth in demand for mobile broadband services, created by the increasing consumer uptake and use of smartphones and tablets. However, more recently there is increasing interest in promoting the growth in machine to machine (M2M) and Internet of Things (IoT) communications. Given this interest, helping meet the future demands for spectrum by M2M and IoT services is one of the priorities set out in our recent Spectrum Management Strategy statement.

6.2 M2M typically describes applications in which devices, that would not normally communicate, are interconnected using wired or, more likely, wireless links. M2M applications are also characterised by data transfer that is initiated without human intervention. While exact definitions vary, the IoT is a broader term and describes the interconnection and exchange of data between many M2M connections, potentially opening up a wider range of cross-sector benefits. The terms M2M and IoT are often used interchangeably and, for clarity, we will use IoT for the remainder of this section.

6.3 The IoT is an emerging area and the range of possible applications is large and growing, but examples include better management of city infrastructures, greater building security, more regular flows of transport traffic, improving energy efficiency, and health monitoring. There are a number of views on how the IoT market will develop and, given the market's relative immaturity, there is often divergence in these views. To help inform our own thinking on the subject, Ofcom recently commissioned a study on IoT application characteristics and their potential impacts on spectrum. The study[23] estimated that the number of IoT connections across a range of sectors could grow to over 360 million by 2022, as illustrated in Figure 11.

[23] "M2M Application Characteristics and Their Implications for Spectrum", technical study by Aegis and Machina Research, April 2014, http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2014/M2MSpectrum

Figure 11: Estimation of the number of IoT connections across a range of sectors by 2022



Source: Data from Aegis Systems/Machina Research for Ofcom

6.4 It also highlighted that there are likely to be a wide range of different IoT applications with service requirements ranging from high bandwidth, wide area coverage and high quality of service, to low bandwidth, short range low quality of service (QoS). As illustrated in Figure 12 some of these requirements can be potentially met by delivery over existing mobile networks or Wi-Fi.

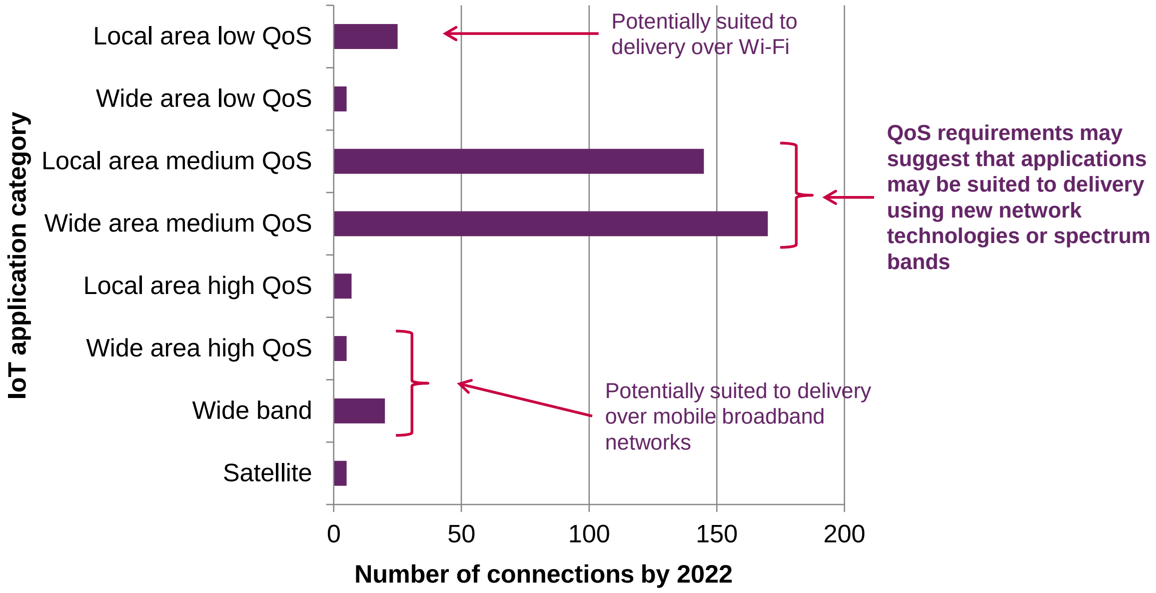
6.5 However, unlike mobile data use, many IoT applications will only require the transmission of a very small amount of data of an infrequent basis whose carriage due to signalling overheads may be inefficient on mobile networks and whose quality of service requirements cannot be met by Wi-Fi. Some applications also require very long battery life operation which cannot currently be achieved using these approaches. In recognition of the varied application and device requirements for the IoT, it has been decided to make the 870 - 876MHz and 915 - 921MHz bands available for a range of applications, such as smart metering[24].

