Flexible spectrum access methods Report for the UK Spectrum Policy Forum

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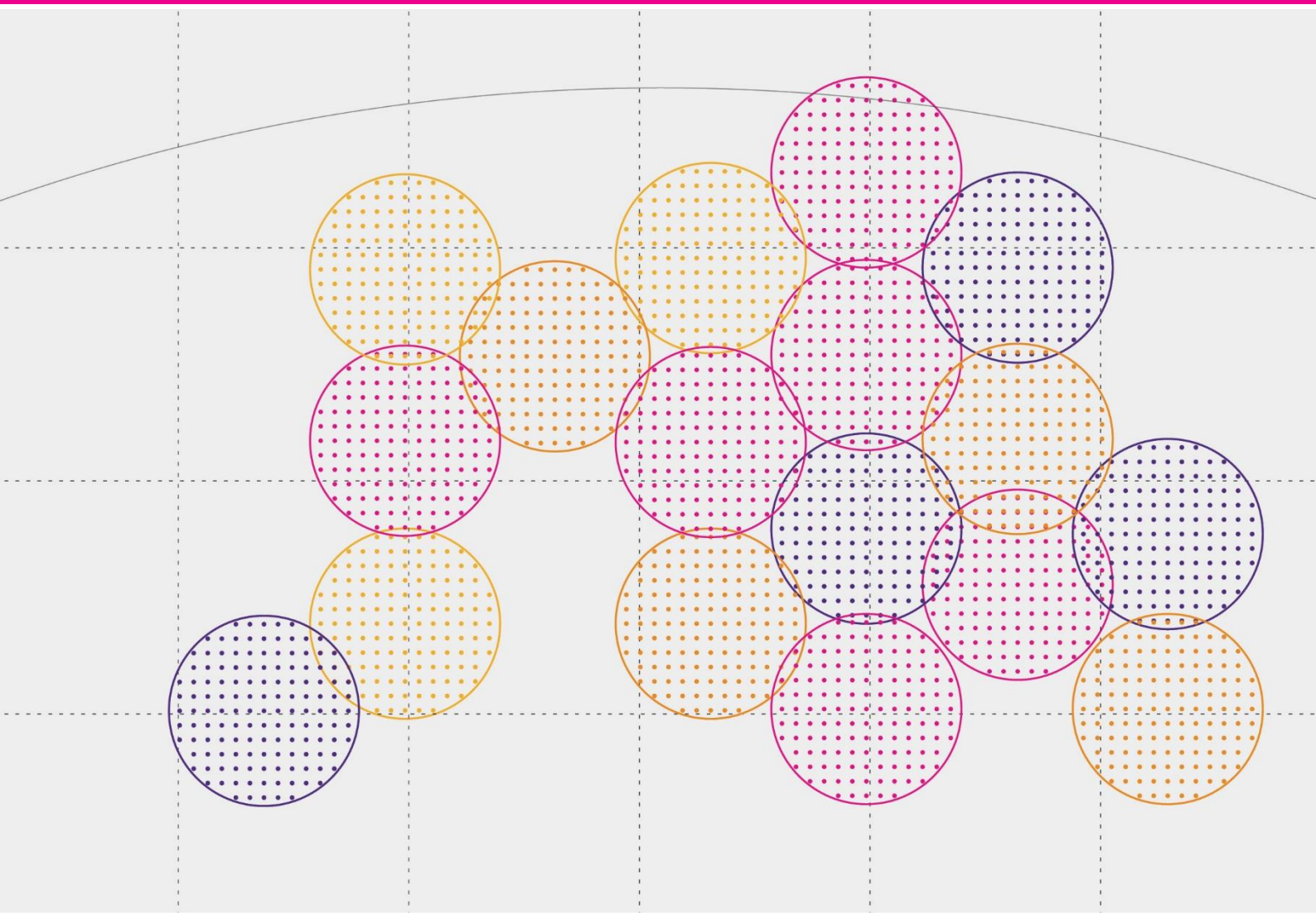

About Plum

Plum is an independent consulting firm, focused on the telecommunications, media, technology, and adjacent sectors. We apply extensive industry knowledge, consulting experience, and rigorous analysis to address challenges and opportunities across regulatory, radio spectrum, economic, commercial, and technology domains.

About this study

This study for UK Spectrum Policy Forum considers flexible spectrum access methods and builds on previous work undertaken by Plum in this area.

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About the UK Spectrum Policy Forum

Launched at the request of Government, the UK Spectrum Policy Forum is the industry sounding board to Government and Ofcom on future spectrum management and regulatory policy with a view to maximising the benefits of spectrum for the UK. The Forum is open to all organisations with an interest in using spectrum and already has over 150 member organisations. A Steering Board performs the important function of ensuring the proper prioritisation and resourcing of our work.

The current members of the Steering Board are:

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- Avanti
- BT
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1 Introduction

This study considers flexible spectrum access methods. It builds on previous work in this area including two reports developed for the Spectrum Policy Forum (SPF) on future use of licence exempt spectrum[1] and licensed shared access.[2]

Flexible spectrum access implies both spectrum sharing (either between different users of the same services or between different services), and the ability to access spectrum quickly and flexibly through an agile licensing approach (possibly such as a database), and possibly for transitory periods.

