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

Licensed sharing, Wi-Fi, and dynamic spectrum access

Consultation

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Contents

Section 1

Executive Summary

1.1 This aim of this consultation is to develop a better understanding of the role that spectrum accessed on a shared basis could play in the mobile broadband and machine-to-machine (M2M) sectors alongside cleared spectrum bands. In particular we are seeking to understand the role that spectrum shared on licensed, licence exempt and a dynamic spectrum access basis could play in opening up access to more spectrum and supporting innovation, alongside any associated disadvantages, such as making it harder to manage interference between different spectrum users.

Demand for spectrum is increasing, whilst supply is limited

1.2 Spectrum is a scarce and valuable resource. There is an expectation that this scarcity will be particularly pronounced in the mobile broadband and M2M sectors as a result of a combination of factors:

- Continued, and potentially increased, demand for spectrum from a wide range of other spectrum users including broadcast television, live event productions, satellite, radar, medical and military;
- Rapidly increasing usage of mobile devices to access the internet, including smartphones, tablets and laptops;
- Increasing use of wireless networks to deliver fixed broadband connectivity to end users, especially in more remote and rural areas;
- An increase in the amount of 'in-home' wireless connectivity and traffic, as consumers use Wi-Fi to distribute high bandwidth content and services; and
- The emergence of a significant number of new devices and services requiring wireless connectivity, notably M2M applications.

1.3 Increasing the capacity and performance of wireless networks, including mobile broadband, is likely to deliver significant benefits to consumers in the form of new and improved services, while also ensuring that the UK's communications infrastructure is capable of supporting future growth and innovation in the wider economy.

1.4 This consultation focuses on the use of shared spectrum access in the mobile broadband and M2M sectors. However, we recognise that this approach also has wider applicability to other sectors and would welcome stakeholder views on other service types where spectrum sharing could potentially deliver significant benefits to citizens and consumers.

Spectrum sharing is a potential solution to meeting the demand for more spectrum for wireless data services

1.5 One important approach being pursued today to increase the future supply of mobile broadband spectrum is to clear spectrum currently used by other services for use by mobile broadband services. The advantage of this approach is that the cleared spectrum can be operated at sufficiently high power to allow its use at existing mobile

cell sites to increase their coverage and/or capacity. There are two main ongoing initiatives in this area:

1.5.1 *To improve coverage*: Additional cleared lower frequency spectrum can be used to provide more cost effective rural coverage and better indoor coverage than higher frequencies. This is being enabled by Ofcom's longer term UHF Strategy, which is creating an opportunity for a change of use of the 700MHz band from digital terrestrial broadcasting to mobile broadband when relevant international harmonisation processes are complete; and

1.5.2 *To increase capacity*: Additional cleared higher frequency spectrum can be used to increase the capacity of medium and small sized cells. Two bands that could be suitable for this purpose are at 2.3 GHz and 3.4 GHz which are being released by the Government Public Sector Spectrum Release (PSSR) programme. In total this programme aims to make an additional 500 MHz of public spectrum available for mobile broadband use by 2020.

1.6 However, looking beyond these initiatives it is becoming increasingly difficult to find significant amounts of additional spectrum that can be fully cleared for use by wireless data services, in particular for highly sought after spectrum below 6 GHz. Spectrum sharing is a potential solution to many of these demands for more spectrum and we have focussed on three key application areas in this consultation:

- **Mobile broadband:** Research commissioned by Ofcom found that under a mid range estimate there will be an 80 times increase in the demand for mobile data capacity by 2030. It also found that in order to meet this demand a significant increase in the amount of mobile broadband spectrum will be needed, alongside other capacity enhancing techniques. These include more efficient mobile standards, smaller cells and offloading capacity onto fixed networks using Wi-Fi;

- **Wi-Fi connectivity:** While the use of Wi-Fi to provide indoor wireless networks is an important service in its own right, Wi-Fi is also offering the opportunity to offload traffic from mobile access networks. Additional spectrum and new approaches to how spectrum is accessed by devices may be needed to help meet future demand for indoor wireless networks, whilst also supporting more Wi-Fi offload for mobile broadband services; and

- **Machine to machine:** Machine to machine (M2M) applications may be a significant driver of even further growth in demand over mobile access networks, and therefore demand for spectrum. These applications can be potentially delivered over mobile broadband networks, Wi-Fi or dedicated networks. In all cases, spectrum sharing may be a highly relevant policy tool to support the development of future M2M applications.

1.7 At the same time, we are also developing our thinking in others areas relevant to accessing spectrum on a shared basis, which will be the subject of future consultations including:

- **Ofcom's long term spectrum strategy**: as anticipated in our Annual Plan, we are developing our future strategic approach to spectrum management and our proposals for the priority areas of our work over the next ten years. This work will

be an important contribution to the Government's recently announced[1] plans for a UK Spectrum Strategy, to cover both civil and public sector spectrum holdings;

- **Mobile data**: we will assess potential future bands for mobile broadband use in response to the need for more fully cleared spectrum for mobile networks. In particular, this work will assess how we should prioritise our longer term work on mobile spectrum beyond current initiatives;

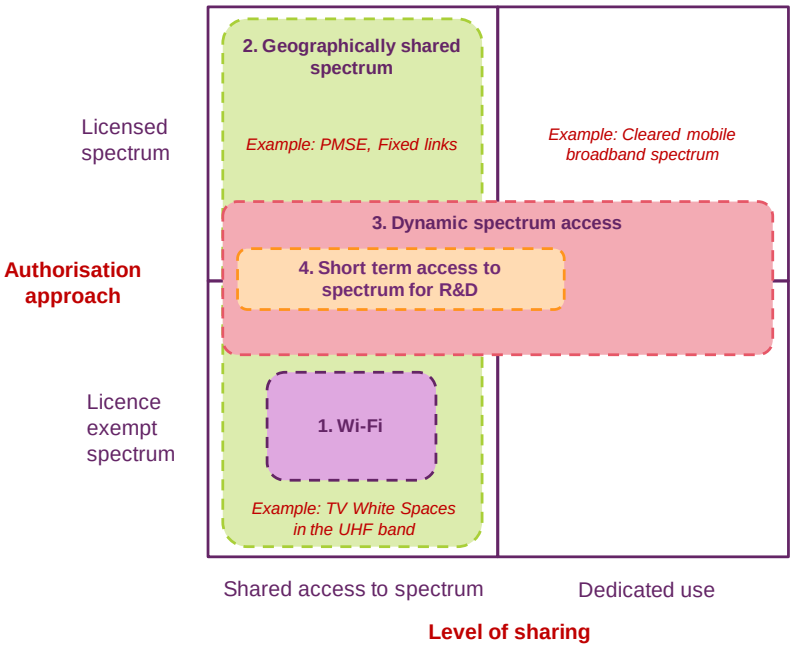
- **Programme Making and Special Events:** we are also developing our future approach for ensuring the supply of spectrum for use by PMSE services, on both a dedicated and shared basis; and

- **Fixed and mobile broadband coverage:** our future approach for ensuring the widespread availability of broadband connectivity throughout the UK.

Focus of this consultation

1.8 Figure 1 illustrates the four key spectrum sharing topics addressed by this consultation: 1) supporting future Wi-Fi use; 2) increasing the future supply of spectrum for mobile broadband and M2M use using spectrum shared on a geographic basis[2]; 3) using dynamic spectrum access technology to improve sharing between devices; and 4) shorter term access to shared spectrum to support research and development.

Figure 1: Overview of spectrum sharing topics addressed in this consultation



1.9 Figure 2 provides a summary of the key questions and issues associated with each of these topics, which are discussed in detail in Sections 3, 4 and 5.

[1] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/225783/Connectivity_Content_and_Consumers_2013.pdf

[2] Throughout this document we use the terms "geographically dependent spectrum" and "geographical sharing" to refer to spectrum that is available for shared use at particular locations and/or times.

Figure 2: Summary of main issues for each spectrum sharing topic

1. Wi-Fi	
Is more spectrum required for Wi-Fi use?	Additional spectrum in the 5 GHz band may be needed to provide higher speed connections to match those provided by the rollout of fixed superfast broadband and to support the increasing use of Wi-Fi to both offload mobile data and create indoor networks.
Is the increasing outdoor use of Wi-Fi likely to lead to a future tragedy of the commons?	The increased deployment of outdoor Wi-Fi small cells, often referred to as hotspots, by different operators could cause increasing levels of interference and reduced quality of service. This has implications for the future viability of Wi-Fi in both public networks and potentially for outdoor M2M applications.
2. Geographically shared spectrum	
Could spectrum accessed on a shared geographical basis help meet demand for spectrum for wireless data services?	Geographical access to unused spectrum in some existing spectrum bands could be particularly well suited to use by the growing number of small sized cells likely to be required in high demand urban areas. The scale of this opportunity is potentially significant and could provide access to over several hundred MHz of additional spectrum in highly sought after bands below 6 GHz.
3. New approaches to spectrum sharing	
Will new approaches to accessing shared spectrum bands be needed for future outdoor use?	Spectrum sharing makes it potentially harder to manage interference between different spectrum users than in dedicated spectrum bands. Advances in Dynamic Spectrum Access (DSA) technologies could enable devices to make more intelligent decisions about how to operate (e.g. which frequency, power level etc.) in a given location to minimise interference.
4. Short-term spectrum access for research and development	
Is there a need for more pro-active approach to access to spectrum for research and development?	The wider use of geographical access to spectrum and DSA for mobile broadband and M2M use is at an embryonic stage. This is aligned with a recent request by Government for Ofcom to consider the role that easier experimental access to spectrum could play in supporting future growth and innovation.

Wi-Fi is set to continue to play an important role in helping meet the demand for wireless data capacity indoors but could require more spectrum

1.10 Wi-Fi is already playing a significant role in helping meet some of the increase in the use of mobile data services indoors. Wi-Fi operates in the internationally harmonised 2.4 and 5 GHz spectrum bands on a licence exempt basis, which has resulted in very large economies of scale and lower equipment prices with over 1.5 billion Wi-Fi enabled devices being sold globally in 2012[3].

1.11 Wi-Fi has proved to be very successful in providing high speed indoor wireless broadband connectivity. The connection speeds provided by indoor Wi-Fi equipment

[3] http://www.abiresearch.com/press/total-cumulative-wi-fi-enabled-device-shipments-re

have increased over time to match those provided over fixed broadband networks. This is set to continue as new faster Wi-Fi standards are developed to enable consumers and businesses to wirelessly distribute within their premises broadband services delivered over superfast fibre and cable connections.

1.12 Research commissioned by Ofcom has found that, whilst the 5 GHz band used by Wi-Fi is currently underutilised, an extension of this band could be required in the future to support the use of wireless superfast broadband connection speeds[4] [5]. We would welcome stakeholders' views on whether this increase in the 5 GHz Wi-Fi band will be required for this or other purposes. Any future decision on an extension of this band would need to consider the level of interference protection required by other spectrum users and the need for international harmonisation.

1.13 Although the 2.4 and 5 GHz Wi-Fi bands are currently servicing most of the demand for mobile data capacity indoors, other bands may be better suited to meeting different types of indoor wireless service connection requirements:

1.13.1 *Very high speed short range connections:* a new Wi-Fi standard at 60 GHz is well adapted to providing very high speed connections within a single room[6];

1.13.2 *Lower speed coverage:* sub 1GHz, low frequency spectrum can play a complementary role to Wi-Fi in providing more extensive low speed in-building coverage, for example, for smart metering home area networks applications [7].

As Wi-Fi use outdoors increases, better approaches to spectrum sharing may also be needed to maintain quality of service

1.14 Data gathered through Ofcom's 2012 Infrastructure Report Update revealed that the use of Wi-Fi small cells or 'hotspots' outdoors represents only 4% of the total volume of mobile broadband traffic 8. However, this is set to increase significantly with the introduction of technology to facilitate easier connection to and roaming between hotspots, more Wi-Fi access points and a greater degree of device to device connectivity.