6.6 The study broadly concluded that existing and planned future spectrum allocations for cellular and licence exempt short range use will continue to play a significant role in meeting the needs of IoT applications. For wide area applications, this conclusion is contingent on the adoption of more efficient cellular technologies, such as the IoT-optimised version of LTE currently being developed. In the local area, our decision to make the 870 – 876MHz and 915 – 921MHz bands available has been an important step in increasing the amount of spectrum available for IoT applications.

6.7 We note the findings of this study as a useful contribution to our thinking on the IoT. However, there was strong feedback from stakeholders that additional spectrum below 1GHz is important for the success of the IoT, as set out below. Given this, the relative immaturity of the subject and the importance of ensuring there are no spectrum-related barriers to the development of the IoT, we propose to undertake further work to develop our view on future spectrum requirements.

[24] Proposals to make Wireless Telegraphy Exemption Regulations 2014 Update, available at http://stakeholders.ofcom.org.uk/consultations/proposal-wireless-telegraphy-exemption-2014/

Figure 12: Many IoT applications have QoS requirements that could be supported by networks in frequency bands that are becoming available



Source: Data from Aegis Systems/Machina Research for Ofcom

6.8 In the consultation, we sought views on the role that spectrum sharing could play in further increasing the supply of spectrum for some IoT applications. This section summarises stakeholder responses on this topic and sets out our proposed next steps.

IoT applications are numerous and varied

6.9 The market for IoT devices and applications is still emerging. Key application areas are likely to include:

6.9.1 **Utilities:** The intelligent management of electricity, water or gas to more efficiently match supply with consumer demand. The use of resources is automatically monitored and reported by devices, enabling providers to plan for and avoid peaks in demand;

6.9.2 **Agriculture:** Improvements in the yield and quality of agricultural and livestock products. Involves the automatic and targeted irrigation and fertilisation of crops based on measured moisture levels, current and future weather;

6.9.3 **Health:** The monitoring of patients and remote administration of medical care to improve levels of health and reduce costs. Monitoring fitness levels can also act as an incentive to proactively manage health; and

6.9.4 **Transport:** Improvements in traffic flow and safety through the monitoring of vehicles and road conditions. Includes communications between vehicles (e.g. to warn of braking), between vehicles and road-side devices (e.g. to advertise parking spaces), and within vehicles (e.g. monitoring the engine performance).

6.10 The wide variety of different applications is likely to have very different communication requirements. For example, a crop irrigation service might only report on soil moisture levels several times a day, with each message containing relatively little data. On the other hand, a vehicle monitoring system might exchange multiple detailed performance measurements while on the move.

6.11 Any consideration of spectrum requirements for IoT applications will need to take the varied nature of applications into account. A single wireless network or frequency band and transmission technology is unlikely to be appropriate for all applications.

6.12 Applications that require short range and/or indoor communication might be well served by using low power, licence exempt technologies such as Wi-Fi, Bluetooth or ZigBee. Applications that communicate over a longer range may require access to licensed spectrum, so that interference between users can be managed; delivery could be via a dedicated, special-purpose IoT network or a conventional mobile network.

6.13 It is therefore important to recognise the need both for an increase in the amount of spectrum and the need for different types of spectrum and spectrum access methods in order to adequately support the broadest range of IoT applications.

Many IoT applications could benefit from access to shared spectrum

6.14 Respondents indicated that there is strong demand for access to shared spectrum for IoT applications. This demand can be categorised as follows:

6.14.1 **Below 1GHz:** The favourable propagation characteristics of transmissions at these frequencies make them particularly suitable for use by applications that require good range or in-building penetration; and

6.14.2 **Above 2GHz:** Some applications, such as video monitoring, require relatively high data rates and, therefore, wider bandwidths. Higher frequencies may be particularly suited for supporting these applications as it is generally easier to make available a sufficient amount of spectrum to support broader bandwidths at higher frequencies.

Shared spectrum below 1GHz

6.15 Respondents noted the importance of our on-going activity, in concert with a number of stakeholders, to open up TV white spaces for new uses. The opening up of TV white spaces is considered an important first step towards making more spectrum available for shared use and increases the supply of spectrum below 1GHz.

6.16 In particular, respondents noted the important role of the geolocation database, which is being developed to manage access to TV white spaces. Respondents felt that such an approach could be further developed to manage access to white spaces in other frequency bands.

6.17 While the prospect of access to additional bandwidth was welcomed, several respondents noted that certain applications may not be suited to TV white space operation. IoT applications that require significantly long battery life will need to use very simple hardware, which may preclude the relatively wide band antennas and tuning range envisaged for TV whitespace devices. In these cases, respondents suggested that additional narrowband shared spectrum opportunities below 1GHz to that available through access to TV white spaces, would be beneficial.