Flexible access and spectrum sharing have been around for a long time. Static spectrum sharing is already a feature of spectrum management in the UK. More flexible / dynamic spectrum sharing using various methods such as dynamic shared access (DSA) and licensed shared access (LSA) has more recently become available in the UK. However, there is relatively commercial little use of these techniques so far. It should be noted that the Wireless Telegraphy Act (WT Act) in the UK already facilitates flexible access / sharing and the more recent Digital Economy Act 2017 makes further provisions in respect of enabling Ofcom to regulate dynamic spectrum access services.

Flexible access and spectrum sharing were key features of the UK Spectrum Strategy published in 2014,[3] as potential enablers to enhance the value delivered to the UK from the use of radio spectrum. It was also part of Ofcom's spectrum management strategy on which a Statement was published in 2014.[4] Ofcom also published a Statement on spectrum sharing in April 2016.[5] More recently these techniques have been discussed as a feature for access to spectrum for 5G systems.

The key requirements of the study set out by the SPF were to:

- Undertake a "current state of play" review of usage of licence exempt and light licensing.
- Investigate emerging technologies, techniques and tools applicable for flexible / light licensing mechanisms.
- Review the current and emerging use cases for such flexible / light licensing access mechanisms.
- Investigate whether current availability of spectrum for such licence exempt and lightly licensed applications is likely to be sufficient in the medium term and (given evolution in technology and use cases) identify potential new spectrum up to 70 GHz suitable for such access mechanisms.
- Investigate potential future scenarios (e.g. wireless backhaul of small cells) where dynamic licensing or block assignments may be a suitable solution for rapid access to spectrum with guarantees of quality.

In addition, there were several specific issues raised by SPF members. These were:

- Provision of in building access on a licence exempt or lightly licensed basis.

[1] Future use of licence exempt radio spectrum – a report for the UK spectrum Policy Forum: John Burns, Selcuk Kirtay and Phillipa Marks, July 2015
[2] Licensed shared access – a report for the UK Spectrum Policy Forum: Tony Lavender and Tim Hogg, October 2015
[3] The UK spectrum strategy, March 2014 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287994/UK_Spectrum_Strategy_FINAL.pdf
[4] Ofcom spectrum management strategy, April 2014 https://www.ofcom.org.uk/__data/assets/pdf_file/0021/71436/statement.pdf
[5] Ofcom: A framework for spectrum sharing, April 2016 https://www.ofcom.org.uk/__data/assets/pdf_file/0028/68239/statement.pdf

- Leasing mechanisms to enable rural access.
- Review potential removal or simplification of DFS to increase effective use of the 5 GHz Wi-Fi spectrum.
- Reduce the time it takes to receive Ofcom approval for fixed links and similar.

Our approach to the study was to consider several scenarios. The scenarios are examples of possible spectrum requirements that could arise, which were divided into cellular (with emphasis on the initiatives within 5G), Wi-Fi and then all other areas. The specific situations raised by SPF members mentioned above were also considered in our analysis. Some of the scenarios highlight specific issues such as in building access, which are likely to become more important looking forward. For issues such as these, we have set out several case studies.

The analysis leads to several recommendations. These are put forward for consideration by the SPF Steering Board.

The remainder of this report is structured as follows:

- Section 2, provides a description of flexible spectrum access concepts.
- Section 3, sets out the scenarios we considered.
- Section 4, highlights issues raised by the scenarios.
- Section 5, presents our conclusions and recommendations.

2 Flexible access concepts

2.1 Introduction

The structure we follow in this section is set out in the simple table below which has two dimensions – whether access is restricted and whether interference is actively controlled once access has been granted.

Table 2-1: Different types of spectrum sharing

	Unrestricted access	Restricted access
No active interference control	Commons	Classical sharing
Actively controlled interference	Light licensing / DSA	LSA

This leads to four different types of sharing. Classical sharing and commons are well understood. In classical sharing licenses are granted to a few selected users (e.g. a satellite operator and a fixed link operator) after calculations show that under certain operational rules such as geographical exclusion they can share without interference. In a commons (or licence-exempt) approach, all can access if they use equipment that adheres to prescribed rules which might limit transmit power, duty cycle, bandwidth or other parameters. We consider the other two approaches further below along with two case studies.

2.2 Light licensing approaches

A 'light licensing regime' is a combination of licence-exempt like use and protection of users of spectrum. This model has a "first come first served" feature where the user notifies the regulator with the position and characteristics of the stations. The database of installed stations containing appropriate technical parameters (location, frequency, power, antenna etc.) is publicly available and should thus be consulted before installing new stations. If the transmitter can be installed without affecting stations already registered (i.e. not exceeding a pre-defined interference criteria), the new station can be recorded in the database. A mechanism remains necessary to enable a new entrant to challenge whether a station already recorded is really used or not as well as in the reciprocal case that a new entrant station is really used or not. New entrants should be able to find an agreement with existing users in case interference criteria are exceeded.