1.15 Unlike the indoor use of Wi-Fi, building walls cannot be relied upon to provide protection outdoors against interference between users and different Wi-Fi hotspots. This creates a risk of interference occurring in high demand urban areas where there is increasing consumer use of Wi-Fi hotspots deployed in the same area by different

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[4] "Utilisation of key licence exempt bands and the effects on WLAN performance", available at http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2013/key-licence-exempt-bands/

[5] "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

[6] Press release from the Wi-Fi Alliance announcing the intention to certify Wi-Fi products operating at 60GHz, http://www.wi-fi.org/media/press-releases/wi-fi-alliance%C2%AE-and-wireless-gigabit-alliance-unify

[7] Recent statement on making the 870-876MHz and 915-921MHz bands available on a licence exempt basis for, *inter alia*, application such as smart metering, available at http://stakeholders.ofcom.org.uk/consultations/870-915/statement/

[8] Infrastructure Report, available at http://stakeholders.ofcom.org.uk/binaries/research/telecoms-research/infrastructure-report/Infrastructure-report2012.pdf

operators. This can lead to a 'tragedy of the commons' whereby each additional hotspot added reduces the performance of other hotspots in its vicinity.

1.16 Any potential increase in the future amount of 5 GHz spectrum for Wi-Fi would also help in meeting demand outdoors. However, research commissioned by Ofcom has indicated that this would need to be combined with improvements to how Wi-Fi devices access spectrum so that they better manage interference between them to maintain quality of service over the long term.

1.17 This means that new spectrum bands may be needed which operate with improved approaches to sharing spectrum to maintain the quality of service for public wireless hot spots and M2M applications.

Sharing spectrum on a geographical basis could be used to increase the overall supply of mobile broadband, licence exempt and M2M spectrum

1.18 Much of the spectrum used today has been allocated to a dedicated single user. This makes it easier to manage interference between users, allowing high power operation and wide area coverage to be achieved. It has also provided certainty of spectrum access which is needed to secure investment in wireless infrastructure. However, it has also led to some spectrum bands not being fully utilised in all locations all of the time. These gaps in spectrum usage can be potentially shared with other users to deliver additional services. Some of these gaps are already being used, for example to support wireless microphone applications in the UHF TV bands.

1.19 This same geographical sharing approach could also be used to increase the supply of spectrum for mobile broadband, licence exempt and M2M use beyond that provided by cleared spectrum bands. Different authorisation approaches could be used to enable access to these gaps in spectrum usage including geographical licenses, geographical licence exempt access or future approaches based on the use of DSA technologies.

1.20 Geographical sharing 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.

1.21 Spectrum made available in this way is likely to provide a complement, as opposed to a replacement, for cleared mobile broadband and M2M spectrum. Where cleared spectrum is more likely to be used at higher power to increase the capacity of wide area mobile broadband networks, geographically shared spectrum is more likely to be used at lower power by small cells to provide localised increases in capacity.

1.22 The attractiveness of a particular frequency band for providing geographical shared access for small mobile broadband cells, licence exempt and M2M cells is dependent on a number of broad factors including:

1.22.1 The level of interference protection required by the incumbent spectrum user, which has an impact on the coverage achievable by the small cells;

1.22.2 The geographical use of spectrum by the incumbent spectrum user, which has an impact on the locations where small cells can be deployed;

1.22.3 The frequency of the spectrum band and whether its propagation characteristics match those needed by small cells; and

1.22.4 The international harmonisation of the shared spectrum band for mobile broadband use, which can create greater economies of scale and lower equipment prices.

1.23 Given these factors, our initial view is that frequency bands where the incumbent use is mainly in remote locations (or could potentially operate there in the future) are likely to be most suited to spectrum sharing with small mobile broadband cells in urban areas. Frequency bands with these characteristics could potentially be made available through the Government Public Sector Spectrum Release programme.

1.24 Responses to this consultation will be used to inform a more detailed assessment of the attractiveness of particular frequency bands for providing geographical shared access to spectrum for mobile broadband and M2M use.

Geolocation databases can make it easier to access gaps in spectrum usage

1.25 Advances in geolocation database technology are making it easier to exploit spectrum sharing opportunities. Here databases hold information on the frequencies available for sharing in different locations, known as *white spaces*. White space devices query the database to determine suitable channel frequencies and powers. In principle, different devices can be allocated different shared access rights to the spectrum depending on the type of service and where they are operating.

1.26 Establishing the geolocation approach represents an important step towards enabling more sophisticated ways of sharing spectrum. We are currently working with industry stakeholders to put in place the first application of this approach in the UK. As a result, white space devices will be able to access unused spectrum in the digital terrestrial TV (DTT) UHF bands. We are planning a pilot for October which will allow us both to test the necessary systems and processes, and to gain information on the coexistence parameters that will minimise the risk of harmful interference into existing licensed spectrum use[9].

1.27 Although the first applications will be in the DTT bands, an important aspect of this approach is that it is not frequency dependent and could equally be used in other spectrum bands. For example, a geolocation database approach is planned to be used in the US to allow small cells to share the 3.5 GHz military radar band in government buildings and to be shared outside these locations on a licensed and licence exempt basis[10].

Dynamic Spectrum Access could enable better quality of service to be achieved in shared licence exempt bands

1.28 A licence exempt approach, such as that used by Wi-Fi, provides lower barriers to spectrum access than a licensed approach. However, the lack of centralised control over who can use the spectrum in a given location makes it harder to maintain quality of service (QoS), in particular in high demand outdoor locations.

[9] For more information on TV White Spaces visit http://stakeholders.ofcom.org.uk/spectrum/tv-white-spaces/

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

1.29 Advances in DSA technologies could enable a better quality of service to be achieved in licence exempt shared spectrum bands. These technologies include an extension of the use of geolocation databases to manage interference between devices, cognitive sensing, carrier aggregation and smart antennas. Overall these developments could allow devices to make more informed decisions about which spectrum to use in a given location and at a specific time, based on information gathered about other devices sharing spectrum. To be at its most effective, this approach would most likely need to be applied in new shared spectrum bands where it can be supported by all devices sharing spectrum.

1.30 This DSA approach could provide a useful complement to the use of Wi-Fi based on licence exempt spectrum outdoors in helping maintain good outdoor quality of service in high demand urban areas. This could provide two important benefits:

1.30.1 A better quality of service to be maintained in publicly available mobile broadband hotspots in cities and towns;

1.30.2 Growth in the emerging M2M market where a good quality of service is likely to need to be combined with low barriers to spectrum access. For example, M2M applications used to enable a more efficient operation of the UK's energy and transport infrastructure[11].

1.31 Through this consultation we would welcome stakeholder views on the development of DSA technologies and the future role DSA could play alongside conventional licensed and licence exempt approaches.

Short term research and development spectrum licences could be used to enable innovation in new wireless technologies

1.32 Many of the advances in DSA technologies remain in a research and development phase and have the potential to be used in future licence exempt as well as dedicated mobile broadband spectrum bands. For example, those used for future 5G services to improve spectrum utilisation and performance. In addition, it may take several years to identify and harmonise at an international level the potential frequency bands that could be used for DSA.

1.33 In the interim period, making spectrum available under short-term research and development licenses could be beneficial for supporting growth and innovation in new wireless technologies.

1.34 To date this is generally carried out in response to a specific request, as researchers apply to Ofcom for a non-operational licence in a particular spectrum band, which is then investigated and approved, if it does not cause harmful interference to other users. As part of its Information Economy Strategy[12], Government has asked that Ofcom investigate the feasibility of implementing a more pro-active approach to make it easier for researchers to access spectrum. Here sharing arrangements for research and development 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.

[11] https://www.innovateuk.org/documents/1524978/1866950/Press+release+-+Multi-million+pound+Future+Cities+Catapult+to+be+hosted+in+London/eb4c5db5-a6ed-479c-84ad-21b5be08b1cb

[12] https://www.gov.uk/government/publications/information-economy-strategy

1.35 Through this consultation we would welcome stakeholder views on the potential benefits that such an approach could bring, the frequency bands which would be of value for research purposes, and whether there are any alternative approaches that could achieve similar outcomes.

About this consultation

1.36 Our aim is to better understand the nature of demand for shared access to spectrum and the techniques that could be used to enable its most effective use. Specifically, responses to this consultation will be used to inform Ofcom's view in three key areas;

1.36.1 On the potential demand for additional spectrum for Wi-Fi in the 5 GHz band;

1.36.2 To inform a more detailed assessment of the bands most suited to providing geographical shared access for mobile broadband and M2M services; and

1.36.3 The techniques that devices could use to access this spectrum, such as DSA, to maximise the benefits they can provide.

Section 2

Introduction

Spectrum sharing has significant benefits, but carries some limitations

2.1 This consultation explores the role that spectrum sharing could play in enabling greater access to spectrum for use by mobile broadband and machine-to-machine (M2M) services. We consider the benefits this could provide from two different perspectives:

2.1.1 *Increasing the supply of spectrum:* The sharing of existing frequency bands on a geographical basis to provide greater access to spectrum;

2.1.2 *Reducing barriers to spectrum access using licence exempt sharing:* Sharing spectrum within a band by different licence exempt (LE) devices can significantly reduce barriers to spectrum access compared to a licensed approach.

2.2 These benefits are potentially applicable to a wide range of services and are already used in some sectors. For example, to increase the amount of spectrum available for PMSE services some of these services share spectrum on a geographical basis in the UHF TV bands. While licence exempt sharing in the Wi-Fi bands has led to innovation in providing high speed short range wireless connectivity and devices.

2.3 The main limitation of spectrum sharing is that it makes it harder to manage interference between different users than when spectrum bands are dedicated to a specific user. This has two key consequences:

2.3.1 For the use of geographical spectrum sharing to increase the supply of spectrum, this can lead to a need for additional effort to establish and enforce co-existence rules between existing spectrum users and new services sharing access to their spectrum;

2.3.2 For licence exempt sharing in a given frequency band, this can lead to a *tragedy of the commons* whereby increasing numbers of users reduce the overall quality of service provided for everyone.

2.4 However, advances in technology may provide the opportunity to maintain the benefits of a shared approach to accessing spectrum, while addressing the impact of the limitations listed above. For example, geolocation database technology could make it easier for devices to identify spectrum available for sharing in a given location and ensure that this spectrum is used at the correct power level to adequately protect the primary spectrum user from interference.

2.5 In addition, Dynamic Spectrum Access (DSA) technologies, including advanced geolocation databases and cognitive sensing, could better manage interference between different users in shared licence exempt spectrum bands to improve the quality of service.

This consultation focuses on the role greater spectrum sharing could play in the mobile broadband and M2M sectors

2.6 Given the potential benefits and limitations described above, this document focuses specifically on the role greater spectrum sharing could play in the mobile broadband and M2M sectors. There are a number of reasons for focussing on these sectors:

2.6.1 Spectrum sharing is already used for Wi-Fi services, but increased demand and the need to provide an acceptable level of quality of service may require more spectrum;

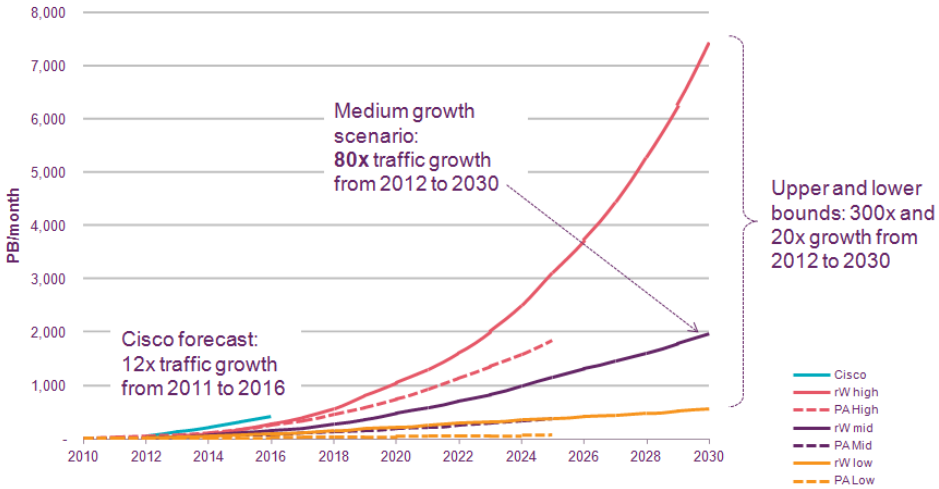
2.6.2 Spectrum sharing is one key mechanism to make available significantly more spectrum in response to the growth in demand for mobile broadband services, alongside dedicated spectrum;

2.6.3 The connectivity required by M2M services shares many of the characteristics of Wi-Fi, with potential material benefits of cross sector innovation enabled by low barriers to spectrum access resulting from licence exempt use. However, given the volume of potential demand, quality of service requirements and the scarcity of spectrum availability, these services may need access to more licence exempt and licensed spectrum which could be made available by spectrum sharing.