6.18 Aside from general interest in access to TV white spaces and to the bands at 870-876MHz and 915-921MHz, that will be made available by July 2014 on a licence exempt basis, there was no clear consensus on which additional bands below 1GHz would be suitable for use by IoT applications. We believe that additional work may be required to establish which bands, if any, may be appropriate.

6.19 There was broad agreement that any bands made available should be internationally harmonised, in order to realise the benefits of economies of scale in the form of low cost equipment.

Shared spectrum above 2GHz

6.20 The focus for many respondents was on shared access to sub-1GHz spectrum for IoT applications. However, several responses also noted the potential for IoT applications to also use spectrum above 2GHz, in particular those requiring broader bandwidth connections, such as video monitoring services.

6.21 Certain short-range applications could make use of existing and potential future allocations for Wi-Fi, including at 2.4 and 5GHz, subject to this technology being suited to the overall application requirements. More broadly, several respondents noted forthcoming developments to the Wi-Fi standards which could make the technology more suited to IoT use. Developments include the 802.11af and 802.11ah standards, which support operation in TV white spaces and improved efficiency respectively. However, respondents also expressed interest in shared access to other frequencies, such as the 2.3 and 3.5GHz bands.

6.22 As with bands below 1GHz, there was broad agreement that any new shared access bands should be internationally harmonised.

Next steps

6.23 Given the potentially important role that access to spectrum on a shared basis could play in meeting the spectrum requirements for many IoT services, we will explore further its application in this sector as part of our wider Spectrum Management Strategy. We will consider undertaking further technical studies, to supplement those already completed, to furnish us with a balanced and comprehensive view of the spectrum implications of the IoT.

6.24 On the basis of stakeholder responses, in the short to medium term particular focus will be placed on ensuring the availability of narrowband (and ideally harmonised) spectrum below 1GHz to help meet the requirements of IoT services that cannot be met using white spaces in the UHF TV bands or the allocations at 870-876MHz and 915-921MHz.

Section 7

Short-term access to shared spectrum for research and development use

7.1 In our consultation we identified that making spectrum available under short-term research and development (R&D) licenses could be beneficial for supporting growth and innovation in new wireless technologies. To date this is generally carried out in response to a specific request, where researchers apply to Ofcom for a non-operational licence in a particular spectrum band. This request is then investigated and approved if it does not cause harmful interference to other users.

7.2 As part of its 2013 Information Economy Strategy[25], Government has asked that Ofcom investigate the feasibility of implementing a more proactive approach to making spectrum available for research use. Here sharing arrangements for R&D use would be agreed by Ofcom with the current users of the spectrum and the spectrum would be accessible, for example, via a geolocation database.

7.3 We noted that this approach could be suited to future research into DSA technologies, which remain in a research and development phase. For example, those used for future 5G services to improve spectrum utilisation and performance.

7.4 Our consultation asked for views on whether short term R&D spectrum licences could be used to enable innovation in new wireless technologies. In this section, we review, based on consultation responses, our approach to short-term access to shared spectrum for research and development use.

Interest in easier access to spectrum for research and development was limited to particular frequency bands

7.5 Overall, there was limited interest from stakeholders for faster short-term access to spectrum for R&D use enabled by an online database. Many respondents believed that faster access to spectrum would be beneficial in principal, but also held the view that access to a wide range of frequency bands would not generally required for R&D purposes.

7.6 Most respondents believed that focusing on a limited number of internationally harmonised bands of most interest to researchers would provide the most effective approach. Often these were bands that were of interest to researchers, but not currently allocated to communications providers. Examples of potential bands cited by respondents included 470-790 MHz and 2.3 GHz.

7.7 However, the majority of respondents were network operators and equipment manufacturers with well-established experience of the present non-operational licensing system. Therefore we recognise that the proposed approach could be of greater interest to small and medium sized businesses (SMEs) and university researchers.

[25] Information Economy Strategy, June 2013, https://www.gov.uk/government/publications/information-economy-strategy

There was interest in measures to complement to the current non-operational licensing system

7.8 Many responses highlighted the benefits of Ofcom's current approach to non-operational licenses, arguing that this system remains fit for purpose. However, respondents did acknowledge the benefits of using an approach based on dynamic spectrum access techniques, specifically the speed and flexibility it could offer in accessing spectrum for R&D.

7.9 As some respondents believed that the established non-operational licensing process would still be the most appropriate method of access in some cases, there was a broad acceptance that using an automated geographic database could provide a useful complement to this approach.

7.10 Other stakeholders noted that this would only be the case of the benefits of establishing such a database outweighed the operational costs. There was also a widely held view that any database should be made sufficiently secure to protect the confidentiality of the R&D users.

Next steps

7.11 Given responses to the proposal set out in our consultation, we are investigating opportunities to support a more proactive approach to R&D access for those bands of most interest to stakeholders.