Table 2-2: Light licensing as a form of spectrum sharing

	Unrestricted access	Restricted access
No active interference control	Commons	Classical sharing
Actively controlled interference	**Light licensing** / DSA	LSA

The table shows that there are two approaches in this category of unrestricted access with actively controlled interference – as well as light licensing there is also Dynamic Spectrum Access (DSA). Broadly, both tend to make use of databases to manage interference, but light licensing uses static databases that only change whenever a new deployment is registered, whereas DSA uses dynamic databases that change hourly or even by the minute to reflect changing uses. We consider DSA in the next section.

Light licensing tends to require some form of registration[6]. So whilst access to the spectrum is typically provided to all who want it (often free or for a minimal charge) some record (database) of deployments is necessary to allow coordination between users. This can improve interference mitigation and can provide some increased certainty of quality of service. Registration of usage also allows the regulator to understand the level of activity in the band which can be helpful management information in determining whether the band is becoming full and whether any spectrum management actions need to be taken.

The need to record the location of devices in a database tends to bias light-licensing applications towards usage at fixed locations including:

- Fixed links.
- Satellite systems.
- Networks with base stations.

The simplest approach to light licensing is to require users to register in a database open to all. (Access can be restricted to pre-checked users or similar where there are confidentiality concerns). Existing users hope that new users check the database and refrain from a deployment that will interfere with an existing use. There is an element of self-interest in this since interference is normally mutual so a user deploying an interfering link will likely suffer interference themselves.

A more complex database could perform a check for any new registration and advise if there would be interference. This might be helpful since many users will have limited ability to conduct such checks for themselves but it does require definition of propagation models and understanding of interference scenarios and may lead to some ambiguity if interference still occurs as to who is responsible.

An even more interventionist approach is to put in place regulation such that if a new entrant causes interference they must resolve it. This would often be by the new entrant turning off their transmitter or moving it in space or frequency. The onus is on the existing user to spot the interference and notify the regulator at which point the registration date for the system or similar establishes who was there first (but this can fail where systems are registered long before deployment).

Another option is to require all those using the band to agree among themselves on the rules for usage and means of mitigating interference. If they were unable to agree then the regulator might impose conditions (this threat is typically sufficient to cause the band users to reach agreement themselves). This can only work with a relatively limited number of players (perhaps ten or less) otherwise the negotiations tend to be very hard and time consuming. It also generally requires most or all users to be identified at the start of the use of the band as any subsequent users do not get to contribute to the development of the rules.

This approach was adopted for the so-called "DECT guard-band" in the UK[7] – a small piece of spectrum that had previously been set aside as a guard band between DECT and GSM1800. Subsequent study determined that a guard band was unnecessary and that the band could be used for low power GSM transmission. 12 licenses were issued allowing access to the entire band. Ofcom is currently reviewing policy for this band and, if it decides to

[6] See ECC, Light Licensing, Licence Exempt and the Commons - http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCRep132.pdf and E-band Corporation, "Light licensing" - www.e-band.com/get.php?f.848

[7] Ofcom, "Proposal for the DECT guard band" - http://www.ofcom.org.uk/static/archive/ra/topics/pmc/consult/gsm1800/gsm1800condocfinalweb.pdf

make changes, these could be published later in 2017.[8] Ofcom has indicated that it is minded to retain the DECT guard band as a 2 x 3.3 MHz block for low power use on a shared access, light licence basis.

In summary, light licensing plays a role where congestion is unlikely but users require certainty that once installed a system will not suffer interference or a drop-in capacity - fixed links often fall into this camp. The category covers a broad range of different approaches, some of which may continue to be useful, but it could be overtaken by DSA approaches described next.

2.3 Dynamic spectrum access

The table below shows that, like light licensing, DSA is a form of management of the spectrum where there is unrestricted access but means of controlling interference.

Table 2-3: DSA as a form of spectrum sharing

	Unrestricted access	Restricted access
No active interference control	Commons	Classical sharing
Actively controlled interference	Light licensing / **DSA**	LSA

The rationale for a more dynamic access than provided by light licensing is that despite the apparent scarcity of spectrum, observations of actual usage appear to suggest it is far from full.

To use this spectrum that is apparently under-utilised a device needs to be able to determine whether the spectrum is currently in use in its location – or more specifically whether, if the device transmits, it will cause interference to the primary or licensed user. Three different ways to do this have been proposed – sensing, beacons and geo-location. Of these, geo-location tends to be preferred.

With geo-location, all determination of free spectrum is done centrally, in a "database" which contains enough knowledge that, given the location of the DSA device and knowledge of its characteristics, it can determine which frequencies are available. It starts with the device determining its location, using methods such as GPS or for a fixed device a pre-programmed location. The device then sends this information to the database using "conventional" communications channels such as available backhaul or using a cellular data channel. (At this stage, it is unable to use dynamic access.) The database then sends back to the device, still over a "conventional" channel, the frequencies that are available in that location. The device decides on which frequency to use and then starts to operate on that frequency.

This approach brings some key advantages:

- Because the devices are under the control of the database their behaviour can be altered by the regulator or other entities should there be any interference problems.
- Future changes in spectrum bands that the devices can access can readily be communicated.

[8] https://www.ofcom.org.uk/__data/assets/pdf_file/0018/103617/Update-on-the-DECT-guard-band-policy.pdf

- Various forms of reservation or device control could be implemented to prevent excessive interference between DSA devices[9].
- Band utilisation levels can be approximated based on the volume of database requests.