Demand for mobile data is forecast to grow significantly

2.7 The increasing penetration and use of mobile data services is driving a rapid increase in demand for mobile data capacity. Ofcom's 2012 Infrastructure Report update revealed that between 2011 and 2012 the amount of data handled over UK mobile networks more than doubled[13]. Looking further ahead, research commissioned by Ofcom predicts that there will be an 80 times increase in demand for mobile data capacity by 2030[14].

Figure 3: Projected growth in UK mobile data traffic



Source: Real Wireless for Ofcom, 2012

2.8 This growth in demand for mobile data is being driven by the increasing penetration and use of connected devices such as smartphones and tablet PCs. Increasing fixed

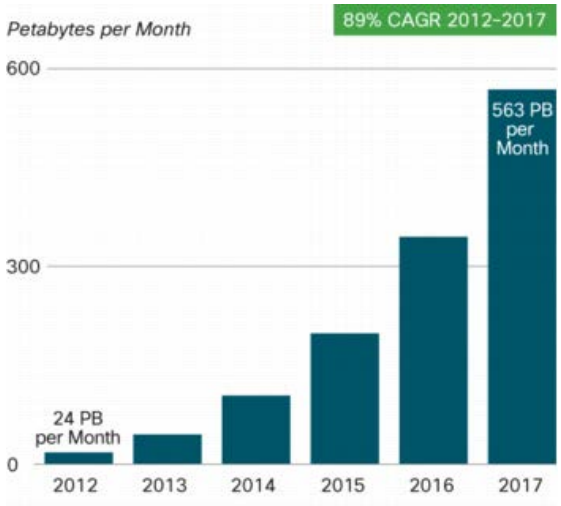
[13] http://stakeholders.ofcom.org.uk/market-data-research/other/telecoms-research/broadband-speeds/infrastructure-report-2012/
[14] http://stakeholders.ofcom.org.uk/consultations/uhf-strategy/statement/

broadband connection speeds and higher resolution video formats are increasing the capacity required in indoor wireless networks.

2.9 Over the longer term, it is also likely that increasing numbers of devices will become wirelessly interconnected, enabling growth in new M2M applications. These are likely to span a wide range of uses, from the remote monitoring of patients through to the smarter delivery of public transport and energy services. The common requirements for many of these services is access to internationally harmonised frequency bands, to provide economies of scale, which are capable of delivering a sufficient amount of capacity with a good quality of service.

2.10 The M2M sector is relatively immature and we recognise that there is currently a significant degree of uncertainty surrounding estimates for likely future demand. However, while the magnitude of future demand varies between different projections, there is general agreement that M2M devices and applications are likely to place a significant demand on spectrum. For example, Cisco has estimated[15] that the global shipment of M2M modules will grow to 1.7 billion devices by 2017, when M2M traffic levels will reach 563 petabytes per month (as illustrated in Figure 4).

Figure 4: M2M traffic to increase 24-fold betweeen 2012 and 2017 (Cisco)



Source: Cisco VNI Mobile Forecast, 2013

2.11 There will be a number of options for meeting this demand for spectrum by M2M services. These include, for example, delivery over mobile networks using licensed spectrum and the use of spectrum on a licence exempt basis.

Spectrum sharing can play an important role in providing access to more spectrum for wireless data services

2.12 A range of different capacity enhancing techniques is likely to be required to ensure the future capacity and performance of mobile networks. These include using additional spectrum, the use of more efficient mobile technologies, reducing cell sizes by adding more mobile sites and offloading mobile traffic onto fixed networks using

[15] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012-2017, available at http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html

Wi-Fi. Spectrum sharing can play two important roles here in providing access to spectrum for wireless data services:

2.12.1 It can help increase the future supply of mobile broadband spectrum by providing greater access to geographically underutilised spectrum in some existing spectrum bands. This approach is likely to be particularly well suited to providing additional spectrum for use in small sized cells which can operate at lower power, making it easier for them to co-exist with incumbent spectrum users. For example, a frequency band where the primary user is only using spectrum in remote locations throughout the UK, might be potentially re-utilised by small cells in high demand urban areas which are distant from these locations.

2.12.2 Licence exempt bands where access is shared with a wide range of consumer equipment could be used to support the increased offloading of mobile data traffic onto fixed broadband networks. This reduces the demands placed on spectrum used for mobile networks and also enables greater re-use of limited spectrum given the smaller size of Wi-Fi cells.

Different approaches to managing inference can deliver different benefits

2.13 Shared spectrum bands can be managed in different ways to meet different service needs. Today there are two general approaches used for managing inference between different users - licensing and licence exemption:

2.13.1 **Licensed approach**: here all services sharing access to the same spectrum band are licensed and are subject to a centralised technical co-ordination process. This makes it potentially much easier to manage interference between different spectrum users enabling, for example, services to operate at higher power and provide wide area coverage whilst maintaining a good service quality. The disadvantage of this approach is that the need for a centralised technical co-ordination process within a licensed environment increases entry barriers for spectrum access. An example of this approach is the 3.6 GHz band, in which a mobile broadband user shares spectrum with satellite earth stations.

2.13.2 **Licence exempt approach**: here some of the devices sharing access to a spectrum band do not require a licence. This reduces barriers to spectrum access, helping support innovation in new services and devices. The main drawback of this approach is that there is no centralised control over who can access the spectrum and licence exempt devices usually need to operate at low power and hence over short distances to minimise interference. It is also often better suited to indoor rather than outdoor applications, where walls can act as a useful barrier to interference between users.

2.14 In addition, a new approach, often referred to as Dynamic Spectrum Access (DSA), is emerging to enable a better management of interference in shared licensed and licence exempt spectrum bands. This may be capable of allowing licence exempt use, in particular, to achieve a better compromise between achieving a good quality of service associated with a licensed approach, whilst maintaining the low barriers to spectrum access provided by a licence exempt approach. DSA is being made feasible by new technology developments described in Section 4, such as advances

in geolocation databases and cognitive sensing, which could allow devices to better manage interference between themselves.

New mobile broadband and M2M spectrum sharing opportunities are also being considered internationally

2.15 As discussed above, one potential use of geographical shared access to spectrum is to provide additional spectrum for use by low power mobile broadband and M2M small cell applications.

2.16 This type of approach has been announced by the Federal Communications Commission (FCC) to enable spectrum sharing and small cell deployment in the 3.5 GHz band, where maritime radars are the primary user[16]. This is managed through an extension of the geolocation database approach which is being developed in the US and the UK to enable shared access to UHF TV bands.

2.17 Proposals to facilitate the increased sharing of spectrum are also being developed within Europe. Licensed Shared Access (LSA) is a regulatory approach which may be helpful in some member states to open up additional bands for spectrum sharing. The LSA concept is currently being developed within the Radio Spectrum Policy Group (RSPG). Work has also been initiated within the Conference of Postal and Telecommunications Administrations (CEPT) on the regulatory framework for LSA, focussing on its potential use for mobile broadband services in the 2.3GHz band.

Structure of this document

2.18 This consultation will cover:

- **Section 3**: This section considers the future role of Wi-Fi, focusing on two areas:
  - Indoor wireless networking: This will consider the role of Wi-Fi as an important component of indoor connectivity, the outlook for future demand for Wi-Fi and the potential need to increase the supply of spectrum at 5 GHz.
  - Outdoor wireless networking: This will consider the increasing use of Wi-Fi to provide connectivity outdoors and whether there are potential limitations on its performance over the long term.
- **Section 4:** In this section we explore the wider opportunities provided by spectrum sharing, focusing on the two related elements set out below:
  - Geographical spectrum access: The role that sharing spectrum on a geographical basis within existing frequency bands could play in increasing the future supply of spectrum for use by mobile broadband and M2M services.
  - Dynamic spectrum access: The potential for new dynamic spectrum access (DSA) technologies to combine the benefits associated with licensed and licence exempt approaches to spectrum management.

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

- **Section 5:** In this section we explore the role of easier and faster access to spectrum for research and development, using for example an online geolocation database, to support future innovation in new wireless services.

Linked documents

2.19 We have also published, alongside this consultation, three independent technical research reports that Ofcom has commissioned to inform our views. They are:

- A study on the utilisation of key licence exempt bands and the effects on WLAN performance by MASS[17];
- A study of the technologies and approaches for meeting the demand for wireless data using licence exempt spectrum to 2022 by Quotient Associates and Europe Economics[18]; and
- A study on the use of Wi-Fi for Metropolitan Area applications by Aegis and Quotient Associates[19].

[17] http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2013/key-licence-exempt-bands/
[18] http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2013/demand-wireless/
[19] http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2013/wifi-met-area/

Section 3

The future role of Wi-Fi in helping to meet the demand for wireless data services

3.1 Wi-Fi[20] equipment operates in the 2.4 and 5 GHz 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.

3.2 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 This has enabled Wi-Fi to evolve 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 to be a huge global market success, with estimated shipments[21] 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 be offered as standard in a growing range of consumer devices.

3.4 The use of Wi-Fi connectivity is currently playing an important role in both:

3.4.1 Providing mobile broadband connectivity in high demand indoor and outdoor locations;

3.4.2 Enabling in indoor wireless network connections between different Wi-Fi enabled equipment.

3.5 In this section we consider the future role Wi-Fi might play in meeting the rapidly increasing demand for mobile data capacity and wireless connectivity. We do this from both an indoor and outdoor perspective:

3.5.1 *Indoors:* The ability of Wi-Fi to support the increasing use of mobile data services and wireless networking indoors;

3.5.2 *Outdoors:* The use of Wi-Fi in a growing number of outdoor small cells to help meet the growing demand for capacity for mobile broadband and machine-to-machine applications.

The future use of Wi-Fi indoors

Wi-Fi is already playing a very important role in delivering indoor wireless connectivity

[20] 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.

[21] "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-

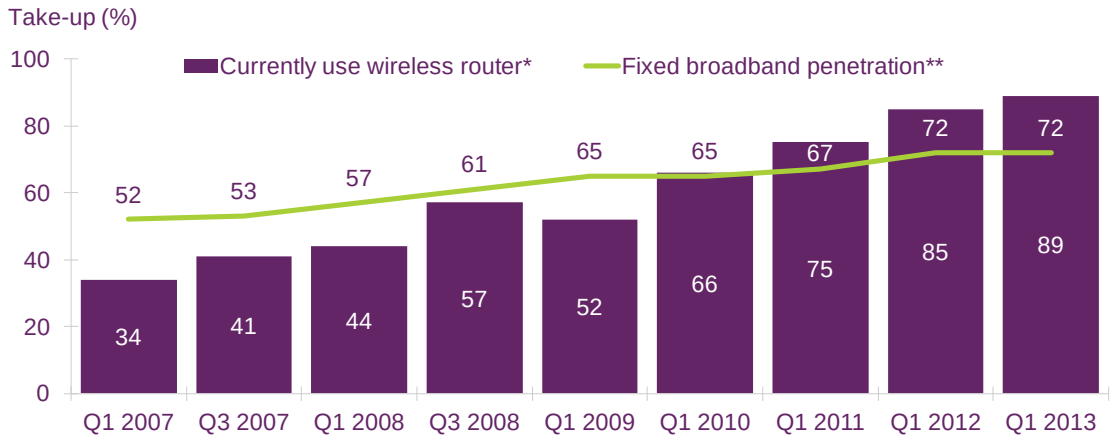
3.6 Wi-Fi is increasingly being used to wirelessly connect devices in offices and homes driven by:

3.6.1 The increasing deployment of in-building wireless networking solutions using Wi-Fi technology;

3.6.2 The increasing penetration and use of Wi-Fi enabled devices, including smartphones and tablet PCs, and their use indoors to gain access to low cost high speed mobile broadband connectivity.

