A framework for spectrum sharing

About this document

This document sets out the framework we will apply to future spectrum authorisation decisions to assess spectrum sharing opportunities. It follows a consultation which we published in July 2015. The framework reflects the need to consider carefully the circumstances of each potential opportunity, covering its costs and benefits.

New sharing opportunities will result in benefits for citizens and consumers from better and potentially new wireless services. Alongside this statement, we are publishing a call for input that invites stakeholders' comments on the first new opportunity we are considering under the framework, for the band 3.8-4.2 GHz.

To help stakeholders identify additional opportunities, we are also publishing more information about existing spectrum authorisations and welcoming expressions of demand for uses that available licences or licence-exempt spectrum cannot cover.

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Section 1

Executive Summary

We will apply our sharing framework to inform future spectrum authorisation decisions

1.1   Demand for spectrum is growing significantly driven by both existing and new services and applications. We expect this to continue. Shared access to spectrum is likely to play an increasingly important role to serve that demand. Greater and more intense spectrum sharing is becoming possible because of more sophisticated technologies and new authorisation approaches.

1.2   Ofcom's principal spectrum duty is to secure the optimal use of spectrum. To achieve this we already authorise shared access to spectrum in many bands. Our Spectrum Management Strategy highlights our increasing emphasis on spectrum sharing to address increasing demand. We said that we would explore and, where appropriate, implement new forms of spectrum sharing and extend sharing across new bands.[1]

1.3   In July 2015 we published a consultation setting out our thinking about a new framework for assessing opportunities for shared access to spectrum.[2] Having taken into account responses to the consultation, this statement sets out our decision to apply the sharing framework to future spectrum authorisation decisions and to take several actions in the short term to promote sharing.

1.4   The framework consists of three elements to help identify potential sharing opportunities in particular bands:

- **Characteristics of use** for both incumbent and prospective users that inform an initial view of the potential for sharing and what tools may be relevant;

- **Barriers** that may limit the extent of current or future sharing, despite the liberalisation of licences and existing market tools such as trading or leasing;

- **Regulatory tools and market and technology enablers** that match the characteristics of use and barriers to facilitate new and/or more intense sharing.

1.5   The framework will continue to evolve over time, as a result of market and technology developments. Its application requires judgment to identify which barriers, tools and enablers may be relevant and which spectrum options may be suitable, in line with the characteristics of use in a particular case.

1.6   Stakeholders recognised the important role of sharing in the context of increasing spectrum demand and were broadly supportive of the framework. However, they raised some general issues on our approach as well as specific issues with regards to some potential barriers and proposed tools.

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[1] *Spectrum management strategy,* Statement, April 2014
http://stakeholders.ofcom.org.uk/consultations/spectrum-management-strategy/
[2] *A framework for spectrum sharing*, Consultation, July 2015
http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-sharing-framework/summary/spectrum-sharing-framework.pdf

- Although respondents generally agreed that the tools and enablers identified were the right ones, some expressed reservations about the appropriateness of particular tools to their use or about the implementation of more innovative tools. We acknowledge these concerns; they will be relevant to assessing sharing on a case by case basis. We also appreciate some technologies, such as sensing, are still developing. But they remain in our list of tools as they are likely to mature over time.

- Many respondents thought that the framework needed to feature more prominently the importance of international coordination and harmonisation. Ofcom is clear that international harmonisation and the cost and availability of equipment are important for new sharing opportunities. There are different levels of harmonisation: different levels of harmonisation are appropriate to different bands and for different services, and some cases of sharing may succeed with more limited harmonisation if equipment could be available at appropriate price points.

- Many respondents were concerned about the costs that new sharing opportunities might give rise to, in particular for coexistence studies and from any new requirement to provide information. When using the framework for specific opportunities we will review costs carefully and the proportionality of any sharing arrangement.

- Some stakeholders recommended "use it or share it" conditions in licences. However, no Wireless Telegraphy Act spectrum licence is exclusive, and we have discretion to authorise multiple uses of licensed frequencies, for any purpose, in line with our statutory duties. Any further authorisation would require careful consideration and we would not expect this to lead to wide-ranging changes across licence categories. For new licence awards, we may consider a form of sharing that exploits potential gaps that main users may leave, if the circumstances justify it, e.g. to create a second tier of users that work around those first-tier main users.

- There was support for a tiered authorisation approach, albeit with some concerns over how enforcing relative priorities would work in practice. We agree that it is one of the tools with greater potential to deliver sharing benefits in the short to medium term and beyond. This includes the potential for opportunistic uses, as is in place for White Space Devices.[3]

- In relation to spectrum pricing, some respondents recommended that sharing should be factored into the calculation of the opportunity cost of a band. Consistent with the SRSP, AIP[4] fees are based on the estimated opportunity cost of spectrum use, considering both the current use and any feasible alternative uses.[5] The scope for sharing, and/or actual evidence of sharing, could therefore in principle be relevant to the assessment of opportunity cost when setting or revising fees based on AIP. Whether, and how, it is appropriate to take sharing into account for setting AIP will depend on the specific circumstances.

- We have amended our list of characteristics of use, particularly the high level technical characteristics which now also cover available information about receivers. We also reflect that some characteristics are more relevant for a new potential user rather than an existing user.

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[3] http://stakeholders.ofcom.org.uk/spectrum/tv-white-spaces/

[4] Administered incentive pricing (AIP). A fee charged to users of the spectrum to encourage them to make economically efficient use of their spectrum.

[5] *SRSP: The revised Framework for Spectrum Pricing*, Statement, December 2010 http://stakeholders.ofcom.org.uk/consultations/srsp/

We are taking action to help prospective sharers

1.7   Lack of availability of information on spectrum use and spectrum demand is a potential barrier to sharing. Stakeholders generally agreed that additional information could support increased sharing, but expressed different views on what would be proportionate.

1.8   We are committed to the release of spectrum information, but we are also mindful that requiring more information about spectrum use from stakeholders could impose costs. We are focussing on releasing information we hold on authorised use, including more detailed technical information, to allow stakeholders to better define the potential opportunity for shared access. We already make a lot of information available.[6]

1.9   Alongside this statement we have released the Wireless Telegraphy Register (WTR) in full and in open format[7] when up to now it was only available to view. This provides a comprehensive record of all civil spectrum user rights. Stakeholders will be able to use the information more easily for network planning and to investigate options for new sharing or innovative uses.

1.10   We are also considering releasing receiver information (where we hold it) to further stakeholders' ability to investigate potential for sharing.

1.11   Some stakeholders suggested that a register for licensees considering sharing would make it easier to identify opportunities for sharing. At this stage, we are of the view that a proportionate response to these suggestions is to establish a mailbox – Spectrum.demand@ofcom.org.uk - for stakeholders looking to gain access to spectrum, including through spectrum sharing. We expect interested parties first to consider whether available WT Act authorisations could meet their demand. Incumbents could also use this mailbox to indicate that they would consider sharing. Further details on how to access spectrum, when available WT Act authorisations are not meeting stakeholders' needs are now available on our website http://stakeholders.ofcom.org.uk/spectrum/licensing-sectors/spectrum-demand-requests/.

1.12   We will review whether other measures may become relevant over time in light of demand.

We are working closely with the public sector on information provision and the potential for sharing

1.13   A number of stakeholders responded that there could be opportunities for increased sharing with the public sector, and that increased information on public sector use could support opportunities for sharing.

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[6] For example, our Spectrum Information System provides information on how radio spectrum is used in the UK, including the types of licences available from Ofcom and details of tradable licences http://spectruminfo.ofcom.org.uk/spectrumInfo/. We also make available our Technical Frequency Assignment Criteria (TFAC), which provides the technical frequency assignment criteria and principles that Ofcom employs when making assignments in frequency bands http://stakeholders.ofcom.org.uk/spectrum/technical/tfac/
[7] Open format means that the information is machine-readable and licensed for re-use.

1.14   In the March 2016 budget, the government announced a new commitment that 750MHz of valuable public sector spectrum in bands below 10GHz will be made available by 2022, of which 500MHz will be made available by 2020.

1.15   We work closely with government on public sector spectrum release, including sharing, and we are also working with government departments and agencies to make better information available. We will provide information where we are able to, subject to confidentiality, for example by showing more detailed information on the public sector use in the interactive spectrum map[8] where we can. We have started this process by releasing information about science use as part of our Space Spectrum Strategy.[9]

We will consider the potential for new sharing opportunities

1.16   Several respondents were keen for Ofcom to identify new sharing opportunities, to build on the experience of authorising White Space Devices in the TV band, to promote innovation and to take concrete steps to address the increasing demand for spectrum.

1.17   In response, we have considered spectrum bands that could support new uses and where we could apply this framework. Our understanding of demand is that, for example, stakeholders may be interested in:

   a)   high bandwidth applications, requiring relatively large amounts of spectrum which are more likely to be available at higher frequencies; or

   b)   applications that require more limited infrastructure and achieve relatively wide-area coverage, and therefore operate at lower frequency spectrum, which is likely to support smaller channels.

1.18   We have identified the upper part of C-band (3.8-4.2GHz) as an initial candidate for the first of these categories. The band is currently used by fixed services, fixed satellite services and a national spectrum licence for Fixed Wireless Access services held by UK Broadband. We wish to understand the opportunities for and impacts of more intensive sharing in this band, with a particular interest in new innovative services. We have published a Call for Inputs alongside this document on potential new sharing opportunities in the 3.8-4.2 GHz band.[10]

1.19   We would welcome feedback from stakeholders regarding other potential opportunities that we could consider in the short to medium term.

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[8] http://www.ofcom.org.uk/static/spectrum/map.html
[9] *Space spectrum strategy*, Consultation, March 2016
http://stakeholders.ofcom.org.uk/consultations/space-spectrum-strategy/
[10] *3.8GHz to 4.2GHz band: Opportunities for Innovation*, Call for Input, April 2016.
http://stakeholders.ofcom.org.uk/consultations/opportunities-for-spectrum-sharing-innovation/

Introduction

This statement sets out our decision to apply our sharing framework to future spectrum management decisions

2.1   In July 2015 we published a consultation setting out our thinking about a new framework for assessing opportunities for spectrum sharing.[11]

2.2   The consultation closed on 2 October 2015. We received 29 responses. Most respondents broadly supported the framework.

2.3   This statement confirms our intention to use the framework to support our spectrum authorisation decisions in response to growing demand for spectrum access. It also outlines the changes we have made in response to stakeholder comments, and our next steps.

2.4   The document structure is as follows:

   a)   In the remainder of this section we set the sharing framework in the context of Ofcom's Spectrum Management Strategy, and explain what we mean by sharing. We also describe our spectrum duties.

   b)   Section 3 gives an overview of the framework and how it can be used.

   c)   Section 4 sets out our updated list of characteristics of use following stakeholder comments. The characteristics of use give a high level picture of what an incumbent or potential new user needs from spectrum access, whether two (or more) users might be able to share, and which (if any) tools or combination of tools may be appropriate to support sharing.

   d)   Section 5 discusses barriers that may limit the extent of current or future sharing.

   e)   Section 6 sets out our list of tools and enablers that could have potential to enable sharing. We also outline some new sharing approaches that stakeholders suggested.

   f)   Section 7 describes immediate actions that we will be taking to enable sharing.

   g)   Annex 1 provides a summary of comments received from stakeholders in response to our consultation and our response to these comments.

The spectrum sharing framework is part of a broader programme of work addressing growing demand for spectrum

2.5   Spectrum is a valuable and scarce resource, and securing its optimal use is key to delivering significant benefits for UK citizens and consumers. Spectrum sharing will

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[11] *A framework for spectrum sharing*, Consultation, July 2015
http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-sharing-framework/summary/spectrum-sharing-framework.pdf

become increasingly important as competing spectrum requirements grow and technology developments make more complex sharing options possible.

2.6 Increased spectrum demand is expected to be driven by a number of sectors. Ofcom has undertaken, is currently undertaking, and plans to undertake, a number of projects to better understand the potential for demand growth. These include the Mobile Data Strategy published in 2014[12] and our Space Spectrum Strategy published in March 2016.[13]

2.7 In our Spectrum Management Strategy we highlighted our intention to consider new opportunities for spectrum sharing to meet growing and competing demand for spectrum.[14] Ofcom has undertaken a number of actions in line with this increased emphasis:

- In April 2014 we published a Statement setting out the steps that Ofcom intends to take to help spectrum sharing play a complementary role alongside dedicated spectrum bands in meeting the significant growth in demand for mobile and wireless data.[15]

- We have introduced database controlled access in the UHF TV band.[16] The licence exemption regulations came into force on 31 December 2015. As of that date, four white space database operators were qualified and listed in the regulations as permitted to provide database services to white space devices (WSDs).

- In April 2015, for an initial two year period, we made 3 MHz of additional spectrum available on a national basis in the UHF2 band (450–453MHz and 464-467.3MHz) for short term civil use licences. This was the result of negotiations with the Emergency Services. Further to this, the Home Office agreed to share an additional 1 MHz of spectrum in the UHF2 band.[17]

- Following our consultation on new spectrum for audio PMSE we have decided to provide access to sub-bands within the 960-1164 MHz band for audio PMSE devices. This will be coordinated with existing aeronautical radionavigation systems. Our decision to allow licensed, shared use of these bands will be implemented according to the technical conditions stipulated in spectrum management rules that have been agreed with the Civil Aviation Authority.[18]

2.8 By enabling more wireless applications to access spectrum, sharing can bring benefits to citizens and consumers as well as contributing to more efficient use of the spectrum.