7.12 We are working on a pilot of measures to pre-agree arrangements for R&D access for bands of particular interest to innovators. This would provide greater clarity "a priori" of the locations and technical conditions under which a technical trial would be permitted. Given the various coexistence issues that need to be addressed as part of this work we are considering those bands that the Ministry of Defence has recently proposed to give up for award. As these bands have some temporary civil users we will also ensure measures are in place to prevent interference to all users of the spectrum (as is the case for current R&D requests).

7.13 As part of this work we are investigating the feasibility and benefits of using an online system to manage such requests for access. We would plan to pilot the new measures this summer, and subject to the outcome of our feasibility work this solution may include an on-line element. Based on the outcome of pilot we may decide to extend this approach to other spectrum bands.

7.14 We envisage that the development of this approach would ultimately act as a complement as opposed to a replacement for the current non-operational licensing regime.

7.15 It may also be possible in the medium term to use dynamic spectrum access techniques to make spectrum available to meet R&D requirements and we will consider this as part of our future work.

Section 8

Glossary

ADSL and ADSL2 – Asymmetric Digital Subscriber Line

A data communications technology that allows copper phone lines to carry high bitrate data at the same time as conventional speech calls. ADSL2 supports faster speeds than ADSL.

5G

The yet to be developed fifth generation of wireless mobile network.

Cell

The smallest unit of mobile network coverage, provided by a single base station.

CEPT – European Conference of Postal and Telecommunications Administrations (Conférence Européenne des administrations des Postes et des Télécommunications)

The coordination body for European post and telecommunication regulators.

Cognitive Sensing

The detection of available spectrum by intelligent devices.

DSA – Dynamic Spectrum Access

Shared access to spectrum that is dependent on external factors such as location, time of day or activity other spectrum users.

DTT – Digital Terrestrial Television

Any form of Terrestrial Television broadcasting delivered by digital means. In the UK and Europe, DTT transmissions use the DVB-T and DVB-T2 technical standards.

FCC – Federal Communications Commission

The U.S. telecommunications regulator.

FTTC – Fibre To The Cabinet

A very high speed broadband connection which is delivered via fibre-optic cable to a street cabinet then by copper wire into the building.

FTTP – Fibre To The Premises

A very high speed broadband connection which is delivered via fibre-optic cable to the building. Speeds attainable are theoretically faster than with FTTC.

Geolocation

The identification of the location of a device by automatic means eg GPS

GHz – GigaHertz

A unit of frequency of one thousand million cycles per second

Harmonised (spectrum)

Spectrum which has been allocated for the same use in multiple countries.

Hotspot

Wi-Fi Internet access point provided for public or semi-public use. Often used in cafes, restaurants etc to attract customers.

Hotspot 2.0

See Passpoint

IoT - Internet of Things

The interconnection and exchange of data between many machine to machine connections, which could open up a wide range of benefits across different industry sectors.

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.

LE – Licence Exempt

Spectrum which can be used within specified constraints (eg low power and no protection against interference) without charge or the need for a Wireless Telegraphy Act licence.

LSA – Licensed Shared Access

Shared spectrum access that provides a higher level of protection to users

M2M – Machine to Machine

Communications that are generated and received without user intervention, including by equipment with no user interface. Typical applications include automation and measurement.

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.

Non-Operational Licence (formerly T&D Licence)

Types of time-limited licence which provide access to spectrum for test and development as well as trials and demonstrations of radio equipment. Additionally they are also used for scientific research.

PassPoint (WiFi)

An enhancement for commercial applications of WiFi that is designed to enable automatic connections to WiFi networks, user roaming between WiFi hotspots and higher security. Also known as Hotspot 2.0.

PMSE – Programme Making and Special Events

A class of radio applications that support a wide range of activities in entertainment, broadcasting, news gathering and community events.

Smart TV

A TV that provides the facility to use software programs or Apps. These typically provide access to additional information and services via the Internet (eg BBC iPlayer)

Spectrum

The continuum of electromagnetic frequencies

T&D – Test and Development (licence)

See Non-Operational Licence

UHF – Ultra-High Frequency

The frequency range from 300 MHz to 1000 MHz. Terrestrial TV broadcasting in the UK uses UHF frequencies between 470 MHz and 790 MHz.

Wi-Fi

Wireless local area networking conforming to the IEEE 802.11 standards. The spectrum currently used for Wi-Fi is are the harmonised 2.4GHz and 5 GHz frequency bands.

Wireless Router

A device used to connect a private network to a broadband network which also provides wireless connectivity (typically Wi-Fi) on the private network.

WLAN – Wireless Local Area Network

A generic term for wireless data networks which work over short distances, typically within a single building.

WRC – ITU World Radiocommunication Conference

WRC reviews and revises the ITU Radio Regulations. Conferences are held every two to three years.

WSD – White Space Device(s)

Radio devices which make use of transmission frequencies that are nominally allocated to other services but which are unused in the vicinity of the device.