3.7 As Figure 5 illustrates, Ofcom research estimates that 89% of consumers with a fixed broadband connection used a wireless router in Q1 2013[22].

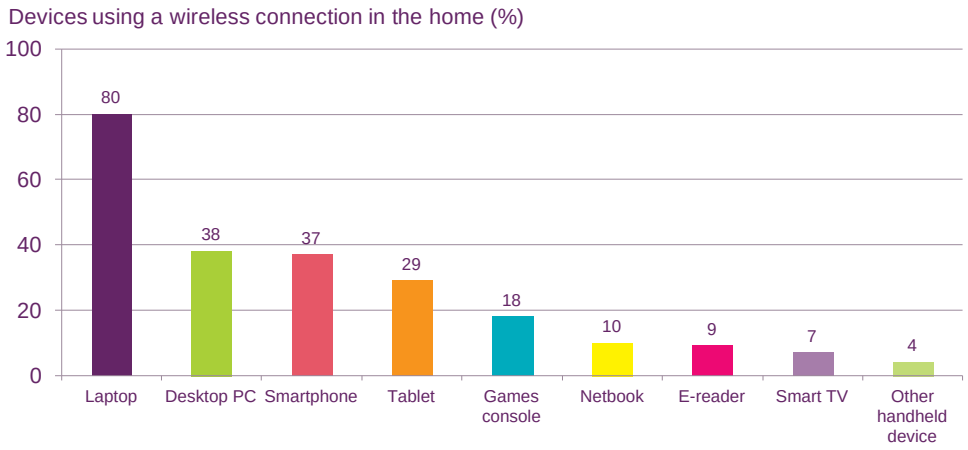
Figure 5: Use of wireless router versus broadband take-up, 2007 – 2013



Source: Ofcom Communications Market Report, 2013

3.8 Figure 6 illustrates how Wi-Fi is also being used to wirelessly connect a range of consumer equipment, including smart TVs, games consoles and security systems. While emerging variants of Wi-Fi are being marketed as fast enough to distribute multiple high definition video streams around the home[23].

Figure 6: Consumer use of wireless devices in the home, 2013



[22] Ofcom Technology Tracker (Q1 2013)
[23] http://www.broadcom.com/press/release.php?id=s637241

Source: Ofcom Technology Tracker, Q1 2013

3.9 From a mobile broadband perspective, Wi-Fi is already playing an important role in helping meet the rapidly increasing demand for mobile data capacity by providing an alternative to mobile networks in providing mobile broadband connectivity indoors. In 2012, Cisco estimated that 28% of mobile data traffic indoors was carried using Wi-Fi. This is predicted to rise to 48% by 2017[24]. With this approach the fixed broadband connection to the building is used to provide a backhaul connection to the internet.

3.10 A more recent report commissioned by the European Commission identified that over 71% of all wireless data traffic that was delivered to smart phones and tablets in the EU was delivered via Wi-Fi[25].

Currently the majority of Wi-Fi use is concentrated in the 2.4 GHz band

3.11 Simple Wi-Fi networks, consisting of one isolated access point and one or more client devices, such as smartphones or laptop computers, typically operate on a single Wi-Fi frequency or channel. There are a finite number of these Wi-Fi channels available, especially in the more commonly-used 2.4 GHz band.

3.12 Multiple Wi-Fi networks operating in the same or adjacent channels can cause interference, resulting in reduced data rates and poor application performance. The potential for interference is generally greater in the 2.4 GHz than the 5 GHz band, because there are a lower number of non-overlapping channels available in the 2.4 GHz band.

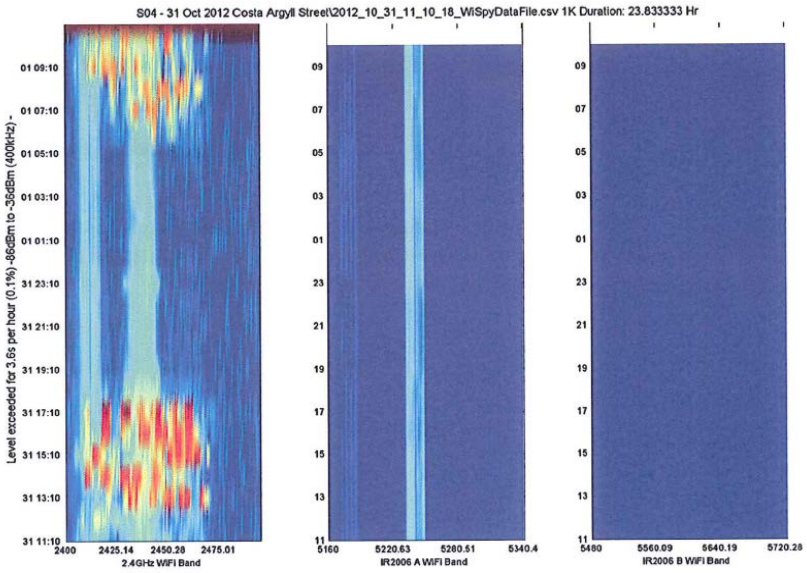
3.13 Recent measurements commissioned by Ofcom identified that the 2.4 GHz band is currently being much more heavily used for Wi-Fi than the 5 GHz band; on average, occupancy of the 2.4 GHz band is approximately 10 times that of the 5 GHz band[26]. An example for this can be seen in Figure 7, which illustrates the levels of Wi-Fi usage for the 2.4 and 5 GHz bands in a central London coffee shop. The colours correspond to the level of usage measured, with blue indicating no usage, green Indicating moderate usage and red indicating high usage.

[24] http://www.cisco.com/web/solutions/sp/vni/vni_mobile_forecast_highlight/index.html#~Country

[25] "Study on impact of traffic off-loading and related technological trends on the demand for wireless broadband spectrum", study for the European Commission, available at http://bookshop.europa.eu/en/study-on-impact-of-traffic-off-loading-and-related-technological-trends-on-the-demand-for-wireless-broadband-spectrum-pbKK0113239/?CatalogCategoryID=CXoKABst5TsAAAEjepEY4e5L

[26] "Utilisation of key licence exempt bands and the effects on WLAN performance", available at http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2013/key-licence-exempt-bands/

Figure 7: Example of Wi-Fi utilisation in an indoor commercial environment



Source: Study on the utilisation of key licence exempt bands and the effects on WLAN performance

3.14 In certain locations, these measurements found that Wi-Fi networks operating at 2.4GHz exhibited degraded performance due to interference, which was mostly caused by densely-packed access points operating on adjacent, overlapping channels. This problem does not occur at 5GHz, due to the non-overlapping channels used in this band.

The key future challenge for indoor Wi-Fi is meeting the demand for higher speed connectivity

3.15 While current use of the 5 GHz band by Wi-Fi is relatively low, we expect this to change rapidly over the coming years. A study commissioned by Ofcom[27] found that the current spectrum allocation for Wi-Fi at 2.4 and 5 GHz is likely to be under pressure by 2020 and that additional spectrum may be required to continue to meet expected demand. This will be particularly the case for high speed indoor wireless networks, which require multiple high bandwidth non-overlapping channels.

3.16 A future challenge for indoor Wi-Fi networks is to provide higher speeds that match those being provided by the rollout of fixed superfast broadband networks. The evolution of theoretical maximum Wi-Fi and fixed broadband speeds is illustrated in Figure 8. The current generation of Wi-Fi equipment, known as 802.11n, offers a significant speed increase, compared to previous versions. This is due to:

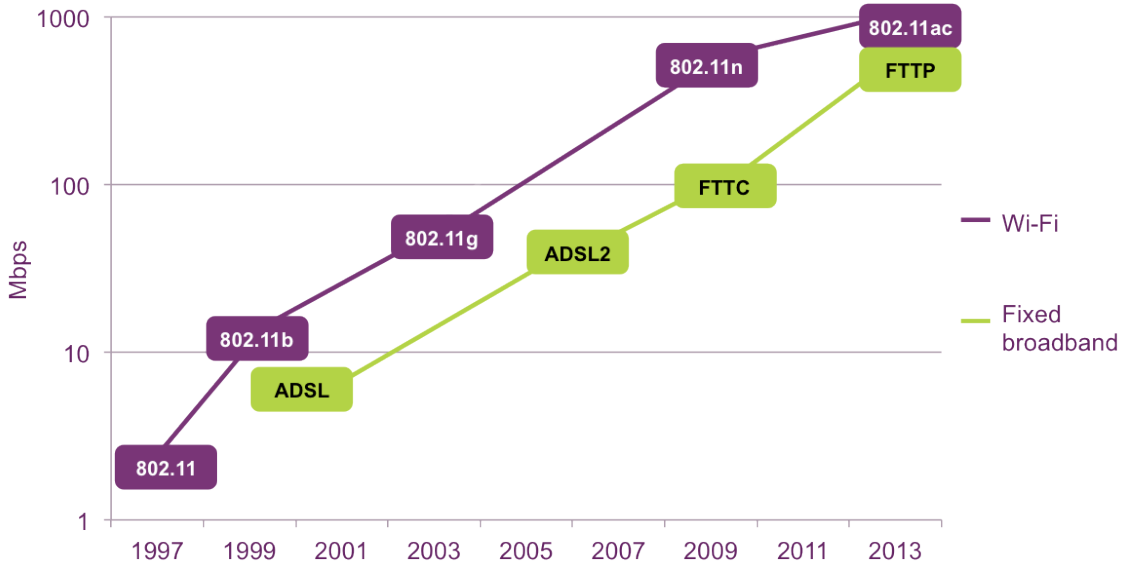
3.16.1 The use of advanced antenna and signal processing technologies, known as Multiple Input Multiple Output, or MIMO, which allow more data to be sent in the same bandwidth;

3.16.2 Support for operation in the relatively unused 5 GHz band; and

[27] "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

3.16.3 Support for operation in 40 MHz channels, in addition to the 20 MHz channels of previous versions.

Figure 8: Evolution of Wi-Fi standards compared to fixed broadband technologies



Source: Ofcom / Plum consulting

3.17 The emerging, next generation Wi-Fi standard, known as 802.11ac, increases data rates further, through improved MIMO support and operation in bandwidths of up to 160 MHz. These enhancements will help Wi-Fi keep pace with developments in fixed broadband, provided there continues to be a sufficient amount of spectrum to support the wider channel widths required.

3.18 Over short ranges, Wi-Fi will be able to deliver very high data rates through the use of advanced signal processing (including MIMO), wide channel bandwidths or a combination of both. Achieving high data rates further away from the access point, however, will primarily rely on the use of wider bandwidth channels of 80 or 160 MHz, as the effects of building losses caused by internal walls and doors reduce the performance gains that advanced signal processing can provide, and wider channel widths operating with reduced modulation levels and greater levels of error correction are needed.

3.19 Hence, in order to deliver comparable data rates to future superfast broadband along with good coverage throughout the home, higher channel bandwidths will be required. Figure 9 illustrates that at least an 80 MHz channel would be required to provide the required data rate, based on the assumption that 16-QAM will need to be used to ensure reliable coverage throughout the home[28]. This is approximately 18% of the spectrum available to Wi-Fi in the 5 GHz band and would mean that where building walls do not to provide high levels of isolation between different Wi-Fi users, there could only be a maximum of five households in the same location able to operate at these high speeds. This may lead to pressure on available, uncontended spectrum in dense urban environments, such as apartment blocks to support higher speed indoor networks.