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[12] *Mobile Data Strategy*, Statement, May 2014 http://stakeholders.ofcom.org.uk/consultations/mobile-data-strategy/
[13] *Space Spectrum Strategy*, Consultation, March 2016 http://stakeholders.ofcom.org.uk/consultations/space-spectrum-strategy/
[14] http://stakeholders.ofcom.org.uk/consultations/spectrum-management-strategy/
[15] *The future role of spectrum sharing for mobile and wireless data services*, Statement, April 2014: http://stakeholders.ofcom.org.uk/consultations/spectrum-sharing/
[16] http://stakeholders.ofcom.org.uk/spectrum/tv-white-spaces/
[17] http://licensing.ofcom.org.uk/radiocommunication-licences/business-radio/uhf2-access/
[18] *New Spectrum for Audio PMSE*, Statement, March 2016 http://stakeholders.ofcom.org.uk/binaries/consultations/new-spectrum-audio-PMSE/statement/statement.pdf

Spectrum sharing can take place in a number of ways

2.9   Spectrum sharing involves multiple users and/or different types of uses accessing the same spectrum band (defined as a specific frequency range).

2.10   We define access to spectrum as relating to one of three main categories:[19]

- Crown access: accessed under the immunity the Crown has from requiring a licence.[20]

- Space science: accessed without explicit need for a licence (licence exempt) or Crown immunity, as its use is either receive-only in the UK or transmissions from outer space.

- Market access: authorised by Ofcom and available to the market, via licence exemption or licensed access. Where we license spectrum use, access is provided through two main types of licence:

    o Ofcom Managed access: where use is authorised by our standard licence products and where Ofcom is responsible for the coordination of individual assignments in the band. This includes some public sector use authorised by Wireless Telegraphy licences.

    o Block Assigned access: where Ofcom grants individual licences for a contiguous block of spectrum over a wide geographic area, e.g. auctioned spectrum licences. In contrast to managed access, Ofcom does not coordinate individual assignments and the technical coordination of use within the frequency block is the responsibility of the licensee.

2.11   Sharing can happen between users within a category of spectrum access. For example, public sector spectrum bands are often shared by more than one public sector user. Sharing can also happen between categories. PMSE services sharing with Ministry of Defence services in the bands 2025-2110MHz and 2200-2290MHz is an example of sharing between market access and public sector users.

2.12   Multiple users can share spectrum for a similar type of use, for example Business Radio users sharing with each other.[21] Alternatively, multiple users can share spectrum for different uses. An example of this would be fixed links, satellite earth stations and a national licence[22] for fixed and mobile broadband sharing in the 3.6-3.8 GHz band.

2.13   The types of shared access above can be achieved across several dimensions:

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[19] As a companion paper to our Spectrum Management Strategy, we provided an overview of how spectrum is accessed in the UK. *Spectrum attribution metrics*, Companion Paper, December 2013: http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/annexes/Spectrum_attribution_metrics.pdf

[20] There is no legal definition of a Crown body but central government departments reporting to ministers such as the Ministry of Defence, Home Office and Department for Transport are generally considered to be Crown bodies. There are other users usually understood to be public sector that use spectrum and do so using Ofcom licences. These uses, such as use by local government, are captured under the market access category.

[21] As part of the UHF 1 and 2 review (420-470MHz), we have are investigating ways to enable more efficient sharing of PMR channels in order to address market demand against spectrum supply.

[22] UK Broadband Limited and UKB Networks Limited

- In frequency – with individual licences each with a specific channel, as opposed to concurrent access for several licensees to the same range of frequencies.

- In geography – with licences including specific geographical areas (or excluding / protecting other areas), or defining the location of transmitting equipment, e.g. between business radio users, and between fixed links and satellite uses.

- In time – some licences have a short term fixed duration rather than being indefinite. For example, PMSE access in a defined geographical area is often for a defined period of time. This could also apply where users have different time requirements, for example where one user has access through the night and the other in the day, although we do not currently licence on this basis.

- Based on technology – this is particularly used in Licence Exempt bands, where equipment is capable of working around other users (e.g. using polite protocols such as low power used for Short Range Devices or listen before talk used in Wi-Fi).

2.14 Shared access may take account of multiple dimensions. For example, White Space Device use is based on geolocation, though the authorisation can be much more dynamic to reflect changes in use over relatively short periods of time

Our spectrum duties

2.15 When making decisions on the conditions of spectrum authorisation Ofcom is required, together with our other general duties, to secure the optimal use for wireless telegraphy of the electro-magnetic spectrum and the availability of a wide range of electronic communications services. In doing that we have to have regard to a range of factors including:

- the desirability of promoting competition in relevant markets;

- the desirability of encouraging investment and innovation in relevant markets;

- the desirability of encouraging the availability and use of high speed data transfer services throughout the United Kingdom;

- the different needs and interests, so far as the use of the electro-magnetic spectrum for wireless telegraphy is concerned, of all persons who may wish to make use of it;

- the different interests of persons in the different parts of the United Kingdom, of the different ethnic communities within the United Kingdom and of persons living in rural and urban areas.

2.16 We have completed an Equality Impact Assessment to understand if the development of our spectrum sharing framework will disproportionately affect any particular group of consumers or raise issues for groups that are protected under equality laws. Although the implementation of sharing in a given case may have an impact on consumers, including members of protected groups, at this stage we are building a framework to inform our spectrum authorisation decisions. We have not identified any such impacts. We expect to undertake specific Equality Impact Assessments on a case by case basis as and when we pursue sharing opportunities.
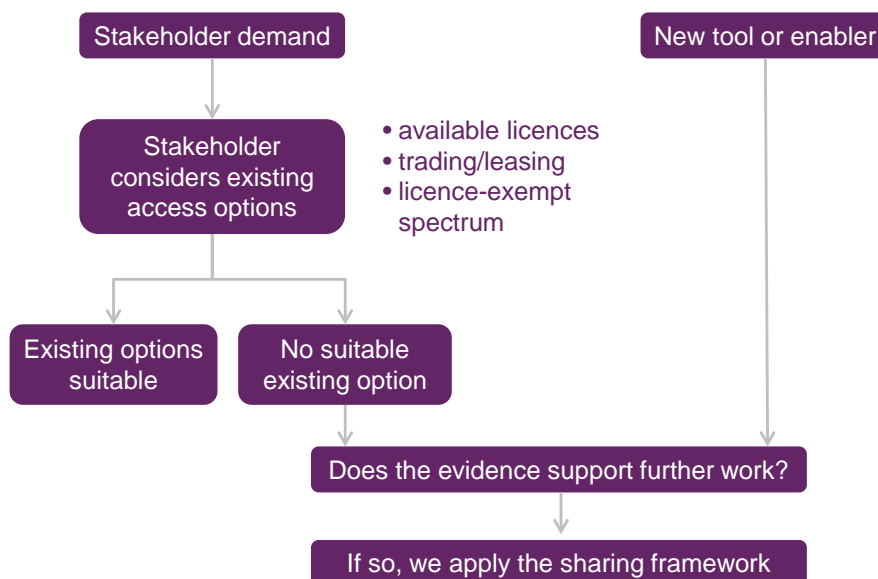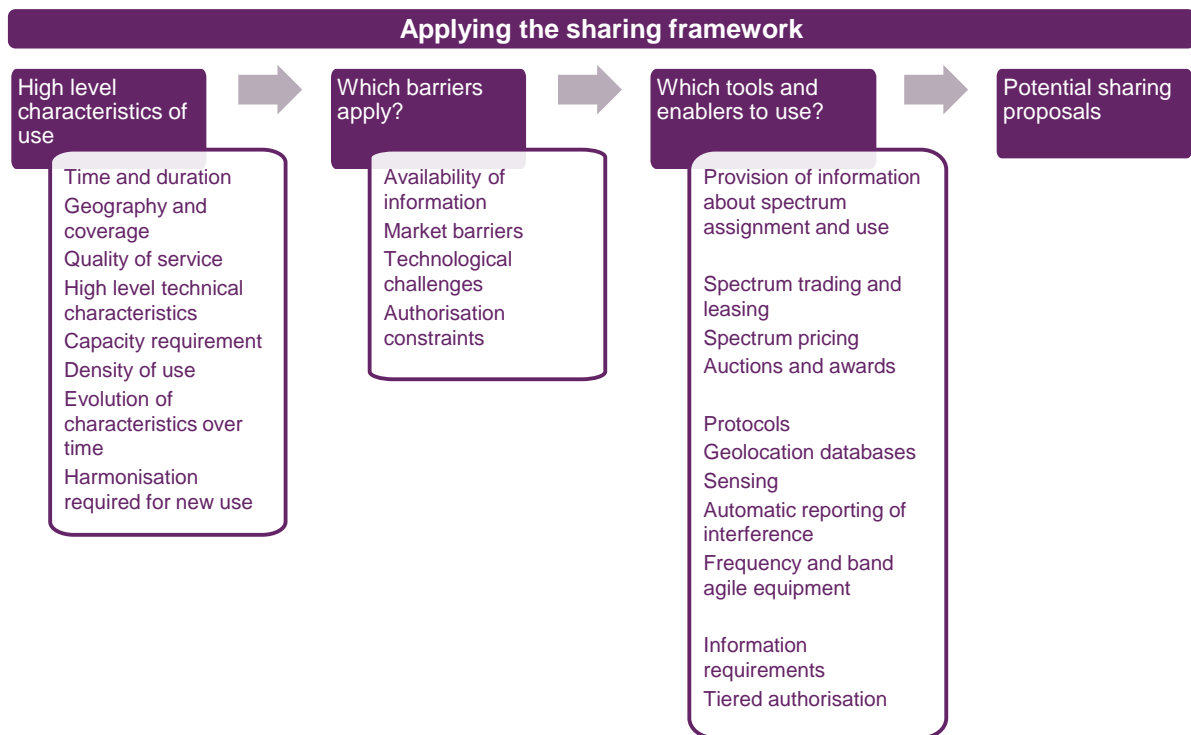
Section 3

Overview of the framework and its use

We will evaluate the potential for sharing in our spectrum authorisation decisions using this framework

3.1 Ofcom already authorises shared access to spectrum in many bands and will continue to do so. The framework is intended to ensure that we consider sharing options systematically in all of our spectrum authorisation decisions. This includes when defining new spectrum authorisations, and when we seek to identify spectrum to meet new demands.

3.2 New opportunities for sharing may come about through commercial agreements (spectrum trading or leasing), in which case the process for evaluating the potential for sharing will be a matter for the parties involved. If commercial agreements are not possible or appropriate we need to consider whether regulatory intervention may be relevant. Authorisation of spectrum use in the UK is regulated through the application of the Wireless Telegraphy Act. Licenses issued under this legislation confer and define rights but do not provide exclusivity of use.

3.3 The framework is relevant to any spectrum band and any new demand to use spectrum, but whether applying the framework leads to proposals for sharing in any given case will depend on its specific circumstances.

3.4 The framework consists of three elements that are relevant to identifying a potential sharing opportunity:

- **Characteristics of use** for both incumbent and prospective users that inform, in any individual case, an initial view of the potential for sharing and what tools may be relevant.

- **Barriers** that may limit the extent of current or future sharing, despite the liberalisation of licences and introduction of market tools such as trading or leasing;

- **Regulatory tools and market and technology enablers** that could facilitate new opportunities for increased and more intense sharing.

3.5 The framework will continue to evolve over time, including in response to market and technology developments.

3.6 Where a stakeholder has unmet spectrum demand, we would expect it first to take into account licences that are available from us, under the WT Act (including those granted via awards), through trading in the secondary spectrum market, or in licence-exempt spectrum.

3.7 If stakeholders are still unable to satisfy their demand, they could approach us, explaining what services or applications they want to deliver (i.e. their characteristics of use), and any barriers they have faced accessing spectrum in the market. We may then consider whether to further investigate the potential for sharing, dependent on the benefits expected for citizens and consumers.

3.8   Were we to further investigate potential spectrum supply we would need to assess incumbents' characteristics of use in bands that might be suitable, using information we already hold in the first instance. We would then consider what tools might be appropriate to make sharing work.

3.9   Where we identify barriers in the market or technological developments capable of creating new opportunities, we may investigate potential for sharing in the absence of an initial expression of demand.

3.10   When we are evaluating whether it is possible to create a new sharing opportunity, we will always need to consider what the relative merits of that opportunity might be. Where there is potential benefit from new sharing we will need to consider the associated changes carefully, taking account of the incremental impact of sharing on incumbents, and the benefits that incumbent services deliver to citizens and consumers. This includes incumbents' incentives to innovate and invest. We would need to consider whether sharing is appropriate if it would involve imposing material new costs on existing users, for instance as a result of an obligation to provide information on use.