However, there are some disadvantages:

- Devices need to be able to locate themselves (or be located) and need an alternative communications path to contact the database. An incorrect location would negate interference mitigation.
- A database needs to be set up and run by some entity.
- It is possible that the records in the database do not reflect well the actual radio transmissions experienced resulting in problems occurring "on the ground" (although these can be corrected once discovered).

These disadvantages tend to bias the users of geo-location databases towards those entities running networks of base stations since these have a known location and permanent backhaul. The terminal devices in such a network can then operate as "slaves" to these base stations so they do not need to geo-locate or contact the database.

For a given device location, if a database knows (1) the possible location of licensed receivers, (2) the frequencies they are using and their receive power levels at those frequencies, (3) the performance of the licensed receivers, and (4) the emission mask of the DSA device transmitter; then the database can determine the maximum transmit power that the DSA device can use before it causes interference.

The location of licensed receivers can be found through predicting the licensed service signal strength and establishing coverage contours showing the areas within which the licensed service could be successfully received. Typically, these are calculated using propagation modelling tools.

The performance of the licensed receivers can be obtained through specifications or, better, from measurements with real-world interference. Finally, the emissions mask of the transmitter can be obtained from the device manufacturer, standards or measurements.

If interference to the licensed service is avoided, there is still a risk that multiple DSA users will access the spectrum in the same place and could cause interference to each other. This is a problem common to all unlicensed bands such as that at 2.4 GHz but with a new access method there may be new possibilities to control or avoid it. Options for unlicensed management of the band include:

1. Leave it to users to deal with the interference, as occurs in other unlicensed bands.
2. Publish codes of conduct that must be adhered to when accessing the band, such as the use of power control and maximum duty-cycle rules.
3. Restrict the use of particular bands through tighter access controls.
4. Use the database to manage the band in some manner.

[9] There is a question as to whether all the legal powers needed to do this are available within the UK. This would merit further investigation if such an option is preferred.

For the first case, users can decide what measures they wish to take. In some cases, different standards bodies might work together to reduce the interference between their technologies. This minimal interventionist approach from the regulator has generally worked well. It has enabled innovation by not restricting usage and the cases of interference have generally been limited and successfully resolved without the regulator. Any deviation from this approach should show clear benefits before being adopted.

Ofcom has considered the use of codes of conduct[10] but noted the difficult balance between rules that are effective while at the same time not restricting new technologies or approaches. In the end, they concluded that some "politeness protocols" could be used which provided high-level guidance as to how to avoid interference. Broadly these were:

- To use power control wherever possible so that the radiated power levels were minimised.
- To avoid continuous transmission such that others had a chance to gain access to any channel.
- To group together like applications in terms of power levels and duty cycles since similar applications tend to co-exist better than highly dissimilar ones.

The final option is new to unlicensed spectrum access since databases have not been used in the past. For example, a database could note multiple requests for frequencies in the same area over a short time period and start to refuse some on the basis that congestion might occur. Or it could accept a certain number for one channel and then start giving out the next channel. However, all these approaches are very inexact since little is known about the level of usage behind each request and the actual congestion that is occurring. Such approaches may also require changes to the legal framework under which database providers work.

One of the big advantages of a database approach is that policy can be changed over time without having to recall devices. Regulators could adopt a relatively open policy at first to see which applications emerge and then, if interference between DSA devices becomes a problem they could progressively tighten regulation as appropriate at the time. This "wait and see" approach could be a very powerful new way of managing spectrum.

2.4 Licensed shared access

The final category we consider is that where access is restricted and interference is also actively controlled. This is known as licensed shared access (LSA) or sometimes as authorised shared access (ASA).

Table 2-4: LSA as a form of spectrum sharing

	Unrestricted access	Restricted access
No active interference control	Commons	Classical sharing
Actively controlled interference	Light licensing / DSA	**LSA**

The concept of LSA is to allow a limited number of additional users into a band on a licensed basis. This might just be one other user in some cases. LSA is currently primarily foreseen as a mechanism to enable mobile broadband operators to access spectrum that has been harmonised in their region for mobile broadband use but where there are incumbents that are difficult to relocate. The idea is to award a licence, similar to an exclusive licence at e.g. 800MHz, but with the requirement to share with the incumbent radio services. This

[10] See http://stakeholders.ofcom.org.uk/consultations/lefr/statement/

approach is particularly useful where the incumbent is a Governmental user such as the military or aeronautical. Frequency bands under consideration for LSA in some countries include the 2.3GHz band and the 3.4-3.8GHz band.[11]

LSA would operate in a very similar manner to DSA. The regulator would define the access rules in conjunction with the incumbent and would facilitate a geo-location database (sometimes described as a repository) that would provide the shared user with the rights to access the spectrum in given locations. The difference would be that the regulator would then award the access rights to a limited number of users, on an individual authorisation basis, perhaps using an auction or similar.

LSA has been proposed by many of the key cellular manufacturers and is currently under consideration at a European level[12].