[28] QAM (Quadrature amplitude modulation) describes a method of combining two amplitude-modulated signals into a single channel, thereby doubling the effective bandwidth.

Figure 9: Wider channel bandwidths will be needed to support high speeds throughout the home

Increase in channel encoding scheme leads to higher data rates – but higher schemes are less likely to deliver extensive reliable coverage indoors

Estimated usable* data rate shared between all users, Mbps

Modulation and coding scheme	Channel bandwidth 20MHz	40MHz	80MHz	160MHz
BPSK	5	15	30	60
QPSK	15	30	55	115
16-QAM	25	55	115	235
64-QAM	50	110	235	485
256-QAM	80	160	350	700

- 16-QAM should give reliable coverage throughout a typical home.
- A channel of at least 80MHz will be required to support a speed similar to future superfast broadband (i.e. 100Mbps)
- There are approximately five 80MHz channels within the current Wi-Fi allocation at 5GHz

** Includes of shared data rate available to applications, in a 2x2 MIMO configuration*

Source: Ofcom

3.20 Therefore, support for broader bandwidths of 80 or 160 MHz are likely to be important for achieving a combination of high data rates and good coverage. This represents an increase in demand for spectrum over the 20 or 40 MHz channels commonly used today and may lead to increased pressure for the supply of additional Wi-Fi spectrum.

3.21 While wider bandwidths will be required to support the higher data rates offered by superfast broadband, an additional, important driver will be the increased use of networked devices within the home or office. For example, a migration to the use of laptops and tablets in offices will lead to a significant amount of data being transferred over Wi-Fi networks; in the home, equipment is emerging that allows the local, wireless streaming of high definition video and audio. Much of this data may be both stored and consumed within the local area and represents a significant demand on top of that required to support the transfer of Internet-based content via a fixed broadband connection.

3.22 There is insufficient bandwidth in the 2.4 GHz 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 5 GHz band. The current allocation of spectrum at 5 GHz for Wi-Fi is illustrated in Figure 10.

Figure 10: Current and potential future allocation of 5GHz spectrum for Wi-Fi

Question 1: How is demand for indoor wireless data connection speeds and capacity likely to develop over the next 5–10 years?

There is an opportunity to increase in the supply of spectrum at 5 GHz

3.23 A proposal to increase the amount of spectrum at 5 GHz available to Wi-Fi devices is being discussed in preparation for the World Radio Conference 2015 (WRC-15) under agenda item 1.1. The proposals put forward so far, also illustrated in Figure 8, are to explore the possibility of making three additional bands available:

3.23.1 5350 – 5470MHz;

3.23.2 5725 – 5850MHz and

3.23.3 5850 – 5925MHz.

3.24 In parallel, as part of the conference preparatory process the European Conference of Postal and Telecommunications Administrations (CEPT) is analysing possible sharing of Wi-Fi with incumbent users in order to develop a European Common Position regarding extending the 5 GHz band[29]. In addition, Ofcom recently issued a call for inputs[30], which sought views on the bands that are to be discussed under WRC-15 agenda item 1.1 and sought views on the suitability of these bands for use by mobile or wireless broadband including 5 GHz bands for Wi-Fi.

3.25 Separately to the WRC-15 proposals, CEPT are also investigating higher power use for Short Range Devices as part of the annual review of the EC decision on Short Range Devices, including consumer Wi-Fi equipment, in the 5.8GHz. This band is already used for higher power Wi-Fi in a number of countries, including the United States. In the UK, higher power use in this band is currently limited to fixed wireless access on a light licensed basis.

3.26 Any increase in the allocation for Wi-Fi in the 5 GHz bands would need to take into account a number of different factors, including:

3.26.1 The level of interference protection required by other spectrum users in the 5 GHz band, including military radar and earth exploration satellite services;

3.26.2 The extent to which these other spectrum users are using spectrum in all locations (including satellite footprints), which impacts the number and size of the locations in which Wi-Fi devices could operate;

3.26.3 The benefits that higher speed Wi-Fi connections and maintaining the quality of service of indoor mobile broadband connections to for example, smartphones and tablet PCs, could provide to consumers; and

3.26.4 The international harmonisation of the additional 5 GHz Wi-Fi bands, which can create greater economies of scale and lower equipment prices.

[29] Conference Preparatory Group Project Team D
[30] See call for input on future demand for mobile broadband spectrum, March 2013, available at http://stakeholders.ofcom.org.uk/consultations/cfi-mobile-bb/summary

Question 2: Will an extension of the 5 GHz band be required if Wi-Fi is to play a sustainable role in meeting the growing demand for indoor wireless connectivity?

Requirements for additional shared spectrum bands for indoor wireless use

3.27 There are other, emerging indoor applications which may require access to alternative spectrum to that provided by Wi-Fi in the 2.4 and 5 GHz bands. These include:

3.27.1 Services which do not require the high data rates supported by Wi-Fi but require more extensive indoor coverage. These might include interconnections between sensors and monitoring systems, such as home area networking for smart meters. A key feature of these applications is that they typically exchange a small amount of data and the priority is for ubiquitous coverage throughout the building, rather than high data rate. For these applications, the use of a lower frequency band with better indoor penetration may be more suitable, such as the 870 – 876MHz band[31].

3.27.2 Services which require a higher data rate than can be supported in the 2.4 and 5 GHz Wi-Fi bands but require less extensive coverage. These might include future wireless interconnections between very high resolution screens and digital receivers and recording devices in the same room. For these applications, the use of the higher frequency 60 GHz band may be more suitable. An additional Wi-Fi standard, called 802.11ad, is emerging that specifies operation in the 60 GHz band. This band is suited to providing very high data rate connections (e.g. in excess of 1Gb/s) over very short ranges.

Question 3: Are there other types of indoor wireless applications will require access to alternative spectrum other than that provided by the licence exempt 2.4 and 5 GHz bands used by Wi-Fi?

The future use of Wi-Fi in small outdoor cells

The increasing deployment of smaller cells and the integration of Wi-Fi are being used to meet the demand for mobile data outdoors

3.28 In addition to providing indoor connectivity, Wi-Fi hotspots are increasingly being deployed outdoors to provide connectivity in high demand locations in cities and towns such as in the outdoor areas of cafes, bars and shopping centres. In addition, Wi-Fi is being deployed to provide coverage over larger metropolitan areas. Recent examples of this are in the City of London and Westminster[32]. This has led to the emergence of a number of different business models for the provision of outdoor Wi-Fi networks by established fixed and mobile network operators, third-party providers and individual businesses installing public Wi-Fi hotspots both indoors and outdoors.

[31] http://stakeholders.ofcom.org.uk/binaries/consultations/870-915/summary/870-915_condoc.pdf
[32] http://www.cityoflondon.gov.uk/business/commercial-property/utilities-and-infrastructure-/Pages/wi-fi.aspx

3.29 Outdoor Wi-Fi networks are often deployed in areas of high demand for mobile data and can be used to carry mobile broadband traffic that would have otherwise been carried on cellular networks. As the use of this approach increases, we expect that there will be a significant increase in the number of small Wi-Fi outdoor cells, in particular to meet the demand for mobile broadband capacity in urban areas; many of these cells are likely to support both Wi-Fi and cellular technologies such as LTE.

3.30 Ofcom research estimates that among those consumers who use a smartphone to access the internet 30% use Wi-Fi outdoors via commercial hotspots[33]. Despite this, the total amount of mobile broadband data being carried on outdoor Wi-Fi networks remains relatively small compared with cellular networks. One reason for this is the relative difficulty today in seamlessly moving between mobile and public Wi-Fi networks. Consumers often need to search for an available network, enter a username and password and, if access is not provided as part of their mobile plan, provide payment details.

3.31 However, new standards, such as Hotspot 2.0 from the Wi-Fi Alliance, are seeking to make the transition between cellular and Wi-Fi networks more seamless. With these standards in place and supported by service providers, users will be able to access public Wi-Fi networks without searching or entering personal or payment information. While this development has obvious benefits to users, one consequence is that the amount of data delivered over public Wi-Fi networks is likely to increase. This may in turn drive up the number of access points required.

3.32 The more extensive deployment of outdoor Wi-Fi access points will also lead to an increased requirement for backhaul connectivity. Some metropolitan area Wi-Fi deployments are using spectrum at 5 GHz to interconnect access points, effectively creating a wireless *daisy chain* back to a shared, wired connection to the core network. While this is a cost effective approach, it has the potential to reduce the supply of 5GHz spectrum available to Wi-Fi access networks at a given location. An alternative could be to use a different frequency band for backhaul, such as higher frequency bands, in much the same way that mobile networks often use higher frequencies for this purpose.

Question 4: What role do you think Wi-Fi will play in providing wireless broadband connectivity outdoors over the coming 5-10 years?

There is a potential risk that a lack of co-ordination between outdoor access points could lead to a reduction in performance over the long term

3.33 As discussed earlier in this section, it is relatively easy to manage interference between multiple, indoor Wi-Fi networks, as walls between buildings can act as a helpful barrier to signals propagating between them. In larger, centrally managed buildings, such as offices, shopping centres and stadia, Wi-Fi is often deployed using a single vendor Wi-Fi network solution which can be centrally co-ordinated to minimise interference between Wi-Fi access points to improve performance and coverage.

3.34 For outdoor Wi-Fi use it is potentially much harder to manage interference and maintain a good quality of service because:

[33] Ofcom Technology Tracker (Q1 2013)

3.34.1 In outdoor environments there can be several different Wi-Fi providers operating in the same locality who cannot be centrally managed to minimise interference;

3.34.2 Unlike indoor use, building walls cannot be relied upon to provide a barrier to interference between uncoordinated Wi-Fi access points.

3.35 Wi-Fi devices have been designed to operate in the same shared spectrum band and to be relatively robust to interference. To achieve this Wi-Fi equipment operates at relatively low transmit powers and utilises polite protocols, by which devices listen to check that the channel is clear before transmitting. If other traffic is detected, the device with data to send waits for a period before checking again for a clear channel.

3.36 This so-called "listen before talk" approach works well where the competing demand for Wi-Fi spectrum is relatively low between Wi-Fi access points and devices, such as those currently found in homes. In these relatively low demand environments, Wi-Fi is able to support high data rates.

3.37 However, if too many uncoordinated outdoor Wi-Fi access points are deployed at a particular location and accessed by a large number of users, performance degrades and users will experience low data rates and dropped connections. This is an example of the "tragedy of the commons", where the difficultly in co-ordinated demand for a shared resource (in this case, spectrum) reduces the quality of experience for all users.

3.38 A study conducted on our behalf investigated the use of Wi-Fi to deploy metropolitan area networks. It concluded that the wider deployment of coordination and management protocols, such as those developed and used in single vendor enterprise networks[34], could not be relied upon to avoid performance degradation in areas of high network density such as metropolitan areas[35]. This is primarily because there will continue to be a wide variety of equipment in operation, with varying degrees of support for co-ordination approaches. Furthermore, even where co-ordination approaches are supported, benefits may be limited due to the inconsistent way in which such enhancements are implemented.

3.39 A potential alternative approach for helping maintain the quality of service provided by Wi-Fi outdoors is to use improved radio access technologies to help manage interference. In particular, the adoption of smart antennas and beam forming, in which transmissions are steered directly between communicating devices, could lead to better spectrum efficiency, improved signal quality and reduced contention[36]. However, whilst these approaches are likely to provide benefits where a Wi-Fi network can be centrally controlled it is unlikely to reduce the risk of interference and reduced performance for uncoordinated outdoor Wi-Fi access points.

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[34] This includes IEEE standards for measuring and sharing network measurements, and for modifying equipment operation (802.11k, 802.11v). Enterprise networks often also use proprietary tools that optimise network performance based on observed measurements.

[35] "Study on the use of Wi-Fi for Metropolitan Area applications" available at http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2013/wifi-met-area/

[36] Multiple devices in the same Wi-Fi network *contend* for access to the spectrum. The more devices and/or the greater the amount of data to be sent, the greater the level of contention in the network. Beamforming can act to reduce contention by physically steering the link towards only those devices that need to communicate at a given time, in effect temporarily reducing the number of devices in the network.