3.11   In addition to potential costs, spectrum sharing can also provide opportunities, including for incumbent users whose spectrum demands also continue to grow and who may need access to new bands.

3.12   Vodafone expressed its concern that spectrum becoming available for new sharing opportunities might provide some stakeholders an unfair advantage compared to others who had previously acquired rights at auction at considerable costs. When making spectrum authorisation decisions, we do so in a fair way, through objective, transparent, non-discriminatory and proportionate measures. This includes, where appropriate, taking competition concerns into account in our decision making.

3.13   Figures 1 and 2 provide an overview of when we expect to apply the framework and of its key components.

Figure 1: When we expect to apply our sharing framework

Figure 2: Structure and key elements of our sharing framework

Applying the sharing framework			
High level characteristics of use	**Which barriers apply?**	**Which tools and enablers to use?**	**Potential sharing proposals**
Time and duration Geography and coverage Quality of service High level technical characteristics Capacity requirement Density of use Evolution of characteristics over time Harmonisation required for new use	Availability of information Market barriers Technological challenges Authorisation constraints	Provision of information about spectrum assignment and use Spectrum trading and leasing Spectrum pricing Auctions and awards Protocols Geolocation databases Sensing Automatic reporting of interference Frequency and band agile equipment Information requirements Tiered authorisation	

Sharing and public sector spectrum use

3.14   A significant number of stakeholders raised points related to public sector use of spectrum, and its potential to be released or shared.

3.15   Respondents said that increased information about public sector use could support opportunities for sharing.

3.16   We also received a response regarding the financial incentives for public sector users to share. Vodafone suggested that individual departments may worry about the "stickiness" of any net AIP reduction, for example whether in subsequent years their budget would be reduced to reflect the reduction.

3.17   As set out at 2.10, some Public Sector spectrum use is accessed under the immunity the Crown has from requiring a licence, and is not authorised by Ofcom. However, the ideas set out in the sharing framework (the barriers, tools and enablers, and characteristics of use described in 3.4) have relevance to both civil and public sectors. Ofcom works closely with Government on public sector spectrum sharing.

3.18   In the March 2016 budget, the government announced a new commitment that 750MHz of valuable public sector spectrum in bands below 10GHz will be made available by 2022, of which 500MHz will be made available by 2020. This builds on government's previous 2010 commitment to make 500MHz of public sector spectrum below 5 GHz available for civil users by 2020.[23] Appropriate incentives to share or release spectrum were part of the discussions leading to the Chancellor's announcement in the Budget. Decisions around public sector incentives are not a

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[23] https://www.gov.uk/government/publications/budget-2016-documents/budget-2016

matter for Ofcom, albeit advised by Ofcom on the value for civil uses of spectrum used by the public sector.

There is an important international dimension to new opportunities for spectrum sharing

3.19   Many respondents to the consultation thought that the framework needed to feature more prominently the importance of international coordination and harmonisation, and Ofcom's role in achieving this.

3.20   We agree that appropriate coordination and harmonisation are particularly important, which is why Ofcom takes such a proactive role internationally, particularly in the ITU, CEPT, RSC and RSPG. International harmonisation and coordination and the cost and availability of equipment are essential criteria for assessing new sharing opportunities. We have built these considerations into our characteristics of use.

3.21   Some cases of sharing might nonetheless be appropriate in bands with more limited harmonisation as long as it is likely that affordable equipment could be available. This may be particularly relevant where we want to encourage innovation and new services.

3.22   We already work globally to promote opportunities for sharing and to learn from experiences in other countries. Our support for spectrum sharing and sophisticated technical coexistence techniques is reflected in our contributions to international forums, particularly CEPT.

Section 4

Characteristics of use

We will use high level 'characteristics of use' to guide consideration of sharing potential

4.1   One of the aims of the framework is to ensure that, when we make authorisation decisions, we give users access to spectrum in a way that delivers the greatest citizen and consumer benefits, taking account of existing and prospective users' needs.

4.2   Our consultation proposed a set of high level characteristics of use, for both incumbent and new users, intended to give an initial, high level view of whether two or more types of users might be able to share and which (if any) tool or combination of tools is likely to deliver what users need.[24] It also involves looking at the likely evolution of the services involved over the medium to long term and, therefore, accounting for the uncertainties associated with longer timeframes and future market developments.

4.3   We would expect parties approaching Ofcom interested in sharing spectrum to describe these characteristics for their intended use.

4.4   The characteristics of use are not a substitute for coexistence studies. They support an initial high level assessment of potential sharing opportunities to determine whether to investigate an opportunity further. If such initial assessment indicates new sharing may work and generate benefits, we would expect to go through several steps to refine that view. The steps would include detailed technical studies, including of the risk of interference with adjacent bands, as part of a broader review of the impacts of the opportunity on incumbents and the benefits that incumbent services deliver to citizens and consumers, and appropriate consultation.

4.5   As at 3.19 we also recognise that requirements for spectrum exist within a broader international context. This includes the availability of relevant competitively priced equipment, which is in turn likely to be significantly influenced by international allocation decisions.

We have updated the list of characteristics in response to stakeholder comments

4.6   In general stakeholders agreed that the characteristics of use were useful for providing an initial assessment of sharing potential. A number of stakeholders suggested additional characteristics that we should include. We have made some refinements to the list of characteristics presented in the consultation in response to stakeholders' comments, not all were included as we considered some suggestions risked being too detailed for a high level test for potential opportunities and are more suited to a coexistence study or cost benefit analysis.

4.7   The main changes to the characteristics are:

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[24] Our initial list of characteristics of use is set out in Section 6 of the consultation.

- We have split the list of characteristics into two, to reflect that some characteristics are more relevant for a new potential user rather than an incumbent already using a band.

- We have expanded the list of high level technical characteristics. And we have recognised the importance of receiver characteristics as well as transmitter characteristics.

4.8   The characteristics of use that we will use, having taken on board comments from stakeholders, are set out in Table 1. We note that these may evolve in future.

Table 1: High level characteristics of use

Criteria	Characteristics (incumbents and potential new users)
Time and duration	Of the service: What are the temporal requirements of the service? Is it always–on, a set time, or unpredictable?
	Does the service require spectrum for long term use, or temporarily?
	Of the transmissions: What are the temporal requirements of the individual transmissions? What duty cycle do these use?
Geography and coverage	Will the service cover the whole UK or be restricted to certain areas?
	Will it be ground-based? Outdoor/indoor?
	Is the service in a fixed location or mobile? Is location predictable?
	Control over end users - does the user know where its end-users are? Can the user control them?
Quality of service	What type of reliability does the service require? Guaranteed availability vs. best efforts.
	What level of interference is acceptable?
	Is the service critical, e.g. used for critical national infrastructure (CNI)?
High level technical characteristics	EIRP (power), typical transmitter height and location (i.e. urban/ rural / on hills etc.), antenna characteristics (beam widths directionality)Typical receiver sensitivity (minimum receivable signal), receiver locations and antenna characteristics (beam widths directionality)
Capacity requirement	How much capacity needed for each device and for the whole service?
	Is this a core capacity requirement or for additional capacity, e.g. for occasional overflow?
Density of use	Number of devices in use, i.e. whether a mass market consumer use or a limited number of terminals
Evolution of these criteria over the life of an authorisation	How will each of these characteristics evolve over the term of the authorisations involved? Including possibilities for future network growth and evolution of new devices
	What is the best way of approaching the uncertainty over longer timeframes?
	What is the payback period on the investment?

Criteria	Characteristics (potential new users only)
Economies of scale and harmonisation	How essential are the benefits from international harmonisation?
	What extent of economies of scale is necessary (e.g. one or several world

	regions or just UK specific)?
	What is essential to securing sufficient harmonisation?
	Standards that apply to the use.

We are mindful of the cost of collecting information, and its potential sensitivity

4.9   One respondent said that the characteristics of use concept would risk being a burden on all current users of spectrum being considered for sharing, and that users would have to provide a relatively detailed level of spectrum information to allow the concept to be used. A number also pointed to security and commercial confidentiality concerns, particularly that commercial users may not wish to disclose how their use might vary over the duration of an authorisation.

4.10   The characteristics of use should be considered as a high level tool to help identify whether there might be an opportunity for new users to share. We will act proportionately, using information we already have and public information in the first instance. If we need information from stakeholders, we will be mindful of the time and cost to collect the information.

4.11   The development of an opportunity beyond an initial assessment may require a lot more detailed information, and we will consider the requirements on a case by case basis.

Section 5

Barriers

Identifying barriers limiting the extent of sharing

5.1   Since Ofcom's inception, we have been developing the authorisation regime to empower stakeholders to get access to spectrum. We have:

- sought to remove technical restrictions by liberalising licences, where possible and where there was demand;[25]

- introduced market tools such as spectrum trading and leasing, with the majority of licence classes now tradable;[26]

- enabled public sector users and/or receive-only services to trade, using Recognised Spectrum Access;

- brought more spectrum into the market with a programme of spectrum auctions, with seven auctions already completed;

- implemented dynamic use of the TV White Spaces within the UHF band; and

- been making more information available, in more useful ways, about spectrum authorisations and access.

5.2   This means that in many cases there should be no regulatory barriers to sharing of similar services taking place within the market and with minimum intervention by Ofcom. However in addition, where justified, Ofcom can intervene to create new sharing opportunities, as in the recent example of the implementation of TV White Space Devices.[27]

5.3   Our consultation highlighted a series of barriers that may be limiting the extent of sharing. These fell into four categories:

   a)   availability of information;

   b)   market barriers;

   c)   technological challenges; and

   d)   authorisation constraints.

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[25] See for example our decision to vary EE's 1800 MHz licences to allow the use of LTE and WiMAX technologies http://stakeholders.ofcom.org.uk/consultations/variation-1800mhz-lte-wimax/statement and our 2015 decision to vary the 1452 – 1492 MHz licence held by Qualcomm UK Spectrum Ltd http://stakeholders.ofcom.org.uk/binaries/consultations/licence-variation-1.4ghz/statement/Statement_on_1.4_ghz_licence_variation.pdf

[26] See for example our June 2011 Statement *Simplifying Spectrum Trading: Spectrum leasing and other market enhancements* http://stakeholders.ofcom.org.uk/consultations/simplify/

[27] http://stakeholders.ofcom.org.uk/spectrum/tv-white-spaces/

5.4　Stakeholders largely responded that the factors we identified as barriers in the consultation document were the right ones. We have therefore retained our four categories of barriers, and have included some additional points from stakeholder suggestions:

- Licensees may be disincentivised from sharing because of potential impact on the value of their spectrum licences, see paragraph 5.26.

- The impact of regulatory delay and timescales, see paragraph 5.37.

5.5　Vodafone, Ericsson and EE argued that while there are barriers to sharing, notably a lack of financial incentives, this does not represent an inefficient economic outcome. If a new user in a band was capable of securing significant benefit from its use, it would be willing to pay for that usage. As spectrum is highly valuable, users are incentivised to use spectrum as extensively as is economically viable. EE questioned the existence of such barriers and the case for regulatory intervention. Several stakeholders were of the view that it should be up to licensees whether they want to explore sharing options.

5.6　We consider the role of commercial discussions for new sharing opportunities at paragraph 3.6. We recognise that the absence of sharing in a band does not necessarily mean that spectrum use is inefficient. However, we also consider that there may be broader benefits to sharing, even in cases where it is not a priority for existing licensees, and that there could be cases in which it may not be within the gift of existing licensees to trade with others to lead to new sharing. If we were to intervene to facilitate sharing we would have regard to the case-specific circumstances and to our duties.

5.7　In the remainder of this section we discuss the responses regarding specific barriers to sharing.

Availability of information

Lack of information prevents identification of opportunities

5.8　We suggested that availability of information on spectrum use and spectrum demand could be a potential barrier. Where such information is not publicly available, it can be difficult for potential sharers to establish whether there is an opportunity for sharing.

5.9　We received responses covering four of types of information.

Information about spectrum authorisation

5.10　Ofcom already provides information about the services that have access to spectrum bands and who licensees are (which we refer to as information about spectrum authorisation), through our Spectrum Information System.[28]

5.11　UKB Group (UKB) and Ericsson made comments about the usefulness and accessibility of the data we provide, in particular that it should be more searchable and detailed.

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[28] http://spectruminfo.ofcom.org.uk/spectrumInfo/

5.12 We recognise the importance of making more spectrum information more easily available and in useable form. In line with this we have released the Wireless Telegraphy Register (WTR)[29] in full. This is explained further in Section 7, see paragraph 7.3.

Information about spectrum use

5.13 Responses to the consultation were divided over whether access to information about actual spectrum use (as opposed to who is authorised to use it) is a barrier.

5.14 Google, Nominet, Internet Solutions, the BBC, UKB and Microsoft said that the ability to access real-time up-to-date information on actual spectrum use would be vital to securing an effective spectrum sharing policy.

5.15 Lack of information may also have an impact on the ability to conduct sharing studies. O3B noted that, traditionally, potential sharers have examined the feasibility of sharing bands by carrying out studies based on publicly available information (such as ITU-R documentation). However, such information may not be available for bands that are awarded on a technologically neutral basis, as there is no obligation for the licensee to publish or make available data on spectrum use. Transfinite has also undertaken studies in which they have been limited by the availability of data about licensed systems, in particular their technical parameters.