The decision of which approach to adopt might also be informed by the nature of the existing licensed usage. For example, if the existing use is intensive then sharing opportunities will be limited. In this case an unlicensed approach may be preferred. Where the licensed use is sensitive, e.g. military usage, then the existing user may prefer a licensed approach where they have close interaction with the users. Where the band is harmonised for mobile broadband but there is an incumbent non-broadband user, then given that mobile broadband operators tend to prefer licensed access then LSA might be a better approach.

Assigning LSA rights may be problematic. The regulator may have little insight into what the existing user will do in future, such as whether they might significantly expand their network. Hence, the guidance given in any auction would be vague requiring the bidders to take significant risk.

At the time of writing in 2017 LSA was still at the proposal stage and had not been commercially implemented. There have been several pilots / trials, including in Italy, France, Finland and the Netherlands. It is still unclear whether LSA is of sufficient interest to be adopted. In the UK there is no legislative barrier to implementation of a LSA type solution.

[11] Note that the 3.4-3.8 GHz band in the UK may not be available on a shared basis. Ofcom has already published its policy on 3.4-3.6 GHz where there a limited number of exclusions for incumbent services. Ofcom also appears minded to migrate incumbent services from 3.6-3.8 GHz spectrum when it makes it available for mobile broadband.

[12] E.g., see the RSPG opinion on LSA, [7].

3 Scenarios

To illustrate the sharing concepts of most interest, we developed several scenarios of possible spectrum requirements that might arise over the coming years. We have divided these into cellular (with emphasis on the initiatives within 5G), Wi-Fi and then all other areas, where we highlight some ideas. The scenarios are set out in the sections below and they were tested at a stakeholder workshop and in dialogue with other stakeholders.

3.1 Cellular (with emphasis on 5G)

Table 3-1:

Specific area	Scenario	Sharing attributes	Possible sharing approaches	Possible spectrum bands[13]
Rural sharing	Ability to self-deploy where MNOs choose not to (e.g. a rural community putting up their own 4G base station).	Secondary access on opportunistic basis.	Leasing to a database access entity (Neutral host networks)	Any mobile bands.
In-building sharing	Ability to self-provide in-building cellular coverage.	Automatic coordination to avoid interference with MNOs and other self-deployed solutions.	Leasing to a database access entity, spectrum commons, or some mix of the two.	Any mobile bands, but higher frequencies more useful
Use of LTE in unlicensed bands	MNOs using unlicensed frequencies for additional downlink capacity.	Polite protocols to ensure equitable access with other users (typically Wi-Fi).	General commons with rules set in standards bodies or similar	5GHz
LSA	Ability for MNOs to access lightly used spectrum	Access with well-defined QoS and rules	LSA	Likely bands below 6GHz.
mmWave sharing	Efficient use of mmWave band given uncertainties about how much spectrum needed and how widespread deployment will be	Coordinated but not necessarily dynamic	Light-licensing, LSA and leasing could all play a role	mmWave

[13] We note that UK plans for the 3.4-3.6GHz and 3.6-3.8GHz bands are well advanced and that the opportunity to implement sharing may have passed. We continue to mention these bands here because (1) they are a good example of where such sharing could have been implemented, (2) there may be opportunities to add in sharing in the future and (3) we often discuss the band 3.4-4.2GHz and at the upper end (i.e. 3.8-4.2 GHz) there may be more flexibility to consider sharing schemes.

3.2 Wi-Fi related

Table 3-2:

Specific area	Scenario	Sharing attributes	Possible sharing approaches	Possible spectrum bands
DFS removal	Use of 5GHz bands without needing DFS.	Simpler way of avoiding radar interference.	TBD.	5GHz.
Additional mid-band spectrum	Additional spectrum around 5GHz for Wi-Fi capacity expansion.	Depends on incumbents, ways to avoid interference needed, very low power may have some applications (e.g. in-car).	TBD	TBD, perhaps 6GHz.[14]
Wi-Gig spectrum	Widespread and simple availability of 60GHz spectrum.	Equitable access.	Classic commons.	60GHz.

3.3 Other scenarios

Table 3-3:

Specific area	Scenario	Sharing attributes	Possible sharing approaches	Possible spectrum bands
IoT: Sub GHz unlicensed	Harmonised spectrum allowing for base stations (e.g. high power, no duty cycle restrictions) and some QoS expectations.	Solutions that allow multiple networks to be deployed and spectrum shared equitably between them.	DSA and possibly agreements between operators.	Sub 1GHz, perhaps shared frequencies at such as 870-876 / 915-921, 863-865, 173.8-175, 401-402, 405-406MHz
Rural broadband	Provision of fixed broadband service in deeply rural areas.	Reasonable certainty of access	DSA	TV white space
Autonomous cars	Cars have many different requirements, V2V seems most likely to need shared access. Used for applications such as emergency brake warnings.	Very high reliability.	Shared spectrum dedicated to V2V application.	5 GHz.

[14] The 5925 – 7125 MHz frequencies, known as the 6 GHz band, have been identified under the 2017 US Airwaves Act for unlicensed use. It is also proposed that further frequencies for unlicensed use should be identified between 7125 and 8400 MHz provided they will not cause harmful interference with the incumbent. See https://www.congress.gov/bill/115th-congress/senate-bill/1682/text .