Question 5: Will the increased deployment of Wi-Fi access points outdoors create a risk of reduced quality of service performance over the longer term and, if so, will approaches to co-ordinate access point performance be able to mitigate this risk?

Increasing the amount of Wi-Fi spectrum available at 5 GHz would be beneficial in maintaining quality of outdoors but new approaches to how spectrum is accessed by devices are also likely to be needed in the longer term

3.40 A study into the technologies and approaches to share spectrum on a licence exempt basis indicated that a new set of rules may be required beyond those currently used by Wi-Fi, if future demand is to be met[37]. Examples of improved sharing mechanisms include advanced dynamic frequency selection, geolocation databases and dependent station enablement[38]. These approaches seek to improve sharing through improved management of interference and will be relevant for outdoor Wi-Fi use.

3.41 Improved sharing mechanisms could create a 'middle ground' between the extremes of using centralised licensing approach to manage interference and the relatively simple spectrum access methods currently used by devices in the licence exempt bands. In this way some of the benefits of a licensed approach in terms of maintaining quality of service could be combined with the low barriers to spectrum access and greater opportunities for service innovation by different industry sectors associated with a licence exempt approach.

3.42 These approaches are likely to benefit from recent developments in Dynamic Spectrum Access technologies such as geolocation databases and cognitive sensing which are set out in the section 4 in more detail. In order to be effective these approaches are likely to require access to new spectrum bands where all of the devices support new approaches to improve how spectrum is allocated and shared between different devices. In section 4 we also explore how some of these new spectrum bands could be made available by exploiting the gaps in geographical spectrum usage in some of the frequency bands currently dedicated to a single service.

Question 6: Will improved approaches to accessing spectrum in licence exempt bands be needed in the longer term to maintain the quality of service achievable for outdoor public mobile broadband and/or M2M services? If so, which approaches are most likely to be adopted and how likely do you think they are to be successful in improving access to spectrum?

[37] "Technologies and approaches for meeting the demand for wireless data using licence exempt spectrum to 2022" available at http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/2013/demand-wireless/

[38] Dependent station enablement describes an approach by which licence exempt devices can only transmit once they have received an enabling signal from a spectrum co-ordinator.

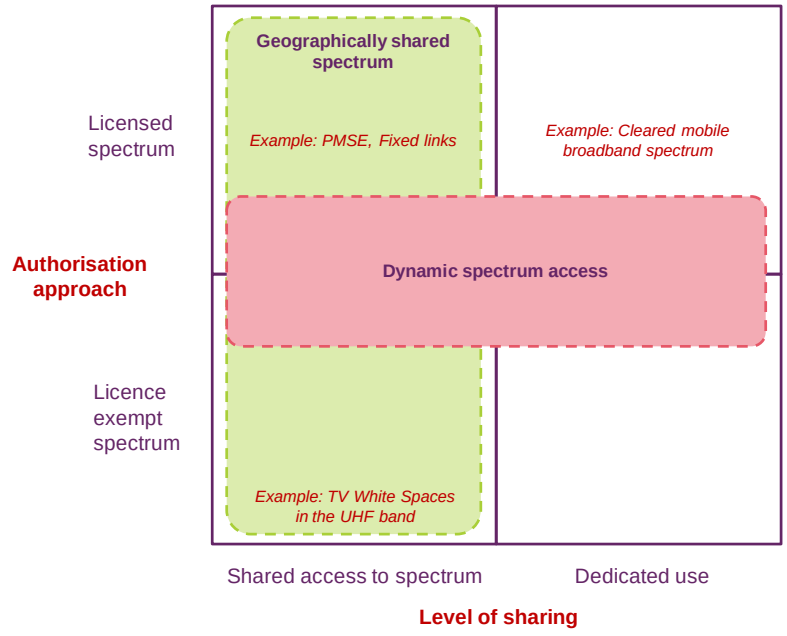
Section 4

Increasing spectrum supply and better managing its use

4.1 In section 3 we identified that LE sharing in the bands used by Wi-Fi is well positioned to help meet the growing demand for wireless data capacity indoors; but that in outdoor locations, new, more advanced approaches may be needed by LE devices to maintain a good quality of service in the longer term. We also identified that these approaches would most likely need to be used in new spectrum bands to minimise the risk that legacy devices, which lack such support, degrade performance.

4.2 In this section we consider the use of different spectrum approaches to both help increase the supply of spectrum for mobile and wireless data services and to better manage its use to deliver improved performance.

Figure 11: Role of geographically shared spectrum and dynamic spectrum access



4.3 Figure 11 illustrates the two broad categories discussed in this section:

4.3.1 **Geographical spectrum use**: This has the potential to increase the supply of spectrum for mobile broadband and machine-to-machine (M2M) use by exploiting gaps in spectrum usage in frequency bands currently dedicated to specific services. We already have a significant programme of work underway (our TV White Spaces project) for the UHF TV bands to enable unused frequencies at different locations, known as white spaces, to be used by licence exempt devices. Here a geolocation database is used to enable devices to identify white space spectrum. This approach is frequency independent and could be extended to other spectrum bands to increase the supply of mobile broadband and M2M spectrum; and

4.3.2 **Dynamic spectrum access**: The potential to enable a better quality of service to be achieved in shared spectrum bands using advances in Dynamic Spectrum Access (DSA) technologies. These might include an extension of the geolocation database approach to also manage interference between devices accessing spectrum. In addition, cognitive sensing techniques can allow devices to monitor how other devices are accessing spectrum, giving devices the ability to make better informed choices over which frequency and/or time slot to use at given location at a particular time of day. Both approaches seek to minimise the risk of harmful interference with other devices. In this way a better quality of service can be potentially maintained for all of the devices sharing access. This is likely to be of particular value in LE spectrum bands where interference between devices is more difficult to manage than in licensed spectrum bands.

Enabling new spectrum bands to be made available by exploiting the gaps in geographical spectrum usage

4.4 Much of the spectrum used today has been allocated to a dedicated single user. This makes it easier to manage interference between users, allowing high power operation and wide area coverage to be achieved. It has also provided the confidence in spectrum access needed to support significant investment in providing national wireless infrastructure. However, it has also led to some spectrum bands not being fully utilised in all locations all of the time. These gaps in spectrum usage can be potentially shared with other users to deliver a wider range of services. Some of these gaps are already being used to a limited extent, for example to support wireless camera and microphone applications.

4.5 This same approach could also be used to increase the supply of spectrum for mobile broadband and M2M use beyond that provided by cleared spectrum bands. Here, rather than fully clearing existing spectrum users, spectrum is shared on a geographical basis between the primary licensed user and mobile broadband services. This approach is likely to be well suited to providing additional spectrum for the growing number of small cells that will be needed to meet the high demand for mobile data capacity in urban areas. This is because these small cells are able to operate at relatively low power making it easier to:

4.5.1 Protect incumbent spectrum users from interference;

4.5.2 Minimise interference between different small cells provided by different operators.

4.6 Spectrum made available in this way is more likely to provide a complement, as opposed to a replacement, for cleared mobile broadband spectrum. This is because cleared spectrum, which can be operated at higher power, is more likely to be used to increase the coverage and capacity of wide area mobile networks and geographically shared spectrum is more likely to be used by small cells to provide localised increases in capacity in cities and towns.

4.7 The attractiveness of spectrum sharing for small cell use in particular frequency bands will be dependent on a number of broad factors including:

4.7.1 The level of interference protection required by the incumbent spectrum user, which impacts on the coverage achievable by the small cells;

4.7.2 The geographical use of spectrum by the incumbent spectrum user, which impacts the locations where small cells can be deployed;

4.7.3 The frequency of the spectrum band and whether its propagation characteristics match those needed by small cells; and

4.7.4 The international harmonisation of the shared spectrum band for mobile broadband use, which can create greater economies of scale and lower equipment prices.

4.8 Given these factors, our initial view is that frequency bands where the current user is using spectrum mainly in remote rural locations are likely to be most suited to spectrum sharing with small mobile broadband cells in urban areas. Frequency bands with these characteristics could potentially be made available through the Government Public Sector Spectrum Release programme, given the nature of some public sector spectrum use.

4.9 Responses to this consultation will be used to inform a more detailed assessment of the attractiveness of particular frequency bands for spectrum sharing in our future work.

4.10 Proposals to facilitate geographical shared access to increase the future supply of mobile broadband spectrum are also being explored within Europe. Licensed Shared Access (LSA) is a regulatory approach currently being considered which aims to promote a more efficient use of a particular frequency band by opening it up to access by new users on a shared geographical basis. LSA is intended to be applicable to frequency bands that are not being used by licensees at particular locations or times, extending a certain level of quality of service to all rights holders, including sub-licensees.

4.11 The LSA concept is currently being developed within the Radio Spectrum Policy Group (RSPG), an advisory group that assists the European Commission with the development of spectrum policy. In parallel, the European Conference of Postal and Telecommunications Administrations (CEPT) has initiated work on an LSA regulatory framework, initially focusing on the possible use of LSA in the 2.3GHz band to provide mobile broadband services.

4.12 The general principle of geographic spectrum access can be applied to any frequency band. Ofcom recently issued a call for inputs[39], which sought views on the future demand for mobile broadband spectrum and the potential role for a range of candidate frequency bands in meeting that demand. The document set out the bands that are to be discussed under WRC-15 agenda item 1.1 and sought views on the suitability of these bands for use by mobile or wireless broadband.

4.13 At this early stage, it is not possible to say which of these bands, if any, may be used by mobile broadband services. Furthermore, it is not yet clear whether bands would be cleared of existing users and made available for dedicated mobile broadband use, or partially cleared and made available on a shared basis.

4.14 Later this year we will be publishing proposals for a mobile data strategy which will consider future bands for mobile broadband more generally.

[39] See call for input on future demand for mobile broadband spectrum, March 2013, available at http://stakeholders.ofcom.org.uk/consultations/cfi-mobile-bb/summary

4.15 Ahead of this work, we welcome views from stakeholders on the suitability of candidate bands to provide additional mobile broadband spectrum through the use of geographical shared access with existing users.

Question 7: Which frequency bands are most likely to be best suited to providing geographical shared access, including via a geolocation database approach, for use by mobile broadband, for example small cells and M2M applications?

Question 8: Would access to these bands best be realised through licensing or licence exemption?

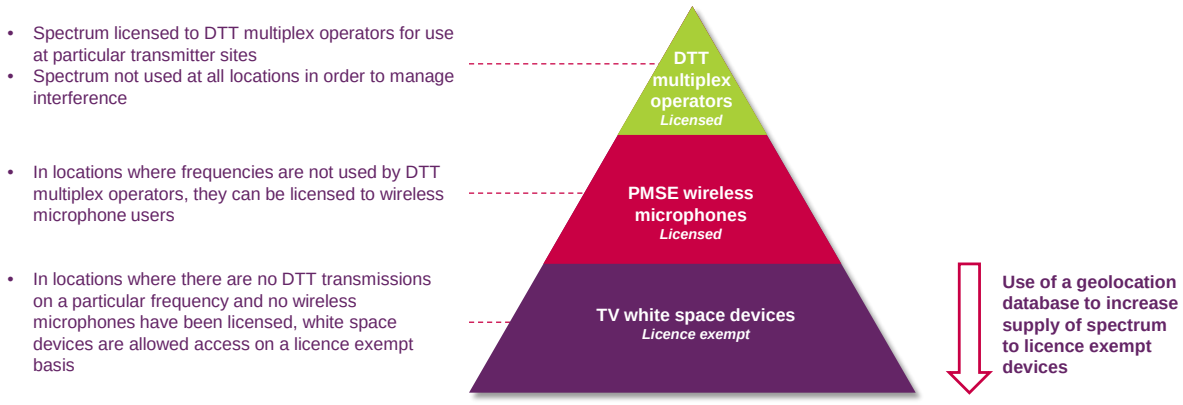
4.16 There are a number of approaches of varying complexity currently used to manage the shared use of spectrum within a geographic area. For example, some lightly licensed/self co-ordinated spectrum bands for fixed link services are co-ordinated (on a link by link basis) by maintaining a publically available record of assignments for the user to access and then use in the co-ordination process. By contrast, programme making and special events (PMSE) access to shared spectrum is co-ordinated electronically through an online system.