5.16 However, others argued that providing information on use would be practically difficult and onerous. There were also concerns about confidentiality, both on grounds of commercial confidentiality and public safety and security.

5.17 We agree that lack of information about spectrum use presents a potential barrier to sharing, but this has to be balanced against the costs to licensees, which must be proportionate. As a result, we are not at this time planning to require licensees to release information on their actual use in a general way. We would consider whether provision of information about spectrum use could be relevant and proportionate when investigating specific opportunities. Our focus for now is on making information available on our spectrum authorisation, for example the release of the full extract of the WTR.

Information about the public sector

5.18 The public sector has access to a large amount of spectrum. A number of stakeholders responded that increased information on public sector use could facilitate opportunities for sharing. However, some also acknowledged that this information may not be suitable for publication where it relates to national security or Critical National Infrastructure.

5.19 We are working with government departments and agencies to make more detailed information available, e.g. on type of applications in a given band. We will provide information where we are able to and subject to confidentiality, for example by showing more detailed information on the public sector use in our spectrum map[30]

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[29] http://stakeholders.ofcom.org.uk/spectrum/information/spectrum-info-FAQ/wireless-telegraphy-register/
[30] http://www.ofcom.org.uk/static/spectrum/map.html

where we can. We have started this process by releasing information about science use as part of our Space Spectrum Strategy.[31]

<u>Information about demand and potential supply</u>

5.20   In the consultation we noted that Ofcom has limited information on demand for spectrum for sharing other than from specific requests.

5.21   We received some suggestions (from JRC, UKB, Ericsson) that a spectrum sharing register for licensees considering sharing would make it easier to identify opportunities for sharing. BT responded that in the event that an incumbent decides that they would like to make their block assignment available for sharing, they should be able to make the relevant information publicly available.

5.22   We are interested in these ideas, but it is not clear what benefit they would bring or what case there is for our involvement. At this stage we think a proportionate response is for us to establish a point of contact for stakeholders looking to gain access to spectrum, including through spectrum sharing, for use that available licences or licence-exempt spectrum cannot cover. It could also be used by incumbents to indicate that they would consider sharing. We discuss these ideas further at paragraph 7.6.

Market barriers

5.23   We identified high transaction costs relative to the potential reward and the risk that sharing could limit licence-holders' ability to respond to future events as market barriers to sharing.

5.24   We summarise below the responses on the relevance and nature of these barriers. We recognise that in some cases such barriers may arise from the legitimate interests of licence holders. We remain of the view that the market barriers in our proposals are relevant factors for us to consider. We therefore retain them as relevant considerations under this framework. Their effects on incentives may be such, in certain circumstances, that they could warrant considering intervention. Paragraphs 3.6 to 3.10 and 5.6 set out when we expect that regulatory intervention may be relevant to address these barriers.

Transaction costs

5.25   Stakeholders including Vodafone, Ericsson, and UKB argued that transaction costs can be prohibitive, particularly where the value to an individual potential user is small, and said that licence holders may be unwilling to devote management time to developing spectrum sharing arrangements at the expense of focussing on their core business. BT noted that market barriers may be particularly significant where there is little or no experience of sharing spectrum, given the initial effort required.

Concerns about impact on spectrum value

5.26   ViaSat argued that licences create a property right that most owners are hesitant to devalue by sharing, as licences are seen as more valuable absent sharing.

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[31] Space Spectrum Strategy – interactive data http://stakeholders.ofcom.org.uk/consultations/space-spectrum-strategy/interactive-data/

5.27   Other licensees made related points. Microsoft suggested that commercial incumbents may view sharing with licence-exempt users as diluting the value of their asset, acting as a form of competition. Vodafone responded that if licensees are compelled to dedicate resource to investigating sharing, this will devalue spectrum and would be unfair to impose retrospectively.

Uncertainty about constraints on future use

5.28   Several stakeholders agreed with our view that uncertainty about the future may discourage licensees from pursuing sharing arrangements. For example, if a potential sharing arrangement does not allow an incumbent sufficient flexibility to adapt its business model in future, e.g. by expanding its network to new locations. BT argued that there are also strategic factors, such as the preference (in the case of block assignment) to hold some channels vacant for expedient use, and also retaining the ability to reorganise the channels used within a network, without the complication of a sharing party.

5.29   JRC said that it had experienced reluctance to share because spectrum users fear their long-term access to it may be lost.

5.30   Uncertainty may also affect potential sharers. Arqiva responded that uncertainty about security of spectrum access and long term ability to guarantee a quality of service makes the funding of innovative services and applications challenging. Ericsson said that uncertainty about duration of access may mean that their business case has to be based on short term payback periods, which increase the costs to consumers.

Technological challenges

Coexistence adds complexity and cost

5.31   We considered that the risk of interference and the costs and length of time for addressing coexistence, i.e. risks of interference between existing and prospective users, are significant concerns for both sides. Caution would tend to reduce sharing opportunities, while seeking to maximise those opportunities would risk constraining existing use.

5.32   Stakeholders' responses highlighted the difficulty of coming to a view on what constitutes an acceptable level of risk arising from potential sharing; the view of an incumbent is likely to differ from that of a potential new user, whereby the former will often want to accept no additional risk even for low likelihood scenarios.

5.33   We agree that coexistence challenges are a potentially significant barrier to sharing, and that these issues are relevant both when private parties are trying to strike a sharing deal by spectrum trading, and when Ofcom is considering a specific sharing opportunity. When we conduct coexistence analysis, our assessment of coexistence issues needs to balance carefully the benefits that could derive from new uses gaining access to spectrum with the need for existing services to operate without suffering undue interference. If our assessment of coexistence is overly cautious this could limit (or deny) access to spectrum for new users by placing onerous and costly constraints on them. Conversely, if our assessment is overly optimistic this could degrade services that are already provided. Our efforts need to be proportionate to the level of risk involved.

Authorisation constraints

Terms of authorisation can limit flexible use

5.34   In the consultation we questioned whether Ofcom's authorisation approach might constrain flexible use, for example if it is onerous for a licence holder to vary the terms of a licence so it can be used by another type of service. We noted that delay in most cases is not caused by the variation process itself but the steps needed to understand coexistence issues, and in some cases the need for us to consult before issuing a licence.

5.35   UKB responded that permission to lease mobile spectrum, subject to a competition check and short public consultation by Ofcom, would improve efficiency of spectrum use and enable the release of capacity to the market to meet the demands of users. We address this suggestion as a potential market enabler in Section 6 (see 6.38).

5.36   ViaSat and UKB responded that restrictions on the use of spectrum can be a barrier to sharing. For instance, where band segmentation plans designate a band as exclusive to one service, even though it is not deployed ubiquitously over the entire area, which could be due to the inability of legacy technology to share. UKB responded that the policy of the European Commission occasionally to mandate particular uses of certain bands may restrict the potential users of spectrum and potentially lead to spectrum not being used in the most efficient way. Ofcom supports technology and service neutrality in authorisation in line with the Authorisation Directive and we note that where new more efficient uses are identified, spectrum use may be liberalised.

Ofcom's regulatory timescales and commitment to sharing

5.37   A number of stakeholders said that when Ofcom tries to introduce sharing it is slow and overly cautious, significantly reducing the possible market opportunity. TV White Spaces was cited as an example of this. Some respondents (particularly Professor Stephen Temple, TechUK, DSA, and Nominet) also suggested that there has been insufficient regulatory commitment to sharing, and that this has a negative impact on investment in new technologies.

5.38   TV White Spaces has now been implemented, and we will consider lessons that we can learn from that process. However, there are a number of factors that will mean that regulatory timescales will not usually be short. The nature of the evidence that we receive from incumbents often sets out significant objections to change. As set out above, coexistence work is detailed and challenging. There are minimum timescales for due regulatory process. Therefore, without consensus, addressing the conflicting views and needs of incumbents and sharers can lead to complexity and delay. We are committed in each case to working through issues in timescales that are as short as practicable in light of the work involved and our priorities.

5.39   With this spectrum sharing framework, we will systematically consider sharing in our spectrum authorisation decisions, using the available evidence.

Sharing tools and enablers

6.1 In the consultation we set out an initial list of tools and enablers that have the potential to increase benefits from sharing, by addressing the barriers discussed in Section 5 and by making new ways of sharing possible.

- By tools, we mean the ways in which Ofcom could potentially **authorise the use of spectrum** to promote further sharing, or make it more effective.

- By enablers we mean:

  o **new types of spectrum information** and better access to it, that could enable stakeholders to identify and pursue spectrum sharing opportunities;

  o **market mechanisms** that could create incentives for existing and potential users to use spectrum more efficiently, as well as market infrastructure; and

  o **technological capabilities** that enhance existing forms of spectrum use and/or enable new ways of accessing, using and sharing spectrum.

6.2 These tools and enablers could be applied in combination, to create new sharing models. Some of the licence conditions or market enablers might require technological solutions (either existing or yet to be developed).

6.3 Our initial list was intended to stimulate stakeholders' consideration of the ways in which spectrum sharing could come about and evolve.

6.4 Respondents generally agreed that the tools and enablers were broadly the right ones. For all of the tools and enablers, some stakeholders considered they show some promise for enabling increased sharing. However, some respondents expressed reservations about the appropriateness of particular tools to their use or about the implementation of more innovative tools (e.g. sensing). Therefore, while we acknowledge these concerns, and note that not every tool will be relevant to every case of potential new sharing, we have not taken concerns from particular users/groups of users as a reason to exclude a tool from our list of options.

6.5 The remainder of this section considers our resulting list of tools and enablers.

Provision of information about spectrum assignment and use

6.6 Provision of more and better information could help increase opportunities for sharing. Consistent with the Spectrum Management Strategy we are already committed to providing more, and more detailed, information on spectrum authorisation.

6.7 In the consultation we suggested that information in the following areas might be helpful to address information barriers to sharing:

- Increased information on public sector use.

- Information on spectrum use, rather than just on what is authorised. This could include real-time usage information from licensees, and/or forward-looking information to help address security of tenure for opportunistic users.

- Information on actual interference.

- Information on spectrum demand.

6.8   Stakeholders generally agreed that additional information could support increased sharing, but expressed different views on what would be proportionate.

- In Section 5 (paragraphs 5.11, 5.14 and 5.21), we set out requests for more searchable and detailed information, views on the value of more information on actual use as well as potential downsides, and interest in ways of aggregating and publishing supply and demand information.

- We received two requests (from TechUK and BT) to provide access to our frequency coordination tools so that users could make sample requests to assess opportunities.

- Google, Microsoft and BT saw potential in interference reporting as an enabler. It was suggested that this information could be used to refine a sharing framework over time. Others pointed out that it is difficult to identify the source of interference, and that this could be resource and time consuming for an uncertain benefit.

6.9   To make our frequency coordination tools available publicly would entail significant cost and complexity, and there may be security issues. We do not think this would be proportionate. Tools are available on the market, and we are making information available to allow stakeholders to investigate opportunities themselves. For most technically assigned licences Ofcom also publishes its Technical Frequency Assignment Criteria (TFAC)[32] which provides the technical frequency assignment criteria and principles that Ofcom employs when making assignments in frequency bands.

6.10   In section 5 we set out our current focus for information provision and that we are working with Government on information about public sector use, see paragraphs 5.17 and 5.19. In section 7 (paragraphs 7.3 to 7.8), we describe the actions we are taking now to make more information available and to receive information about demand.

Information about spectrum characteristics

6.11   We consulted on the potential to set out relatively simple information on spectrum that is potentially available for a particular purpose, to help prospective users understand and compare opportunities. We suggested that this could cover for a given application, for example, international harmonisation, any constraints on geographical and population coverage from incumbent use, interference environment, and a propagation indicator as a proxy for the extent of infrastructure necessary to provide services.

6.12   Stakeholders were generally supportive of this approach, with many responding that it would be useful. However those in support took different views about what elements might usefully inform such a high level comparison. Others were unsure

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[32] http://stakeholders.ofcom.org.uk/spectrum/technical/tfac/

about the value of providing this information, because it is too general to be of real use or because, to some extent, it duplicates information Ofcom already published. They urged that any exercise should be measured and proportionate, as compiling such information would have an associated cost for Ofcom.

6.13   We agree that, at this stage, there may not be a clear benefit from proactively providing information where there may not be demand for new sharing. We therefore expect to focus on applying the analysis of characteristics of use, as described in Section 4, in cases where we have a role to play in investigating a new sharing opportunity.

Market enablers

6.14   Market enablers are most likely to be relevant to sharing in two broad cases: where potential sharers hold block assigned licences and leasing or trading part of the attached rights is possible; and where we hold primary awards of rights to use spectrum. In the consultation we listed three types of market enablers: spectrum trading and leasing, spectrum pricing, and auctions.

Spectrum trading and leasing

6.15   Most UK spectrum licences can be traded. Trading can facilitate sharing, because in addition to full trades, trades can be partial (i.e. selected frequencies or locations), temporary (i.e. time-limited transfer) or concurrent (i.e. multiple licensees who hold the same rights to the same frequencies and who coordinate between themselves for interference management). In the case of concurrent trades, the terms of access can then be set out in a separate commercial agreement.