Specific area	Scenario	Sharing attributes	Possible sharing approaches	Possible spectrum bands
Trains	Passenger communications using e.g. mmWave to carriage roof and Wi-Fi inside.	Geographical reuse of mmWave	Via agreements with operators/license holders (e.g. leasing)	mmWave.

3.4 Summary

The scenarios show that:

- All different types of sharing potentially having a role.
- Many different bands are relevant ranging from sub 1 GHz to mmWave but this is partly a reflection of the focus on 5G. Sharing could potentially be applied retrospectively in bands already awarded to the mobile operators.
- There is a need for additional spectrum at 5 GHz and around or above 60 GHz for Wi-Fi, Wi-Gig and 5G.
- Sharing has many strong potential roles in the coming years. Equally, many of these scenarios have been relevant for years or decades and yet sharing solutions to address them have not emerged, hence there are clearly barriers to adoption which we discuss further in the following sections.

4 Outputs and issues

In this section, we consider the outputs of the scenarios and issues raised in our analysis.

There were common themes that arose in the analysis, the most prevalent of which points to two distinct views for spectrum access looking forward. We discuss these below. We then go on to discuss several specific issues.

4.1 Two emerging views for spectrum access

Two distinct views emerged during the stakeholder exercise.

- Conventional. Here, spectrum use and access mechanisms continue much as they are today. This view tends to be favoured by "incumbents". In this world spectrum remains band focused and a clear distinction remains between licence exempt bands and licensed bands.

- Alternative. Here there is more significant change and a different mix of spectrum-using players. This view tends to be favoured by those wishing to enter and disrupt (both small and large[15]). In this world there are more flexible access arrangements and a range of access methods within a band. Ideally there would be quick access to spectrum (e.g. through an online interface). Spectrum database techniques would play a significant role.

These two views are to some extent driven by the nature of the player expressing the view and their level of existing investment in spectrum-using services. Despite many years of innovation with spectrum access methods as highlighted in Sections 2 and 3, the conventional world largely prevails today. This may be because incumbent spectrum users tend to prefer the status quo[16] (apart from mechanisms like LSA, which was conceived to allow mobile operators access to the harmonised 2.3 GHz mobile band). Also, because input to regulatory processes (e.g. consultations) tends to be driven by those making these investments, there is a tendency to favour the conventional world scenario (those wanting flexible access often lack the voice, an identifiable champion and bargaining power in these processes). Indeed, in some cases alternative deployments and services might be non-commercial, such as a charitable organisation established by a rural community, however, this does not mean there is no value in provision of the service.

In the conventional world, the two most likely areas for flexible spectrum access / sharing are:

- mmWave spectrum where there is a general recognition that there is much uncertainty and that new approaches will be required (although there is still a desire by terrestrial mobile network operators and equipment vendors for a licensing system for mobile that is like that currently in use for mobile licenses).

- LSA, as mentioned above for bands that cannot be cleared.

Generally, the result in the conventional world is a preference by terrestrial mobile operators and equipment vendors for clearance and auction of spectrum, but that view is not held by satellite proponents

[15] Note these players, such as building owners, often lack a voice in spectrum discussions.
[16] The status quo also includes the route to new systems, through standards bodies which themselves tend to prefer conventional solutions.

In the conventional world, less likely (but still possible) outcomes, for reasons explained in subsequent sections, are:

- Self-deployment of cellular type solutions in rural areas.
- In building solutions beyond the use of Wi-Fi and the limited deployment of femto-cells used today.
- New solutions for licence exempt IoT deployments.

In the alternative world, a more equal consideration would be given to incumbents and potential new entrants, including those without an effective voice today, such as building owners and rural communities. There would be more acceptance in the regulatory community of innovation in spectrum access and of the risks that this sort of innovation might bring, but also of the economic and wider benefits it could potentially generate.

In the alternative world, the areas for sharing (in addition to the conventional world) could include:

- Self-deployment of cellular type solutions in rural areas.
- In building solutions with self-deployment in a neutral / shared band.
- A greater range of solutions for licence exempt IoT deployments.
- Ways to increase the capacity of Wi-Fi.

The views expressed here for the conventional and alternative worlds are derived from the input received from stakeholders (including some from outside the SPF circle). Ultimately, though, the view that prevails is a policy choice for Government and an implementation choice for Ofcom when it comes to the consideration of specific spectrum awards.

A common issue when considering potentially interesting and innovative ideas is that the results and the benefits come in the future, whereas incumbents have interests today that they wish to protect. A good example of this is the CBRS initiative in the US, where it may be years before the outcome is clear. If it is successful it may encourage other countries to adopt the approach but it may also be too late to achieve some of the benefits that such an approach could potentially offer. This could be characterised as the "chicken and egg" problem that often occurs when considering the interaction of innovation and regulation.

We believe that a credible case could be made for the alternative world. It fits with the ethos of the spectrum strategy and potentially could deliver more value from spectrum use. However, in the absence of any change to culture and the positioning of the various players in radio spectrum, the position that will transpire is what we have described here as the conventional world. We recommend that this is a policy area that DCMS should consider further and note that work has already been done on social value aspects of spectrum allocation.[17]

4.2 Specific issues raised

There were several specific issues raised by stakeholders. These were:

- Provision of in building access on a licence exempt or lightly licensed basis.