4.17 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). Different devices can be allocated different shared access rights to the spectrum depending on what type of service they are being used for and where they are operating.

4.18 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) [40]. These spectrum bands have been licensed for use for DTT services and are also shared with 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. Devices operating in white spaces use the databases to 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.

[40] http://stakeholders.ofcom.org.uk/consultations/whitespaces/summary

Figure 12: Example of tiered spectrum access enabled by sharing



Source: Ofcom

4.19 This approach creates a tiered shared access model in the UHF TV bands (see Figure 12), in which the method of managing access to the same band of spectrum can be tailored to different devices or applications. In this example, the primary users are the digital terrestrial TV (DTT) multiplex operators. Wireless microphones are licensed in those locations where the primary licensee is not using the spectrum (subject to the operating parameters provided by geolocation databases). White space devices access any remaining unused spectrum, which in effect increases the overall supply of LE spectrum.

4.20 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, 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 increase in quality of service is required.

4.21 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 3.5 GHz band, where maritime radars are the primary user, is being pursued for use by small cells[41]. 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.

Question 9: Do you believe that tiered shared access to a range of spectrum bands has a role in meeting demand for mobile and wireless data and, if so, which applications and devices do you think will be particularly suited to this access model?

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

Maintaining quality of service in LE spectrum bands using DSA

4.22 Wi-Fi devices operate on a LE basis and employ and a range of relatively simple approaches for managing interference between spectrum users, including:

4.22.1 An access point will listen for incumbent spectrum users, such as radars, before transmitting, switching to an alternative frequency if the channel is busy;

4.22.2 An access point can also reduce its transmit power in order to reduce the likelihood of interference with incumbent users; and

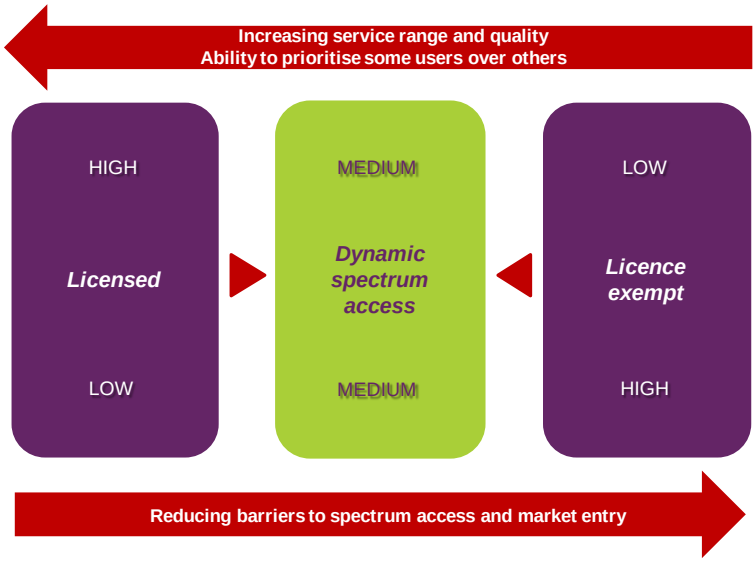
4.22.3 Wi-Fi devices use a "listen before talk" approach, whereby devices with data to transmit listen to check that the channel is free of other Wi-Fi devices before transmitting.

4.23 This polite approach works well in lightly congested environments, where it reduces the likelihood of interference with incumbent services and shares the spectrum with other Wi-Fi users. However, it is susceptible to a *tragedy of commons* occurring in more heavily congested areas, where increasing numbers of users reduce the quality of service for everyone.

4.24 A new approach, often referred to as Dynamic Spectrum Access (DSA), is emerging to enable a better management of interference in shared licensed and licence exempt spectrum bands (see Figure 13). This may be capable of allowing licence exempt use, in particular, to achieve a better compromise between achieving a good quality of service associated with a licensed approach, whilst maintaining the low barriers to spectrum access provided by a licence exempt approach.

4.25 The DSA approach involves devices using a combination of geolocation and cognitive sensing technologies to gather information on the use of the same spectrum band by other users. This information is then used to make real-time decisions on how it should operate at a given location (e.g. frequency, power level etc.), enabling devices to avoid causing interference with others and to achieve a better quality of service overall.

Figure 13: Different approaches to sharing spectrum



Source: Ofcom

4.26 In order for this approach to achieve its full potential in improving the quality of service, it would need to be adopted by all of the devices sharing spectrum with the primary user. This will be potentially much easier to achieve in new DSA spectrum bands where there are no legacy devices that do not support these more sophisticated approaches to sharing spectrum.

4.27 In addition to helping maintain the quality of outdoor mobile broadband services more generally, the use of DSA techniques is likely to be of particular benefit in the emerging M2M market where:

4.27.1 Low barriers to spectrum access, enabled by LE spectrum sharing, could act as an important enabler for innovation new M2M applications by a wide range of different industry sectors; and

4.27.2 Good quality of service connections will be needed for M2M applications used, for example, to enable a better management of critical transport and power network infrastructure.

4.28 There are a number of technological developments than can allow spectrum to be more effectively shared between devices in heavily congested areas. Some of these have been developed specifically to access white spaces, and can be further developed to support DSA, while others are general wireless technologies that are also applicable to DSA:

4.28.1 **Geolocation databases – assignment:** As described above, a geolocation approach can be used to help increase the supply of spectrum. The geolocation database, as currently envisaged for TV white space use, assigns access to devices on a licence exempt basis using frequencies and power levels that have been calculated to minimise the risk of harmful interference to incumbent users. The role of the database is only to manage interference to primary users; the database does not actively manage the assignments made to non-primary, white space devices, which must be sufficiently polite to share spectrum fairly. For example, they might employ “listen before talk” protocols similar to those used by Wi-Fi to avoid interfering with nearby white space devices;

4.28.2 **Geolocation databases – assignment and management:** Future generations of database could have their functionality extended to more actively manage spectrum. Here, the database would log assignments and use this information as an input to future assignments. For example, the database could actively steer new assignments towards bands with fewer devices in order to reduce contention. It will also be possible to reflect devices’ (or users’) quality of service requirements through this finer grained assignment and management approach. This could facilitate the tiered approach to sharing described in the previous section, with access to spectrum and protection from interference tailored to each device or user type;

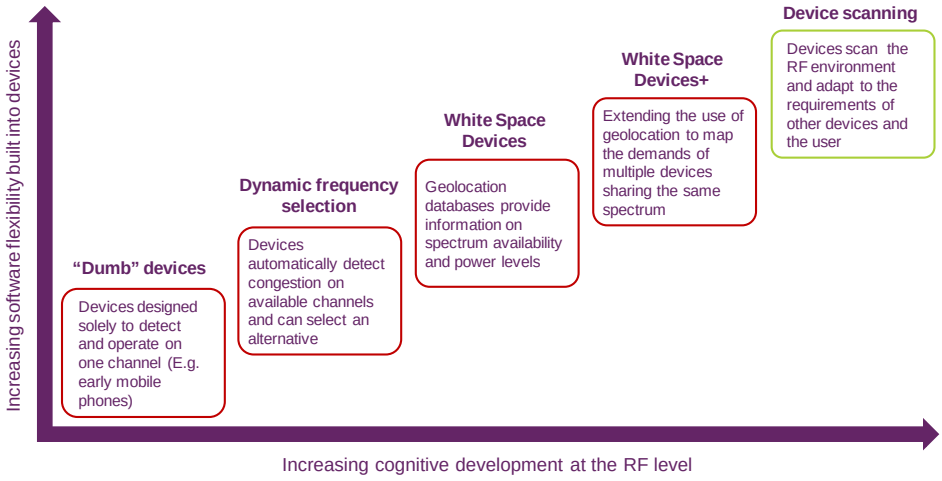
4.28.3 **Sensing approaches:** Our previous work on TV white spaces[42] acknowledged the technical barriers to implementing cost-effective spectrum sensing in consumer equipment. We concluded at the time that sensing would only become viable in the longer term. We note ongoing development work to realise cost-effective sensing and activities that are exploring hybrid approaches, combining both geolocation databases and sensing[43];

4.28.4 **Smart antennas:** Intelligent antennas, that are able to accurately focus their energy between transmitter and receiver, could be used to reduce interference between users; and

4.28.5 **Carrier aggregation**: In the event that the spectrum available at a given location is non-contiguous, aggregation enables a device to combine frequency bands together into a usable carrier of sufficient bandwidth.

4.29 The above DSA techniques are at various stages of maturity and many technical, regulatory and commercial aspects of dynamic spectrum access remain to be resolved. Such uncertainty notwithstanding, we believe it is useful to set out our broad thinking on a future development roadmap for dynamic spectrum access, as illustrated in Figure 14.

Figure 14: Illustrative roadmap for the development of dynamic spectrum access



Source: Ofcom

4.30 We would welcome views on this roadmap and when different DSA technology approaches are likely to reach a sufficient level of maturity to become a mass market proposition.

Question 10: Do you believe DSA could play an important future role in the future in enabling a better quality of service and low barriers to spectrum access alongside conventional licensed and LE spectrum approaches?

[42] Statement on "Digital Dividend: Cognitive Access", July 2009, available at http://stakeholders.ofcom.org.uk/binaries/consultations/cognitive/statement/statement.pdf
[43] The Cognitive PMSE project, http://cpmse.research-project.de/index.php/en/

Question 11: What barriers still remain to the realisation of cost-effective sensing appropriate for low-cost consumer devices and what activities are ongoing to try to address them?

Question 12: Over what timescales could DSA become a mass market proposition?

Question 13: What role should Ofcom play, if any, to support the development of DSA and relevant technologies?

Question 14: Do you have any other views on any of the issues discussed in this consultation?

Section 5

Supporting innovation through short-term access to shared spectrum

5.1 In section 3 we have highlighted how licence exemption (LE) can reduce barriers to spectrum access, acting as a catalyst for innovation and the development of new wireless products and services.

5.2 In Section 4 we set out how spectrum sharing more generally can increase the supply of spectrum for use by wireless services and advances in dynamic spectrum access (DSA) technologies could enable a better quality of service to be achieved in shared spectrum bands. These approaches also have the potential to feature in the development of future mobile technology. However, many spectrum sharing developments remain in a research development phase and it may take several years to identify and harmonise at an international level the potential frequency bands needed to support their widespread use. In the interim period, making spectrum available on a short-term non-operational basis to support research and development (R&D) activity could be beneficial for supporting innovation in new wireless technologies.

5.3 Spectrum made available for R&D activity currently happens in response to specific requests through the non-operational licensing regime. We are interested to establish views as to how to enhance current arrangements for R&D access to spectrum, which could be used to advance the development new wireless technologies.

5.4 In addition, as part of its Information Economy Strategy[44], the Government has asked Ofcom to investigate the feasibility of implementing a geolocation database, which holds information on the spectrum that could be used for research purposes in different locations, with the aim of providing easier access to spectrum for innovation into for example 5th generation mobile (5G) and other advanced communication technologies.

Ofcom's current approach to granting access to spectrum for research and development

5.5 Ofcom currently provides access to spectrum for the purpose of research and development, testing, trials and demonstrations under the non-operational licence regime. Licences under this regime are issued on a short-term basis and share spectrum on non-protected/non-interference basis with existing users of the spectrum. Each application is individually coordinated with other potentially impacted users of the spectrum by Ofcom in order to minimise its risk of interference to them[45].