6.16   We distinguish between spectrum trading and leasing. In spectrum trading a new user is granted a licence by us to use spectrum following a commercial transaction with an existing licensee involving the transfer of the licence rights and obligations. In spectrum leasing, spectrum may be accessed for a specified period under a contract with an existing licensee without obtaining a further licence from us.[33]

6.17   Trading and leasing offer a private route for spectrum rights to flow to higher-value users, and give the freedom to private parties to explore opportunities and to negotiate spectrum access deals with limited or no regulatory involvement.

6.18   UKB recommended that leasing be extended to licences for mobile services, subject to a competition check and short public consultation by Ofcom. Leasing has already been introduced in a range of bands. However, since the current leasing approach does not require any Ofcom involvement including a competition check, extension to mobile licences would require further consideration. Ofcom would consider extending leasing in bands where it is not currently available if there are likely to be net benefits, including sufficient evidence of demand to lease spectrum, and there is a proportionate way to address any competition concerns.

6.19   In principle intermediaries or trading platforms could increase the role of trading and leasing but, so far, such market participants do not appear to have taken a strong

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[33] See *Simplifying Spectrum Trading: Spectrum leasing and other market enhancements*, Final Statement, June 2011
http://stakeholders.ofcom.org.uk/binaries/consultations/simplify/statement/statement-spectrum-leasing.pdf

role. It is not clear what the business case may be for them today or how it might evolve over time. However, respondents did not raise any specific concerns regarding spectrum-related regulatory obstacles to their emergence or growth.

Spectrum pricing

6.20   Spectrum pricing that reflects opportunity cost gives licensees an incentive to hold spectrum efficiently. Where demand for spectrum exceeds supply, such incentive pricing is a valuable complement to other market-based mechanisms to ensure optimal use of spectrum.[34] Ofcom already implements spectrum pricing in the form of Administered Incentive Pricing (AIP). HM Treasury sets charges for spectrum that government departments use, informed by advice provided by Ofcom on the opportunity cost to civil uses of this spectrum.

6.21   Respondents made the following key points in relation to pricing.

- Sharing and/or demand from sharers should be factored into the calculation of the opportunity cost of a band.

- Ofcom should consider applying a fee discount to incentivise sharing. Specifically:

    o   Vodafone said that if there is a policy goal to incentivise sharing, it may be appropriate to apply a discounted AIP where an incumbent can demonstrate that they are sharing spectrum.

    o   ViaSat responded that Ofcom could encourage sharing by offering a discounted fee to Fixed Service licensees that agreed to share spectrum with Fixed Satellite operators for opportunistic use.

6.22   Our high level AIP principles and methodologies are set out in our 2010 Revised Framework for Spectrum Pricing (SRSP).[35]

6.23   In line with the SRSP, licence fees are based on the opportunity cost of the use of spectrum. The scope for sharing, and/or actual evidence of sharing, could be relevant to the assessment of opportunity cost. The appropriate way of taking sharing into account for setting AIP will depend on the specific circumstances.

6.24   The SRSP also sets out that, in general, (a) uses of spectrum that deliver wider social value do not, as a general rule, justify AIP fee concessions, because direct subsidies and/or regulatory tools other than AIP are normally more likely to be efficient and effective, and (b) it is not generally appropriate to provide AIP concessions in order to promote innovation.[36]

6.25   Regarding ViaSat's suggested "discounts" to fixed links fees, fixed links users already share with other users and uses, like other users in Ofcom managed bands. The pricing methodology applied to licences in these bands takes account of the opportunity cost of this use, namely the value of the spectrum access denied to others. This is based on frequency, geographical location, bandwidth, geographical

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[34] Where AIP is not justified, we set fees that reflect our spectrum management costs. We refer to this as 'cost-based' pricing. This applies where spectrum is not scarce or where fees based on the value of the spectrum would be lower than the relevant costs.

[35] *SRSP: The revised Framework for Spectrum Pricing*, Statement, December 2010 http://stakeholders.ofcom.org.uk/binaries/consultations/srsp/statement/srsp-statement.pdf

[36] Paragraphs 4.250-4.262.

coverage or other measure that reflects the geographical extent of coordination requirements and, in some cases, the exclusivity of an assignment.[37] If additional users are, in future, able to use the band without impacting the rights of existing users it is not clear that there would be a rationale for applying a concession to the fixed link fee.

Auctions and awards

6.26   There are three main ways in which auctions may support better sharing.

6.27   Firstly, where relevant, we could look for opportunities for bidding in auctions to reflect demand for shared use. We have made licences available for concurrent use of frequencies in two previous auctions.[38]

6.28   In the consultation we suggested that there might be several options for allowing auctions to reflect demand from shared use, including creating specific licences for sharers, additional to (or possibly instead of) those for the anticipated primary group of users, and selecting the highest value outcome across all bids; or awarding bidding credits to bidders who commit to accommodating sharers. This would offer prospective sharers an open and transparent opportunity to secure spectrum rights.

6.29   In the consultation, we identified a range of potential risks with the use of these options. A number of stakeholders agreed with these risks and we continue to view the following risks as important considerations. There are regulatory failure risks in defining how to accommodate sharing demand, e.g. in defining licences for sharers or in any setting the appropriate level of bidding credits to compensate those willing to accommodate sharers. There is also a risk of adding complexity to an auction design, which may already be relatively complex, making participation more difficult, and potentially deterring certain parties from participating.

6.30   Secondly, auctions could help improve the efficiency of shared use. For example, we suggested that databases such as those in use to control spectrum access for TV White Space Devices could incorporate market-based enhancements to prioritise access between prospective sharers, with auctions to resolve conflicting demand.

6.31   Finally, we could use auctions for the purpose of introducing new sharing, with two main examples.

- Two-sided auctions provide for a way to compensate existing spectrum licensees for returning (part of) their licensed rights so as to make spectrum available for new uses. We do not currently have the legal power to carry out such auctions. We could seek these powers if we considered this to be appropriate and necessary to performing our duties.

- Overlay auctions identify new users who can then agree with existing users on how and/or when to extent their use beyond what the licences available in the auction allows. The conditions of the award, including new licence(s), define how existing and new users must share the spectrum, potentially for a limited time, and manage

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[37] See methodology 3, paragraph 5.140 page 98 of the SRSP
[38] See the 2006 award of licences for 1781.7-1785 MHz/1876.7-1880 MHz at http://stakeholders.ofcom.org.uk/spectrum/spectrum-awards/awards-archive/completed-awards/award_1781/documents/ and the 2013 award of licences for the 2.6 GHz band at http://stakeholders.ofcom.org.uk/consultations/award-800mhz-2.6ghz/statement/

the risk of harmful interference between their respective uses. The incumbent user(s) then have the choice whether to relinquish some or all of their rights to the spectrum (earlier in the case where there is a limited time for these rights to continue) under a commercial agreement with new user(s).

6.32 Any of these options may be relevant to future authorisation decisions. When considering this issue, we have to weigh up the pros and cons of facilitating sharing in awards on a case by case basis, having regard to our legal powers, the scope and demand for sharing in the available spectrum, the potential (private and broader) value of allowing sharing, and the risks for the award process discussed at paragraph 6.29 above.

Technology enablers

6.33 New developments in technology have the potential to enable more intelligent and efficient ways of sharing spectrum. The technology enablers we set out in the Consultation, and which we retain in the Statement, were protocols, geolocation databases, sensing, automatic reporting of interference, and frequency and band agile equipment. In retaining all of the tools, we recognise that these technologies may have limitations but that they continue to develop and could play a role in future sharing models.

Protocols for accessing shared spectrum

6.34 In the consultation we described a number of technical approaches or protocols for accessing shared spectrum in a way that manages interference risks:

- A common family of access control methods are termed Carrier Sense Multiple Access (CSMA). This approach - often termed "listen before talk" - is implemented by Wi-Fi equipment, whereby devices with data to send listen for the transmission of other devices on the network. They only transmit if no other devices can be heard.

- This approach can also extend to other technologies, often termed "d*etect and avoid"* or "sensing" (see paragraphs 6.42 to 6.44 below). For example, Wi-Fi access points using Dynamic Frequency Selection (DFS) can listen for other users of spectrum, such as radar services, and, if found, they switch to another, clear frequency within the band. A variant of this approach sees Wi-Fi access points select frequencies that are less used, or not used at all, by neighbouring access points. Detect and avoid approaches can therefore be used to both protect existing spectrum users and improve the performance of Wi-Fi networks.

6.35 Respondents focussed on the potential for interference, and the applicability of these protocols to particular services.

6.36 Protocols are a well-established method for enabling access to shared spectrum, and services that rely on their use (e.g. Wi-Fi) provide deliver significant benefits. Protocols also continue to evolve, and we are interested in future developments. However we recognise the limitations of these enablers and we will need to be mindful of these when considering their application.

Geolocation database technologies

6.37 Geolocation databases are making it easier for devices to identify spectrum that is available for sharing while protecting the operation of existing services. While the current focus in on the use of databases to manage access to TV white spaces within

470-790 MHz, the fundamental principle is not frequency specific and can be extended to a broader range of frequencies.

6.38 In the consultation we suggested some ways that geolocation databases may evolve:

- In the future, the concept could potentially be extended to manage access between opportunistic sharers, improving quality of service.[39]

- Where incumbent use is static, e.g. around radio telescopes or military sites, database information could potentially be integrated into devices, removing the need to connect to a database to confirm whether it is possible to transmit.

6.39 Respondents to the consultation viewed geolocation databases as a promising enabler, and we were urged to expand the use of geolocation technology to bands beyond UHF, to build on the TV White Spaces use case. However some raised concerns relating to the reliability of the databases, the accuracy of location information, and the ability of users to bypass the parameters set by the databases where devices are manually configured.

6.40 In implementing geolocation for TVWS, Ofcom has gone through a process of qualifying third-party databases by testing a range of requirements including many regarding the integrity of elements controlling power radiated at any frequency. Ofcom also has the ability to test on-going compliance, and interference management procedures.

6.41 Ofcom recognises that practical geolocation technology is in its infancy and Ofcom's TVWS Statement on manually-configured devices set out how devices can be manually configured as a temporary measure until geo-locating technology in whitespace devices is commonplace.[40] The configuration of such devices is subject to greater control than those that automatically geo-locate.

Sensing

6.42 Sensing describes the ability of devices to listen for other nearby spectrum users and determine whether it is possible to transmit. An advantage of a sensing approach is that a device is able to determine autonomously whether spectrum is available for use without the need to contact a database.

6.43 Respondents to the consultation recognised that sensing offered new opportunities for spectrum sharing in conjunction with geolocation database technologies, but we received a number of responses outlining the limitations of sensing, and the dangers of relying on sensing alone. In particular, sensing may not identify receive-only or low powered systems, or receivers that are not co-located with their transmitter (or some other beacon), creating the possibility that devices may mistakenly transmit on an occupied frequency.

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[39] Under the current TVWS framework, databases provide information to users about whether and on what frequencies and at what power levels they may transmit to avoid causing harmful interference to incumbent users in and adjacent to the band. Coordination to prevent interference between different white space users is not currently mandated in the UK.
[40] *Licensing manually configurable white space devices*, Statement, September 2015 http://stakeholders.ofcom.org.uk/binaries/consultations/manually-configurable-wsds/statement/Licensing_manually_configurable_white_space_devices.pdf

6.44   Barriers to achieving cost effective and accurate sensing remain but technical research is continuing to address these challenges. Having taken into account the recent responses, our view remains that, in the longer term, we believe spectrum sensing is likely to play a role in conjunction with geolocation databases.[41]

Automatic reporting of interference

6.45   Our consultation proposed that automatic reporting on interference between users would serve to provide real-world feedback on technical co-existence. This would enable technical parameters to be optimised, assumptions refined and margins reduced, resulting in more efficient sharing and greater value extracted out of spectrum.

6.46   Microsoft and Dynamic Spectrum Alliance (DSA) responded that, in principle, this enabler could allow for more efficient spectrum use, reducing the over-protection afforded to incumbent users by conservative coexistence frameworks. Microsoft noted that the plan for the US 3550-3700MHz band envisions automatic reporting to a spectrum management system by base stations, with the spectrum management system sending instructions for base stations and devices to adjust output power levels accordingly.

6.47   However, this enabler would depend on being able to reliably identify when interference is occurring and its source, which respondents including The EMEA Satellite Operators Association (ESOA) and the Global VSAT Forum (GVF) and BT said would be difficult. Where detection is possible, this would be after the interference has already occurred. There were also concerns over the cost burden from including the reporting capability in equipment.

Frequency and band agile equipment

6.48   Equipment that can tune across a wide spectrum range in a more agile way than being engineered to very specific bands could allow greater flexibility in sharing. This could help reduce dependence on band harmonisation to help achieve sufficiently low device price points and increase the pool of frequencies a sharer can build its business on – thus ultimately reducing the risk that its business case is damaged by changes in the incumbent's spectrum usage.

6.49   A number of stakeholders agreed with Ofcom that frequency agile equipment could allow for greater flexibility in sharing and should be encouraged. However, respondents also agreed that such agility could add extra device complexity and therefore costs.