[17] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/480112/SVOS_REPORT_-_FINAL_18112015REV26112015.pdf

- Leasing mechanisms to enable rural access.
- Review removal or simplification of DFS to increase effective use of the 5 GHz Wi-Fi spectrum.
- Reduce the time it takes to receive Ofcom approval for fixed links and similar.

We consider each of these below.

4.2.1 In building access

In this section, we consider the concept of in-building provision of cellular-type solutions as a case study to understand the possible issues in more detail.

The underlying concept is to allow building owners and tenants to self-deploy wireless routers which have cellular capabilities. This is like the femtocell concepts, but instead of the cell being owned by an operator, or using spectrum belonging to that operator, it would use neutral spectrum enabling access from any cell phone regardless of operator. This makes in-building deployment much simpler since no complex permissions are needed and one device can accommodate all mobile phones. Such a solution enables better in-building coverage, seamless provision of voice calls, and managed load-balancing between Wi-Fi / WiGiG and cellular.

There are many different possible approaches that could be used to enable this sort of solution and we have not explored all options in detail. We describe here one approach which appears viable. In this approach a band is auctioned in a conventional manner but the licence holders (most likely the MNOs) would be able to lease unused spectrum to a neutral database "host", which they might jointly establish. Small cells deployed by building owners would then automatically contact this neutral host and be assigned spectrum under terms agreed collectively by the licence holders. For example, an MNO might lease spectrum in geographical areas where they are not using it, potentially withdrawing the lease (with any required notice) if they subsequently do decide to roll out.

It is important that the band selected is widely supported in handsets but is also not used extensively by the MNOs, perhaps because they only need it for capacity in dense areas. Higher frequency mobile bands tend to be better in this respect. A variant of this approach might also provide some minimum level (e.g. 20 MHz) guaranteed for in-building. The precise details would require further study.

There are potential issues with such an approach, discussed below.

- *Interference caused to the cellular operators*. The MNOs would only lease spectrum that they believed would not result in interference.
- *Insufficient incentive for cellular operators*. Operators might not establish such a system because they might perceive the risk as outweighing potential returns to them, or might be concerned at enabling potential competitors. However, given that such a solution is in the interests of the country since it enables more efficient use of the spectrum and brings clear societal benefits, Ofcom should have backstop powers to establish the neutral host and require operators to lease spectrum unless they can provide clear evidence as to why this would cause them operational issues.
- *Insufficient investment certainty for in-building eco-system*. If the in-building eco-system (e.g. the router manufacturers, core network software manufacturers, etc) perceived that the market was uncertain because, for example, access to spectrum was uncertain, they might not invest in products. In this case, apart from some effort to establish the framework, nothing would have been lost compared

to the status quo. In practice, equipment is already becoming available in the US for CBRS operation and so the effort required to develop a UK-variant may be minimal.

- *Insufficient certainly for those deploying in-building*. It seems likely that bands above 3GHz will only be deployed in dense urban areas. Some inputs we received estimate this is <10% of the UK population in which case 90% of buildings will have unrestricted access to the entire band. Where these bands are deployed by MNOs it will generally be on the existing cellular base stations, and will only have a range of ~50% of the cell radius - so even in dense areas something like 75% of the cell by area may not have high frequency coverage. Then, there will be differences between MNOs, so where there is coverage from one, there may not be from another. Taking all these factors into account it seems likely that 95%+ of buildings could make sensible use of this band providing a high level of probability to those deploying, and assuming operators were prepared to lease at a fine level of geographical granularity. Further, we do not envisage that deployment will be a significant investment. Most likely support for the band will be included in Wi-Fi routers, adding little to their cost and implemented whenever a router upgrade is due. If there is no spectrum availability then the router will simply revert to Wi-Fi. The loss to the building owner is minimal.

- *Delays caused to auctions while the approach is debated*. This approach would require minimal change to licenses, primarily the provision of leasing, any legal framework needed for the neutral host, and the addition of the backstop powers for Ofcom. These could be added to the licence in outline form now, with the details agreed post-auction. Hence, there may not be any need for delay.[18]

- *Misalignment with the rest of the world*. At present, no other country appears to be interested in exactly this concept, although CBRS in the US may come close. If the UK was unique this might not be problematic. Most of the band would still be used for 4G/5G deployment as envisaged e.g. at a European level. Roaming, economies of scale, and so on would be unaffected.

In summary, there are clear issues with this approach, that would require further study but none that would seem to prevent it. The most critical question is the frequency band that this would be implemented in and whether there remain any options for using the 3.4-4.2GHz bands.

4.2.2 Rural access

In many cases a licence holder with a national licence will not deploy across the whole country[19]. Mobile operators might not deploy in rural areas, military users might not deploy in urban areas, and so on. It could be imagined that others might wish to deploy themselves in these cases, for example a rural community might wish to deploy its own cellular solution or a regional supplier of some telecoms services might become established. A similar position could apply to enterprises that require LTE spectrum for private LTE services. In principle, the licence holder would lease them spectrum since it would then gain income from an otherwise unused asset. In practice, we are not aware of any examples of this happening.

A key reason why it has not happened is that MNOs are not allowed to lease under the current licence regulations. This clearly needs to be addressed and we recommend that Ofcom enable leasing for all MNOs across all bands as soon as possible.