5.6 This approach has proved highly effective at providing spectrum access to innovators for R&D activity across a wide range of spectrum and applications. We believe that there remains a requirement for this type of approach to meet the breadth of

[44] https://www.gov.uk/government/publications/information-economy-strategy
[45] More information on non-operational licensing can be found at http://licensing.ofcom.org.uk/radiocommunication-licences/non-operational-tech-licence/guidance-for-licensees/

requirements in this area. However, this is a bespoke approach, with the complexity of some requirements meaning that spectrum access may take time to arrange and the nature of the spectrum available may be uncertain until the completion of the licensing activity. We are therefore interested to hear views on whether access to spectrum for research purposes using a geolocation database might have a complementary role to play alongside non-operational licensing, and more generally how current spectrum sharing arrangements could be enhanced to support innovation.

The Government's Information Economy Strategy has highlighted the importance of short-term access to spectrum for research and development purposes

5.7 The Government's Information Economy Strategy has set out a desire to explore how public sector users can share their spectrum with researchers and innovators in new ways. The strategy highlights the work that Ofcom has been carrying out on ways of sharing the unused spectrum between TV transmitters for applications, including machine-to-machine (M2M), and for future mobile broadband systems in 2.3 GHz spectrum. It suggests that this technology has further potential to make shared access to spectrum available on demand for R&D purposes. Clearances could be for a very short period (such as a few hours) and authorisation could happen immediately.

5.8 As part of its strategy, Government has asked Ofcom "to investigate the creation of an automated online geolocation database aimed at providing on-demand, short term spectrum licences for R&D into 5G and other advanced communication systems using spectrum primarily used by the public sector."

5.9 This consultation forms an important part of our response to the Government's request.

A geolocation database could enhance arrangements for providing short term spectrum access for R&D to better enable innovation in spectrum sharing

5.10 Under the approach envisaged in the Information Economy Strategy, Ofcom might create an online database which researchers could use to identify available spectrum for experimental use and to also apply for short term use of available spectrum. The database would be populated with co-existence data relating to existing users of the band and so enable access to be facilitated immediately with no need for further bespoke coordination.

5.11 The authorisation provided would be a Wireless Telegraphy Act licence similar in form to the current non-operational licence. It would define the technical details under which the licensee can operate and provide access on a non-interference/non-protected basis. Should interference arise, the licensee would be required to cease transmissions immediately.

5.12 Such an approach could potentially have a number of advantages over current arrangements including:

5.12.1 reducing barriers to entry for innovators in terms of timescales and the complexity of spectrum coordination;

5.12.2 allowing existing users to support more dynamic sharing of spectrum (this point is particularly relevant to public sector bodies);

5.12.3 provide more certainty as to the availability of spectrum for R&D purposes than current arrangements (as many of the co-existence conditions for a band will be defined a priori);

5.12.4 Allow researchers to access new bands which may be released on a shared basis and which are not yet otherwise available.

The spectrum required to support R&D in spectrum sharing and other wireless communication technologies

5.13 In section 4 we identified the broad characteristics of the frequency bands which have a good prospect of being useable on a geographically shared basis in the longer term. We recognise that researchers are also likely to value access to these bands for R&D purposes. However, we are also interested in the value that access to other frequency bands might bring in the R&D phase.

5.14 Information on the spectrum bands of most value to innovators would allow us to focus measures to improve access to spectrum for them. In such bands we could explore how co-existence and sharing arrangements could be developed to support easier access, perhaps through a geolocation based solution but also through potential enhancements to our existing arrangements.

Question 15: What are the frequency bands that would be of most value for R&D purposes?

Question 16: What are the potential benefits of using a geolocation database approach for short-term access to spectrum for R&D and how would you see this working from a practical perspective? Are there alternative approaches that could deliver similar benefits?

Question 17: What characteristics do you view as important to researchers in arrangements to facilitate temporary access to spectrum for research and development purposes?

Annex 1

Responding to this consultation

How to respond

A1.1 Ofcom invites written views and comments on the issues raised in this document, to be made **by 5pm on 7 November 2013**.

A1.2 Ofcom strongly prefers to receive responses using the online web form at http://stakeholders.ofcom.org.uk/consultations/spectrum-sharing/howtorespond/ as this helps us to process the responses quickly and efficiently. We would also be grateful if you could assist us by completing a response cover sheet (see Annex 3), to indicate whether or not there are confidentiality issues. This response coversheet is incorporated into the online web form questionnaire.

A1.3 For larger consultation responses - particularly those with supporting charts, tables or other data - please email spectrumsharing@ofcom.org.uk attaching your response in Microsoft Word format, together with a consultation response coversheet.

A1.4 Responses may alternatively be posted or faxed to the address below, marked with the title of the consultation.

Fergal Farragher
Strategy, International, Technology and Economics Group
Riverside House
2A Southwark Bridge Road
London SE1 9HA

Fax: 020 7981 3706

A1.5 Note that we do not need a hard copy in addition to an electronic version. Ofcom will acknowledge receipt of responses if they are submitted using the online web form but not otherwise.

A1.6 It would be helpful if your response could include direct answers to the questions asked in this document, which are listed together at Annex 4. It would also help if you can explain why you hold your views and how Ofcom's proposals would impact on you.

Confidentiality

A1.7 We believe it is important for everyone interested in an issue to see the views expressed by consultation respondents. We will therefore usually publish all responses on our website, www.ofcom.org.uk, ideally on receipt. If you think your response should be kept confidential, can you please specify what part or whether all of your response should be kept confidential, and specify why. Please also place such parts in a separate annex.

A1.8 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and will try to respect this. But sometimes we will need to publish

all responses, including those that are marked as confidential, in order to meet legal obligations.

A1.9 Please also note that copyright and all other intellectual property in responses will be assumed to be licensed to Ofcom to use. Ofcom's approach on intellectual property rights is explained further on its website at http://www.ofcom.org.uk/about/accoun/disclaimer/

Ofcom's consultation processes

A1.10 Ofcom seeks to ensure that responding to a consultation is easy as possible. For more information please see our consultation principles in Annex 2.

A1.11 If you have any comments or suggestions on how Ofcom conducts its consultations, please call our consultation helpdesk on 020 7981 3003 or e-mail us at consult@ofcom.org.uk . We would particularly welcome thoughts on how Ofcom could more effectively seek the views of those groups or individuals, such as small businesses or particular types of residential consumers, who are less likely to give their opinions through a formal consultation.

A1.12 If you would like to discuss these issues or Ofcom's consultation processes more generally you can alternatively contact Graham Howell, Secretary to the Corporation, who is Ofcom's consultation champion:

Graham Howell
Ofcom
Riverside House
2a Southwark Bridge Road
London SE1 9HA

Tel: 020 7981 3601

Email Graham.Howell@ofcom.org.uk

Annex 2

Ofcom's consultation principles

A2.1 Ofcom has published the following seven principles that it will follow for each public written consultation:

Before the consultation

A2.2 Where possible, we will hold informal talks with people and organisations before announcing a big consultation to find out whether we are thinking in the right direction. If we do not have enough time to do this, we will hold an open meeting to explain our proposals shortly after announcing the consultation.

During the consultation

A2.3 We will be clear about who we are consulting, why, on what questions and for how long.

A2.4 We will make the consultation document as short and simple as possible with a summary of no more than two pages. We will try to make it as easy as possible to give us a written response. If the consultation is complicated, we may provide a shortened Plain English Guide for smaller organisations or individuals who would otherwise not be able to spare the time to share their views.

A2.5 We will consult for up to 10 weeks depending on the potential impact of our proposals.

A2.6 A person within Ofcom will be in charge of making sure we follow our own guidelines and reach out to the largest number of people and organisations interested in the outcome of our decisions. Ofcom's 'Consultation Champion' will also be the main person to contact with views on the way we run our consultations.

A2.7 If we are not able to follow one of these principles, we will explain why.

After the consultation

A2.8 We think it is important for everyone interested in an issue to see the views of others during a consultation. We would usually publish all the responses we have received on our website. In our statement, we will give reasons for our decisions and will give an account of how the views of those concerned helped shape those decisions.

Annex 3

Consultation response cover sheet

A3.1 In the interests of transparency and good regulatory practice, we will publish all consultation responses in full on our website, www.ofcom.org.uk.

A3.2 We have produced a coversheet for responses (see below) and would be very grateful if you could send one with your response (this is incorporated into the online web form if you respond in this way). This will speed up our processing of responses, and help to maintain confidentiality where appropriate.

A3.3 The quality of consultation can be enhanced by publishing responses before the consultation period closes. In particular, this can help those individuals and organisations with limited resources or familiarity with the issues to respond in a more informed way. Therefore Ofcom would encourage respondents to complete their coversheet in a way that allows Ofcom to publish their responses upon receipt, rather than waiting until the consultation period has ended.

A3.4 We strongly prefer to receive responses via the online web form which incorporates the coversheet. If you are responding via email, post or fax you can download an electronic copy of this coversheet in Word or RTF format from the 'Consultations' section of our website at www.ofcom.org.uk/consult/.

A3.5 Please put any parts of your response you consider should be kept confidential in a separate annex to your response and include your reasons why this part of your response should not be published. This can include information such as your personal background and experience. If you want your name, address, other contact details, or job title to remain confidential, please provide them in your cover sheet only, so that we don't have to edit your response.

Cover sheet for response to an Ofcom consultation

BASIC DETAILS

Consultation title:

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

CONFIDENTIALITY

Please tick below what part of your response you consider is confidential, giving your reasons why

Nothing ☐

Whole response ☐

Part of the response ☐

Name/contact details/job title ☐

Organisation ☐

If there is no separate annex, which parts?

If you want part of your response, your name or your organisation not to be published, can Ofcom still publish a reference to the contents of your response (including, for any confidential parts, a general summary that does not disclose the specific information or enable you to be identified)?

DECLARATION

I confirm that the correspondence supplied with this cover sheet is a formal consultation response that Ofcom can publish. However, in supplying this response, I understand that Ofcom may need to publish all responses, including those which are marked as confidential, in order to meet legal obligations. If I have sent my response by email, Ofcom can disregard any standard e-mail text about not disclosing email contents and attachments.

Ofcom seeks to publish responses on receipt. If your response is non-confidential (in whole or in part), and you would prefer us to publish your response only once the consultation has ended, please tick here. ☐

Name

Signed (if hard copy)

Annex 4

Consultation questions

The future role of Wi-Fi in helping to meet the demand for wireless data services

Question 1: How is demand for indoor wireless data connection speeds and capacity likely to develop over the next 5–10 years?

Question 2: Will an extension of the 5 GHz band be required if Wi-Fi is to play a sustainable role in meeting the growing demand for indoor wireless connectivity?

Question 3: Are there other types of indoor wireless applications will require access to alternative spectrum other than that provided by the licence exempt 2.4 and 5 GHz bands used by Wi-Fi?

Question 4: What role do you think Wi-Fi will play in providing wireless broadband connectivity outdoors over the coming 5-10 years?

Question 5: Will the increased deployment of Wi-Fi access points outdoors create a risk of reduced quality of service performance over the longer term and, if so, will approaches to co-ordinate access point performance be able to mitigate this risk?

Question 6: Will improved approaches to accessing spectrum in licence exempt bands be needed in the longer term to maintain the quality of service achievable for outdoor public mobile broadband and/or M2M services? If so, which approaches are most likely to be adopted and how likely do you think they are to be successful in improving access to spectrum?

Increasing spectrum supply and better managing its use

Question 7: Which frequency bands are most likely to be best suited to providing geographical shared access, including via a geolocation database approach, for use by mobile broadband, for example small cells and M2M applications?

Question 8: Would access to these bands best be realised through licensing or licence exemption?

Question 9: Do you believe that tiered shared access to a range of spectrum bands has a role in meeting demand for mobile and wireless data and, if so, which applications and devices do you think will be particularly suited to this access model?

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Question 11: What barriers still remain to the realisation of cost-effective sensing appropriate for low-cost consumer devices and what activities are ongoing to try to address them?

Question 12: Over what timescales could DSA become a mass market proposition?

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Supporting innovation through short-term access to shared spectrum

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Question 17: What characteristics do you view as important to researchers in arrangements to facilitate temporary access to spectrum for research and development purposes?

Annex 5

Glossary of abbreviations

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

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.