6.50   We note that some PMSE and satellite stakeholders were of the view that frequency agile equipment would be irrelevant to their sectors. BEIRG responded that this enabler was ineffective at large scale events where most available spectrum is already in use. ESOA and GVF pointed out particular difficulties for satellite, as the frequency bands used by the satellites cannot be changed after the satellite is launched, and there are large frequency separations between satellite bands.

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[41] This is consistent with our view as set out in a previous Statement on sharing for mobile and wireless broadband, published in April 2014. http://stakeholders.ofcom.org.uk/consultations/spectrum-sharing/

6.51   Nevertheless we consider that for some uses frequency agile equipment might help to alleviate concerns with certainty of spectrum availability in the future.

Authorisation tools

6.52   The Spectrum Management Strategy noted that we need a combination of market mechanisms and regulatory action to deliver optimal spectrum use. New opportunities for sharing may come about through commercial agreements, using trading and leasing. But if commercial agreements are not possible or appropriate, then regulatory action may be relevant. We could use authorisation conditions to provide incentives to share or to make sharing technically feasible. This includes, for example, the potential to create new 'tiers' of users (as in the example of TV White Space), or obligations in licenses for licensees to provide information. Ofcom action also may be required for the implementation of some of the enablers mentioned previously.

Information requirements

6.53   In paragraph 6.7 we set out that the provision of more and better information could help to increase opportunities for sharing. Obtaining additional information may require obligations in licences, where appropriate.

6.54   The comments we received on this enabler related to the types of information we might collect, or gave support for a 'use it or share it' approach. Our current focus for information is set out at paragraph 5.17. We discuss 'use it or share it' conditions below from paragraph 6.67.

Tiered authorisation approach

6.55   In the consultation we described the tiered authorisation approach as a hierarchy of rights for different categories of user in a given frequency band. An example of tiered access is the model in place for TV White Spaces, with Digital Terrestrial Television as tier 1, PMSE as tier 2 and white space devices as tier 3. DTT licensees take precedence over all users of the band. PMSE licensees fit around DTT licensees, but take precedence over White Space Devices (WSDs). WSDs fit around all other users. We proposed that the idea of tiered access could cover the definition of relative priorities between groups of licensed users, between licensed and licence-exempt users and between groups of licence-exempt users.

6.56   The benefit of a tiered authorisation approach is that it should create conditions in which existing users can continue to invest and in which new users have some clarity on the opportunity a band offers. However, balancing the impact on any incumbent(s) and the usage constraints on any new user is a challenge. If access for lower tiers can only be opportunistic, this increases risk to the users because uncertainty about security of spectrum access and long term ability to guarantee a quality of service may make investment more challenging.

6.57   There was support for a tiered authorisation approach, albeit with some concerns over how it can be enforced in practice. Several respondents were keen for us to identify new sharing opportunities soon, to build on the WSD initiative and to promote innovation, with some stakeholders suggesting a model similar to the model the FCC is implementing at 3.5 GHz in the USA.

6.58   We agree that a tiered authorisation approach is one of the tools with greater potential to deliver sharing benefits in the short to medium term and beyond. We are

reviewing the options for bands that might provide such opportunities in the short to medium term, and have published a Call for Inputs on the first such band (see Section 7, 'Actions on sharing').

Some stakeholders suggested additional tools and enablers

6.59   Some stakeholders made suggestions in their responses for tools and enablers that could help to facilitate particular kinds of sharing. This included:

- Open Access Network.

- Multi-operator Core Networks; and

- "Use it or share it" conditions.

Open Access Network

6.60   Rivada Networks proposed the creation of an open-access market for capacity on one or more mobile networks. It referred to two countries, Mexico[42] and the US,[43] where new networks could form the basis of such a market.

6.61   The model Rivada Networks presented involves dedicated mobile spectrum and a dedicated LTE network that provides sufficient capacity for an open market to operate. The market can also receive capacity from other sources, in particular from existing mobile licensees.

6.62   In this model, providers of mobile services to end users, but also wholesalers and intermediaries, can bid for capacity covering different time periods and locations, e.g. for the year ahead, and then within that year, on a gradually more granular basis, e.g. for the month and then hour ahead. The market would have rules to establish the opportunity costs of winning bidders' demands and to keep bidders honest about their future requirements.

6.63   In principle, an open access model of the kind proposed by Rivada could potentially promote competition and efficient use of spectrum. We will be interested to see the effectiveness of early implementations of such capacity markets and will give further consideration to the scope for a similar model in the UK.

Multi-operator core networks

6.64   UKB responded that Ofcom should also consider alternative forms of spectrum sharing, such as Multi-Operator Core Networks ("MOCNs"). MOCNs are a way in which MNOs can share frequencies and share a radio access network, whilst each operating their own core network. Radio resource is dynamically distributed according to a rule agreed between the parties. For example, with two operators, each operator may be allocated half of the capacity when their combined use matches the resources; when use by one of the parties decreases below 50%, the other can use the delta.

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[42] The Mexican Government has set aside a large amount of spectrum for a public provider to bring competition to the existing mobile duopoly.
[43] In the USA, FirstNet holds the rights to part of the 700 MHz with public safety requirements. There is an opportunity to make capacity available to others to the extent that FirstNet's use is likely to be occasional and limited to times and areas where emergency services deal with particular events.

6.65   UKB responded that its parent company, HKT, has employed two MOCN spectrum capacity sharing arrangements on a commercial basis in Hong Kong.

6.66   We recognise that a sharing arrangement of this kind could have technical efficiency benefits and potentially broader benefits when sharing resources between similar services based on the same 4G technology but may be less applicable when considering how different uses and technologies may share the same spectrum. However, as with other asset-sharing arrangements such as network sharing, there is a risk that it may reduce competition between operators. Such sharing arrangements would therefore require careful consideration and the spectrum trading regulations include a competition check for mobile spectrum trades. It is also not clear whether other mobile spectrum holders are interested in offering and getting access to spectrum in this way.

"Use it or share it" conditions

6.67   Some stakeholders were in favour of "use it or share it" conditions in licences.[44] However, several existing spectrum users (Vodafone, Telefonica, EE, BT, JRC) emphasised that sharing should be voluntary, driven by market forces.

6.68   Licences issued under the WT Act are not exclusive[45], and we have discretion to authorise multiple uses of licensed frequencies, for any purpose, in line with our statutory duties. It is therefore not necessary to change existing licences for us to have the option to introduce additional uses if it is in line with our statutory duties. For new licence awards, if there is evidence of demand for shared use, we will consider whether such demand may lead to consumer benefits, by applying this framework. One of the tools discussed above that has the potential to address the underlying objectives of stakeholders favouring "use it or share it" conditions is a tiered authorisation approach, with one or more lower tiers of users being able to use spectrum where primary users does not do so.

6.69   We have also previously set out our view of "use it or lose it" conditions.[46] We do not consider that imposing such obligations is in the interests of citizens and consumers. Such clauses could introduce uncertainty for licensees which could undermine investment incentives. There are also a number of legitimate reasons why a licensee might not be using their spectrum at any specific time without this leading to

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[44] Microsoft and the DSA responded that Ofcom should consider a 'use it or share it' approach for licensed users. Prof Stephen Temple proposed a presumption of sharing above 2GHz at some point in the future. Rivada Networks suggested that future spectrum auctions include the duty to make spare network capacity available in an open access market.

[45] *Assessment of future mobile competition and award of 800 MHz and 2.6 GHz*, Statement, July 2012, paragraph 5.67 http://stakeholders.ofcom.org.uk/binaries/consultations/award-800mhz/statement/statement.pdf
Public Sector Spectrum Release: Award of the 2.3 and 3.4 GHz spectrum bands, Statement and consultation, May 2015, paragraph 7.63
http://stakeholders.ofcom.org.uk/binaries/consultations/2.3-3.4-ghz-auction-design/statement/statement.pdf

[46] *2.3 and 3.4 GHz spectrum award: Consultation on a 3.4 GHz band plan, varying UK Broadband Limited's licence and a call for inputs on other aspects of the award*, October 2013, paragraph 5.24 http://stakeholders.ofcom.org.uk/binaries/consultations/2.3-3.4-ghz/summary/2.3-3.4-ghz.pdf
and *Spectrum Management Strategy*, Consultation, October 2013. Annex 5 'Principles for our market-based approach to spectrum management', paragraph A5.6
http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/summary/spectrum_management_strategy.pdf

inefficient use of spectrum over the longer term, e.g. in circumstances in which technology and equipment standards may need to be developed to enable the anticipated use that may subsequently increase the value of the spectrum. There may also be significant challenges to enforcement.

Actions on sharing

7.1 With the publication of this Statement, we confirm our commitment to apply the sharing framework to our spectrum authorisation decisions.

7.2 We are also already taking, or planning to take, a series of specific actions that should help to promote sharing.

We are taking action to help prospective sharers

7.3 To continue with our efforts to make more information available on spectrum use in the most useful forms,[47] alongside this statement we have released an extract of the Wireless Telegraphy Register (WTR) in open format.[48] This information is important as it is the only comprehensive record of all civil spectrum user rights. It provides information about who is authorised to use spectrum, via a Wireless Telegraphy Act licence, and the technical transmission parameters associated with the licence.

7.4 While the Register has been available on the Ofcom website for some time, up to now the information could only be viewed and not downloaded. Release in open format will allow stakeholders to use the information more easily e.g. for their own network planning purposes and to investigate options for new sharing or innovative uses. We expect to update this information quarterly at first and may do so more frequently if there is demand for it.

7.5 We are also considering releasing receiver information (where we hold it) to further stakeholders' ability to investigate potential for sharing. Presently we release the transmitter information under the Environmental Information Regulations 2004 (EIR) as transmissions are classed as emissions under the regulations. As receivers do not emit, to extend the release of information to include receivers we will need to make new regulations under Section 31 of the WT Act.

7.6 Some respondents to the consultation were also interested in better ways to show their interest in participating in sharing or trading, for example a spectrum broker role or spectrum sharing register.

7.7 We do not know what the level of demand for such systems might be. We are also mindful that some stakeholders may want information about their demand for spectrum, or their willingness to share, to remain confidential. Therefore at this stage we think a proportionate response is to establish a point of contact for stakeholders looking to get access to spectrum, including through spectrum sharing, for which there are no existing suitable authorisations in place. It could also be used by incumbents who wish to indicate that they would consider sharing. We have established a new mailbox, Spectrum.demand@ofcom.org.uk, for such requests. However, this is not intended to duplicate Ofcom's well-established licensing

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[47] http://stakeholders.ofcom.org.uk/market-data-research/opendata/
[48] http://stakeholders.ofcom.org.uk/spectrum/information/spectrum-info-FAQ/wireless-telegraphy-register/ Open format means that the information is machine-readable and licensed for re-use.

processes, and stakeholders should first check our website to confirm that this is the most relevant route.[49]

7.8   These requests will be reviewed to consider whether a more structured approach (e.g. new authorisation) by Ofcom could be required to address new demand from potential new users. We will review whether more sophisticated, and costly, measures may be justified in light of demand.

We will consider the potential for new sharing opportunities

7.9   Several respondents were keen for us to identify new sharing opportunities soon:

- to build on the WSD initiative; and

- to promote innovation, by considering a tiered authorisation approach.

7.10   In response to this feedback we have considered spectrum bands that could support new uses and where we could apply this framework. Our understanding of demand is that, for example, stakeholders may be interested in:

- high bandwidth applications, requiring relatively large amounts of spectrum which are more likely to be available at higher frequencies; or

- applications that require more limited infrastructure and achieve relatively wide-area coverage, and therefore operate at lower frequency spectrum, which is likely to be available in smaller channels.

7.11   We have identified the upper C-band (3.8-4.2GHz) as a potential candidate for the first of these categories. The band is currently used by fixed services, fixed satellite services and a UK wide spectrum licence for Fixed Wireless Access services held by UK Broadband. We wish to understand the opportunities for and impacts of more intensive sharing in this band, with a particular interest in new innovative services, and have published a Call for Inputs alongside this document.[50]

7.12   We would welcome feedback from stakeholders regarding other potential opportunities that we could consider in the short to medium term.

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[49] http://stakeholders.ofcom.org.uk/spectrum/licensing-sectors/spectrum-demand-requests/
[50] *3.8GHz to 4.2GHz band: Opportunities for innovation*, Call for Input, April 2016.
http://stakeholders.ofcom.org.uk/consultations/opportunities-for-spectrum-sharing-innovation/

Annex 1

Summary of responses

A1.1   This annex summarises the responses of stakeholders to our consultation, together with our responses to their submissions. We received 29 responses, two of which were confidential. Organisations that submitted non-confidential responses are shown in Table 2.

A1.2   This summary follows the eight questions we asked in the consultation. Where stakeholders have made the same, or very similar, comments in respect of multiple questions in their response we have sought to cover it only once under the question to which it has greatest relevance.

Table 2: List of non-confidential respondents

Arqiva	Internet Solutions	Professor Stephen Temple
BBC	Mr JP Gilliver	Rivada Networks
BEIRG	Joint Radio Company (JRC)	TechUK
BT	London Underground – Capital Programmes Directorate	Telefonica
DSA		Transfinite
EE	Microsoft	UKB Group (UKB)
Ericsson	NATS	ViaSat UK
Google	Nominet	Voice of the Listener and Viewer (VLV)
Global VSAT Forum (GVF) and EMEA Satellite Operators Association (ESOA)	O3B	Vodafone
	OneWeb	

Responses to Ofcom's potential barriers to sharing (Questions 1 and 2)

Question 1: Do you have any comments on the barriers to increased sharing that we have identified above? Which are the most significant and why? Are there others we should take into account?

Question 2: Have you experienced or are you experiencing the effects of these barriers? If so, in what circumstances and with what impact?

Theme	Stakeholder comments	Ofcom response
Information barriers	We cover responses on this point under Question 3.	
Market barriers	Transaction costs Vodafone, Ericsson and EE questioned whether absence of sharing represents an inefficient economic outcome. As there are strong incentives on existing users to make efficient use of spectrum. Sharing will only be worthwhile if a sharer is prepared to cover the costs to the existing user from allowing shared use. JRC noted that costs may appear excessive to potential sharers compared to the annual cost of a licence for similar spectrum. BEIRG noted there will also be hidden costs for a potential sharer, of time, effort, knowledge and experience. BT noted that market barriers would be higher if there was no comparable case of successful sharing. Impact on spectrum value ViaSat and Microsoft responded that incumbents may view sharing as devaluing their asset, for example because "exclusive" licences are seen as more valuable than shared licences. Constraints on future use Arqiva, GVF/ESOA and UKB Networks were concerned that sharing would constrain licensees' future use and act as a barrier to investment. JRC reported experiencing resistance to sharing as incumbents fear long term access may be lost.	We appreciate that transaction costs could be a barrier of concern in specific cases, but that this is not necessarily the case. We discuss in Section 3 the circumstances in which we expect to consider sharing opportunities. We set out our views on market barriers at paragraphs 5.23 to 5.30. As highlighted in paragraph 3.2 the spectrum licences we grant are not exclusive and investigating a sharing opportunity will always involve considering the impact of the opportunity for both prospective sharers and existing users. When we consider specific new sharing opportunities we will assess the circumstances and the benefits delivered by both existing users and prospective users. See paragraph 5.39.

	Ericsson argued that uncertainty of access to spectrum is a constraint on a sharer, and may result in higher costs including for end-users.	
Technological barriers: challenges of coexistence analysis	O3B and Transfinite highlighted that availability of data to carry out coexistence analysis may be a limit, in particular technical parameters. A confidential respondent said that technological challenges are not sufficiently understood, as a potential new user is unlikely to be willing to provide sufficient technical data on future deployments, due to competition concerns. NATS considered that views on acceptable coexistence risks may differ between incumbents, Ofcom, and potential new users. Vodafone argued that a conservative approach is essential to provide confidence to incumbents. Some thought that particular types of uses were more difficult to share with, e.g. mobile, satellite and broadcasting.	Ofcom recognises that certain types of uses are more difficult to share with. The technical specificities of incumbent and potential new services require careful consideration when assessing the potential to share. Where there is a role for us, we will consider sharing on a case by case basis. Regulatory action on co-existence is complex and time-consuming, as discussed at paragraph 5.43.
Authorisation barriers	Conditions for authorisations UKB suggested that the inability to lease spectrum covered by the Mobile Trading Regulations (MTRs) is a constraint, and recommended leasing for mobile spectrum, subject to a competition check and consultation. UKB also argued that the European Commission's policy to mandate uses for certain bands restricts spectrum from being used in the most efficient way. Regulatory timescales and commitment Microsoft stated that regulatory authorities have taken an overly conservative, slow approach to sharing. A number of respondents including techUK, DSA and Nominet argued that regulatory uncertainty and delay stifles innovation and investment, and makes it difficult for companies to develop strategies involving spectrum use. They point to TV White Spaces as an example.	See paragraph 6.18 for a discussion of a potential extension of leasing. See paragraph 5.36 for a discussion of the scope for services other than those harmonised in European decisions. We recognise that cases that require further liberalisation may lengthen regulatory timescales. See paragraph 5.38 regarding regulatory timescales. We are committed in each case to working through issues in timescales that are as short as appropriate and practicable.

Other comments	Five respondents stated that sharing should be voluntary for licensees. Nominet recommended that Ofcom state that sharing is the preferred way to access spectrum. EE believed that Ofcom had not provided evidence of demand for increased sharing, that barriers are preventing parties from expressing that demand, or that removing barriers through regulatory intervention would facilitate more efficient use of spectrum. Only when the market fails should there be intervention.	We address these comments in section 3. We have set out our view that sharing is likely to play an increasingly important role to serve growing demand for spectrum. This framework involves considering systematically whether sharing has a role to play in new authorisation decisions, but not seeking to apply a sharing model in cases where it is not in the best interests of citizens and consumers.

Responses to Ofcom's suggested tools and enablers (Questions 3 - 7)

Question 3: Are the categories of information set out in paragraph 5.5 the right ones? Are there any areas here that you think we should prioritise? Are there other types of information that we should be improving?

Theme	Stakeholder Comments	Ofcom response
Information on spectrum use – commercial and public sector use	Many respondents would welcome more information about government use of spectrum, e.g. where it is under-used, or about opportunities to share with commercial operators. Google, DSA, Internet Solutions, Microsoft and Nominet stated that access to information on spectrum usage would be vital to dynamic sharing opportunities. However, many acknowledged that some information cannot be published for security and public safety reasons. Others raised concerns regarding commercial confidentiality, potentially requiring arrangements such as independent third parties, and the costs or difficulty of making certain types of information available, e.g. real-time or forward looking. There would be limitation to use of some data, e.g. estimates in forward-looks or how representative monitoring may be.	We discuss provision of information on spectrum use and public sector use at paragraphs 5.17 and 5.19.
Information on spectrum	UKB stated that information regarding who is licensed to use spectrum is a pre-requisite for sharing. UKB and	We have now published a full extract of the WTR (see 7.3). This extract includes details of assignments and

authorisation	Ericsson suggested improvements to our online database (the WTR) including information on Crown use, a contact for sharing, and different search criteria.	licences for the licences we grant.
		Requests to access our frequency allocation tools are discussed in paragraph 6.9.
	TechUK and BT asked for access to Ofcom's frequency coordination tools, so users can make sample requests for opportunity assessment.	As indicated in the Spectrum Management Strategy, we conduct regular reviews of the different sectors that use spectrum, consulting with stakeholders, to understand the changes affecting the market and the specific sector involved. Where licences are tradeable, subject to potential market failures, we would expect trading and liberalisation to support use by the highest value users over time.
	TechUK also suggested the use of a timeline for the continued use of a band by an incumbent or when review of current user could take place.	
Information on interference	Microsoft, Google and BT considered such information useful. Microsoft suggested Ofcom should seek information on the threshold for actual harmful interference to incumbents operating in a spectrum band. BT further stated that it may be difficult to identify interference and its source. GVF/ESOA agreed that interference is difficult to identify, and said that it can be resource and time consuming; they did not see what the value of this enabler would be.	Understanding what would risk causing harmful interference generally requires coexistence studies, which we discuss above (see barriers).
		We discuss automatic reporting of interference from paragraph 6.45.
	Constraints on services expressed in terms of interference to other services are not necessarily enforceable and require action after the damage has occurred.	
Information on demand, and spectrum supply	Rivada responded that information on demand from existing and potential users is a priority. Ericsson considered that information on demand is interesting, but questioned whether a new user would want such information made public. UKB argued it would be useful for potential users to register demand for a particular frequency range and to inform existing users of that demand.	As noted at paragraph 5.20, we have limited information on demand for spectrum sharing.
		See paragraph 7.7 regarding the point of contact we are establishing for stakeholders to raise sharing requests, or when they may be interested in sharing spectrum they have rights to.

Question 4: Do you think the information about spectrum characteristics described in paragraph 5.9 would be useful? What information would need to be included as a minimum to make it useful?

Stakeholder Comments	Ofcom response
Stakeholders generally supported this enabler. We received a large number of suggestions for additional characteristics to be included. Stakeholders including DSA, Google, Internet Solutions, Nominet, London Underground and O3B suggested the following: geographic coverage, propagation characteristics, international harmonisation and details on adjacent band uses. GVF/ESOA, UKB and ViaSat believed the suggested characteristics were too general or simplistic.	We discuss this potential enabler at paragraphs 6.11 to 6.13.

Question 5: Have we identified the relevant market enablers, or are there others we should take into account? For each one, what is the potential for it to facilitate sharing and what are the downsides? Are there any that you think would be particularly effective or problematic?

Theme	Stakeholder Comments	Ofcom Response
General comments on market enablers	ViaSat, OneWeb, O3B and NATS responded that many market enablers were not relevant due to their sectors' multi-national spectrum use and international coordination.	Ofcom recognises that some enablers have more relevance to some sectors than others and will consider the particular conditions when considering potential sharing opportunities.
Trading and leasing	Google, UKB and DSA expressed support for the expansion of trading and leasing, with UKB recommending permitting leasing for mobile spectrum. Microsoft favoured ensuring that rules adequately protect against anti-competitive behaviour and ensure opportunities for new entrants and business models. Ericsson suggested that transaction costs could be reduced by preparation and approval of pro forma agreements that are deemed to be enforceable by Ofcom.	We address trading and leasing in Section 6 of the Statement including the potential for extension of leasing to bands subject to the Mobile Trading Regulations, see paragraph 6.18. Different transactions may require different agreements, but where pro forma documents can apply, it is for the parties involved in commercial agreements and their advisers to develop such documents.
Pricing	UKB agreed that spectrum pricing should reflect opportunity cost and take account of demand from potential sharers. Mr JP Gilliver thought that using pricing as an incentive to share could be effective for new allocations.	Paragraphs 6.20 to 6.25 set out our approach to Spectrum Pricing.

	Vodafone suggested that Ofcom could consider the impact of sharing on AIP valuations if an incumbent agrees to share. This would depend on whether, beyond the incumbent, the sharer would be the best alternative user. They suggested discounted AIP could support a policy goal to encourage sharing. ViaSat proposed a discounted fee if incumbents in the Fixed Service agree to share with Fixed Satellite operators for opportunistic use.	
	DSA argued that where spectrum management costs to Ofcom are small and multiple users can share access to spectrum, there should be no spectrum fees.	
Auctions and awards	JRC and OneWeb responded that spectrum access should be based on the wider social benefits of use rather than to the highest bidder. The BBC argued that participating in spectrum auctions might not be feasible for all those who seek to make use of sharing opportunities, because of the time and resources involved.	When awarding spectrum we seek to do so in a way that is consistent with our duties, for example regarding efficient use of spectrum. Where appropriate we have regard to issues such as auction complexity, risk of market failure and wider social benefits.
	Arqiva and a confidential respondent were of the view that auctions are not an enabler of sharing, but a way to displace incumbents.	We discuss the role of auctions and awards in supporting sharing opportunities at paragraphs 6.26 to 6.32.
	Vodafone urged caution regarding the risk of distortion of auction outcomes from new provisions. It thought the best approach is to have licence conditions that facilitate sub-letting of spectrum and to let the market determine if it is worthwhile doing so.	
	London Underground, Vodafone, and UKB highlighted the risk of complexity from offering spectrum lots specifically for sharers, incentive or overlay auctions (including for potential transactions following the auction).	
	The DSA encouraged us to develop our policy on sharing and auctions as flexibly as possible to allow a range of sharing scenarios.	
	BT noted that specific licences for sharers were introduced	

	in the 4G auction; however it thought the implementation limited the interest in those licences.	
Stakeholder suggestions	Rivada Networks proposed a dynamic market place model for bandwidth and suggested that future spectrum auctions should include an obligation to make spare network capacity available in an open access market. Internet Solutions also responded in favour of real-time or "on demand" markets.	We discuss Rivada Networks' and UKB's proposals at paragraphs from 6.59.
	UKB proposed the use of Multi Operator Core Networks (MOCNs), which enable multiple mobile users to share capacity.	We also comment on intermediaries at paragraph 6.19.
	London Underground argued for the creation of an independent body to facilitate future spectrum trades.	The GRMT and N-Systems Methodology were covered in reports we commissioned, although they have not been adopted as policy.
	Transfinite proposed their Generic Radio Modelling Tool (GRMT) and N-Systems methodology.	As explained in Section 7, we are looking at ways to improve our online provision of information about spectrum authorisation. We are also moving towards more online provision of licensing where feasible, for example, some Business Radio light licences will be available online in the coming months. However, spectrum assignment is complex and this is unlikely to be feasible for many/most licensed products.
	Nominet proposed that the enablers in the consultation should be components of an integrated software platform bringing together a searchable spectrum authorisation and use registry with means to obtain permission for spectrum usage. This could also integrate online licence applications, trading and auctions marketplaces, and geo-location services.	

Question 6: Have we identified the relevant technology enablers, or are there others we should take into account? For each one, what is the potential for it to facilitate sharing and what are the downsides? Are there any that you think would be particularly effective or problematic? What, if any, role should Ofcom play in helping to develop them?

Theme	Stakeholder Comments	Ofcom Response
Protocols for accessing shared spectrum	A confidential respondent argued that detect and avoid technology must be robust and sufficiently enforced to ensure protection of incumbent services. Two respondents gave the example of 5GHz broadband impacting	We consider that so-called polite protocols, like those used in Wi-Fi technology, have a role to play in helping sharing in some circumstances. Their relevance in any given case will depend on the specific circumstances, e.g. whether

	meteorological radar.	available technologies are indeed capable of identifying and coexisting with services they may need to work around. We note that where licence-exemption in harmonised bands is already in place, the details of the operation of licence-exempt technology rests in standards, which bodies other than us are responsible for producing. We discuss protocols for accessing shared spectrum in Section 6, from 6.34.
	DSA responded that detect and avoid protocols have the potential to introduce inefficiency and additional costs.	
	Microsoft argued that there must be a strong and shared mechanism for mutual and fair co-existence of different services sharing a band. Whilst the use of protocols relying on licensed ancillary channels may increase capacity of licensed operators at locations and times of heavy demand, it would in fact reduce the amount of spectrum sharing during these periods by crowding out license-exempt use.	
	GVF/ESOA and OneWeb said that the nature of satellite signals means it is not practical for other devices to detect the signal or determine where it is being received.	On interference to meteorological radar in 5GHz, it is a requirement under the WT Act and a condition of the UK's licence exemption regulations that no radio equipment is installed or used in the UK unless it meets minimum requirements designed to manage the risk of interference. An arrangement is in place between the Met Office and Ofcom that ensures that we take appropriate enforcement action in the event of interference.
Geolocation databases	Arqiva and Ericsson responded that geolocation does not work in certain environments, such as when devices are located indoors. GVF/ESOA said that the identification of some end-users may not be possible (e.g. TVROs) making the creation of geolocation bases extremely challenging.	Ofcom recognises that practical geolocation technology is in its infancy and permits databases to qualify for manually-configured devices.
	Google and BEIRG highlighted the importance of automated geolocation against manual configuration.	In implementing geolocation for TVWS, Ofcom has gone through a process of qualifying third-party databases by testing a range of requirements including control of radiated power. We also have the option to test on-going compliance, and interference management procedures.
	Nominet suggested that PMSE users could be included in the scope of TVWS geolocation database.	We discuss geolocation databases in Section 6, from 6.37.
Sensing	A number of respondents outlined limitations in sensing, and the dangers in relying on it alone. BEIRG, BT, GVF/ESAO, London Underground and Transfinite highlighted specific technical challenges (identifying receivers through beacons, difficulty with low power systems or hidden devices, intermodulation risks, delay in transmissions to process sensing data).	Significant spectrum sharing issues can arise where listen-before-talk sensing is the only scheme used at an autonomous transmitter. This is especially true where there is significant asymmetry in radiated power and receiver sensitivity for example.
		We agree that sensing is a technology in development, and we plan to continue to assess its potential, in

	BT, DSA, Internet Solutions and Microsoft saw potential benefits to sensing or solutions to its challenges, e.g. in conjunction with geolocation database technologies or when using a network of sensors.	combination with other techniques, and we will assess its relevance to particular opportunities over time based on the circumstances. We discuss sensing in Section 6, from 6.42.
Automatic reporting of interference	Microsoft and DSA responded that this enabler could allow for more efficient spectrum use. Microsoft noted that the plan for the US 3550-3700MHz band envisions automatic reporting from base stations to a spectrum management system and back to devices to adjust output power levels. DSA argued it could reduce over-protection of incumbents under conservative co-existence frameworks. However it is challenging to reliably identify when interference is occurring and its source (GVF/ESOA and BT) and it captures an issue without preventing it. BEIRG was concerned about performance degradation; Mr JP Gilliver and Ericsson were concerned about costs for receivers.	We expect that the role of automatic interference reporting would be primarily to help assess the effectiveness of measures to mitigate interference, not as a mitigation. It has to potential to be helpful for that purpose. We also accept that such features are probably more relevant to the medium to longer term, as they are not commonly available today. We discuss this enabler in Section 6, from 6.45.
Frequency and band agile equipment	Microsoft and BT agreed that frequency agile equipment could allow for greater flexibility in sharing. Google added additional benefits of redundancy, better continuity of service and improved throughput. DSA and BT acknowledged that implementing frequency-agile technology adds cost. However, DSA said that it could also make equipment more valuable and extend its life. BEIRG and GVF/ESOA considered this enabler irrelevant to their sectors, because of the intensity of use of available spectrum or the large frequency separation between bands.	There are various levels of frequency agility, from the manual retuning of systems through to automatic techniques like dynamic frequency hopping. If equipment was commercially available, these features could enhance the scope for sharing. We discuss frequency and band agile equipment in Section 6, from 6.48.
International harmonisation	Several stakeholders, including Arqiva, BT, Nominet and techUK argued that global standardisation and harmonisation are vital, citing the resulting reduced equipment costs for example. GVF/ESOA and O3B responded that the implications of	Ofcom agrees that the creation of economies of scale through international harmonisation will be beneficial to spectrum sharing. We discuss this further at paragraphs 3.19 to 3.22, including the proactive role that Ofcom takes in international forums.

	sharing should be considered on a global basis because of the international nature of satellite services. Arqiva, Nominet and BT responded in support of Ofcom playing a leading role internationally to promote and enable sharing.	We agree that considering harmonisation options needs to reflect the geographical footprint and value chain relevant to the services involved.
Other points	Several stakeholders invited us to take action regarding innovation for sharing, e.g. monitoring emerging technologies (London Underground), encouraging sharing-friendly standardisation (ViaSat), and promoting research throughout industry (Vodafone).	We monitor new technology developments and consider their potential implementation where this is in line with our statutory duties. We are also active in many harmonisation forums to promote the benefits of new technologies and sharing approaches and publish research into a range of technology solutions (see http://stakeholders.ofcom.org.uk/market-data-research/other/technology-research/).

Question 7: Do you have any comments on the authorisation tools that we have identified above? Are there others we should take into account? For each one, what is the potential for it to facilitate sharing and what are the downsides? Are there any that you think would be particularly effective or problematic?

Theme	Stakeholder Comments	Ofcom Response
Tiered authorisation	The BBC, Microsoft, Vodafone, UKB, BT, DSA, Transfinite and Google all stated that the tiered access model has potential. Microsoft and Rivada made suggestions for a version of tiered access with dynamic assignment techniques. The DSA recommended that Ofcom apply dynamic spectrum access to other bands following TVWS, noting the example of the US sharing regime in the 3.5GHz bands. BT, Ericsson, UKB and Vodafone highlighted challenges such as the scope for further tiers to operate alongside mobile services or how to make harmonisation and interference management work for licence-exempt tiers. JRC supported prioritising the establishment of a licensing	We discuss tiered authorisation at paragraphs 6.55 to 6.58 and in our Call for Inputs on 3.8-4.2 GHz, where we invite views on its application in that band. We don't license Crown users. Government is looking at how Crown use may evolve to make it easier to manage sharing and coexistence more flexibly and effectively across both civil and public sector spectrum.

	method enabling the public sector to sub-let spectrum without losing long-term access.	
LSA	Arqiva, BBC and Transfinite saw LSA as a useful tool for other member states, or with potential relevance for PMSE sharing in the UK at 2.3 GHz. Transfinite suggested Ofcom could manage a band with LSA or provide support to the area licence holder to manage the LSA.	LSA could be a relevant regulatory approach to enable spectrum sharing in environments where necessary, for example where the existing regulatory approach may not already facilitate multiple users or uses. The Wireless Telegraphy Act already facilitates sharing between multiple uses and users in the UK but Ofcom takes an active role in the development of LSA as a regulatory approach at both RSPG and in CEPT.
Other points	London Underground considered Ofcom could have a role in addressing challenges in commercial discussions on sharing. Microsoft and Ericsson commented that predictability and clarity of regulatory processes and decisions was important for sharing.	It would not be for us to advise stakeholders about their potential agreements. However, it is open to us to consider whether there may be a case for regulatory intervention, e.g. where commercial discussions fail. We agree that a clear legal and regulatory framework is important for stakeholders to invest and to deliver services. This framework contributes to this, complementing our Spectrum Management Strategy and associated policies, and consistent with our statutory requirements.

Responses to Ofcom's suggested characteristics of use

Question 8: Are the characteristics of use we have identified sensible and sufficient to provide a high level indication of sharing potential? Are there other factors that we should expect to take into account? Are there any factors that you consider to be particularly significant? Are there any which we should attach less weight to?

Theme	Stakeholder Comments	Ofcom Response
Scope of proposed characteristics	BEIRG, Ericsson, JRC, OneWeb, Vodafone and techUK broadly supported our proposals, also elaborating on the parameters that support our descriptions (EIRP and beam widths, effect on noise floor, interference risks e.g. compatibility between narrow and broadband systems,	We welcome these comments and set out our updated lists of high-level characteristics in section 4. As stated at 3.10 and 4.4, before implementing a sharing opportunity we would review its net benefits, taking the effects for existing as well as prospective new users and

	dynamic use, effective error free data rate).	their value to citizens and consumers into account. However, such value assessments are a complement to, but not part of, the characteristics of use we proposed.
	techUK, Arqiva and BT argued that the potential value/benefit of the new shared use should be taken into account and whether, as a consequence, sharing is justified.	
	DSA responded that true figures for licence exempt use may be difficult to find, but we should avoid worst case assumptions. Nominet encouraged us to focus on bands with greater harmonisation when applying the characteristics. Vodafone suggested that we illustrate how we intend to use the characteristics.	See also Section 2 of the Call for Input *3.8 GHz to 4.2 GHz: Opportunities for Innovation* for an application of the characteristics of use in that case.
Additional technical characteristics	BBC, Ericsson, Internet Solutions, Microsoft and JRC suggested additional characteristics such as some that relate to temporary sharing (referring to the provisions for the 2.3 GHz and 3.4 GHz bands), protection criteria for incumbents and cross-border constraints, equipment capability to use geolocation databases and dynamic channel assignment or details of transmit masks.	We have added to our proposed characteristics for high level assessments, to capture time variability in a better way. We also agree that the sharing capabilities for equipment available for the spectrum under consideration are helpful to inform the timescales in which sharing opportunities might be relevant. The other suggestions for additional characteristics are more relevant to detailed investigations. They are helpful, but primarily are relevant to a subsequent stage of coexistence analysis.

Annex 2

Glossary

4G	Fourth generation mobile phone standards and technology
AIP	Administered incentive pricing. A fee charged to users of the spectrum to encourage them to make economically efficient use of their spectrum.
CEPT	European Conference of Postal and Telecommunications Administrations.
Earth Stations	A station located either on the earth's surface or within the major portion of the Earth's atmosphere and intended for radio communication with one or more satellites or space stations
EIRP	Equivalent Isotropically Radiated Power. This is the product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain).
FCC	Federal Communications Commission (US)
Fixed link	A terrestrial based wireless system operating between two or more fixed points
Frequency band	A defined range of frequencies that may be allocated for a particular radio service, or shared between radio services
Geolocation	The capability of a white space device to determine the latitude and longitude coordinates of its antenna and the level of uncertainty in the accuracy of its antenna latitude and longitude coordinates, specified as $\pm\Delta x$ and $\pm\Delta y$ metres respectively, corresponding to a ninety-five per cent confidence level.
ITU	International Telecommunications Union. Part of the United Nations with a membership of 193 countries and over 700 private-sector entities and academic institutions.
LTE	Long-Term Evolution is a standard for communication of high-speed data for mobile phones and data terminals. The term 4G is generally used to refer to mobile broadband services delivered using the next generation of mobile broadband technologies, including Long Term Evolution (LTE) and WiMAX
Ofcom	Independent regulator and competition authority for the UK communications industries

Opportunity cost	The cost of a decision or choice in terms of the benefits which would have been received from the most valuable of the alternatives that was foregone
PMSE	Programme Making and Special Events. A class of radio application that supports a wide range of activities in entertainment, broadcasting, news gathering and community events.
RSC	Radio Spectrum Committee
RSPG	Radio Spectrum Policy Group. High-level advisory group that assists the European Commission in the development of radio spectrum policy.
SRSP	Ofcom's Strategic Review of Spectrum Pricing, published in 2010
UHF	Ultra High Frequency. The ITU (International Telecommunications Union) designation for radio frequencies in the range between 300 MHz and 3 GHz.
Wi-Fi	Commonly used to refer to wireless local area network (WLAN) technology, specifically that conforming to the IEEE 802.11 family of standards. Such systems typically use one or more access points connected to wired Ethernet networks which communicate with wireless network adapters in end devices such as PCs. It was originally developed to allow wireless extension of private LANs but is now also used as a general public access technology via access points known as "hotspots".
WSD	White Space Devices - which make use of transmission frequencies that are nominally allocated to other services but which are unused in the vicinity of the device.
WT Act	Wireless Telegraphy Act 2006
WTR	Wireless Telegraphy Act Register. The WTR provides basic information about individual licences. At present, this information is limited to licences that can be traded.