[18] The UK Mobile Trading Regulations do not currently allow leasing of spectrum. Only full or partial transfers are permitted. However we understand UK Broadband (now part of 3UK) can lease their spectrum but we are not aware of this happening to date.
[19] We note that Ofcom ha a work item in its 2017/18 workplan on improving the coverage of fixed and mobile communications services to meet the needs of people and businesses across the UK, including in rural and remote areas where commercial approaches have often failed to deliver on expectations

Even once enabled, licence holders may be unwilling to lease because:

- They may be enabling a competitor to their core business.
- The barriers to the first lease are relatively high in that legal agreements will be needed; the regulatory process needs to be tested and experience gained with issues arising such as interference.
- The revenue streams from these leases are likely to be relatively small and hence insufficient to provide significant leverage.
- There are risks, such as the ability to revoke the lease if the operator subsequently decides to roll out coverage.

It is also likely that potential users of the spectrum are unaware that the spectrum is available or that a leasing process is possible. Even if aware, finding the right person in the licence holding company to talk to would likely be very challenging.

Again, many different approaches are possible and we have only considered a small number. It would seem that a similar approach to the in-building coverage suggested above could be enabled using leasing of spectrum into a neutral host database. This might be at multiple frequency bands, since in rural areas it is likely that most bands are not fully utilised. There would clearly be advantages in reusing much of the same database infrastructure for both in-building and rural areas.

Even if shared access to rural spectrum is granted, not-for-profit organisations such as rural communities might be unaware of this possibility, or unable to understand the costs, process and benefits. A set of case studies, developed in conjunction with such communities, would illustrate the possibilities and provide a valuable source of information on many aspects of the issue. As well as objective insight into financial and technical issues, some subjective information on aspects such as likelihood of long-term access to the spectrum would be valuable. Ofcom or Government should commission the development and publication of such case studies.

DFS

This is an issue raised by major Wi-Fi players. There is clear evidence that DFS frequencies are little used and that the detect-and-avoid approach has unavoidable issues such as false triggering. Equally, we are aware that this is an issue that has been considered on many occasions and no progress made. We suggest that Ofcom consider a UK-only approach (although other countries may subsequently adopt), looking seriously at whether DFS is needed in the UK, taking into account sharing constraints with other radio services (e.g. radiolocation) If it is needed, alternative approaches such as database access should be examined, working in conjunction with the manufacturing industry and key users such as Sky and BT to ensure that they meet the needs of stakeholders and result in an improvement to the status quo.

Ofcom approval for fixed links

Stakeholders raised the time it takes to receive Ofcom approval for fixed links and similar (e.g. the 42 days stated under the WT act). Given the trend to provision of more flexible access and backhaul networks, and the likely increase in the need for these resources with further 4G and potentially 5G deployment, stakeholders highlight that the existing processes are not fit for purpose where much more dynamic allocation is required. Our view is that consideration should be given to block allocations (or a method delivering similar flexibility) to operators to self-manage (e.g. 5G small cell backhaul >100 GHz).

5 Conclusion and recommendations

5.1 Conclusions

The study considers a broad topic and we have inevitably had to put some bounds on the scope and the issues it has considered. However, we believe that it addresses the requirements raised by the SPF and that the scenarios and specific issues examined have provided a good basis on which to make recommendations. The position on each of the study tasks is set out below.

Table 5-1: Outcome of study tasks

Study tasks	Outcome
Undertake a "current state of play" review of usage of licence exempt and light licensing.	Completed, based on discussions and some literature review, usage appears, overall, to be constrained by lack of flexibility, future certainty and risk-aversion (despite use of licence exemption and light licensing for some fixed services) .
Investigate emerging technologies, techniques and tools applicable for flexible / light licensing mechanisms.	Completed, few novel tools have emerged in recent years, but many tools such as DSA, LSA, LAA, CBRS still yet to be adopted and some show promise.
Review the current and emerging use cases for such flexible / light licensing access mechanisms.	See scenarios and discussion in the report.
Investigate whether current availability of spectrum for such licence exempt and lightly licensed applications is likely to be sufficient in the medium term and (given evolution in technology and use cases) identify potential new spectrum up to 70 GHz suitable for such access mechanisms.	Evidence from stakeholder suggests that there is insufficient in some areas – Wi-Fi, in-building cellular. New spectrum includes 3-4GHz for in-building, 5-6GHz for Wi-Fi, mmWave sharing at 26-30GHz, Wi-Gig at 60 GHz, 5G above 66 GHz.
Investigate potential future scenarios (e.g. wireless backhaul of small cells) where dynamic licensing or block assignments may be a suitable solution for rapid access to spectrum with guarantees of quality.	Harder to do until dynamic approaches in place but applications might come from military, railways, self-deployment of cellular and Wi-Fi, mmWave deployments.

The study has shown that, in addition to some specific issues which require resolution, that there are two divergent views developing for spectrum access methods. We termed these the "conventional" and "alternative" worlds. Which of these worlds prevails is ultimately a question for government and Ofcom to determine. In practice, the outcome is likely to lay between the two worlds we describe depending on the value which government / Ofcom attach to enabling more flexible spectrum access, the innovation it could foster and the economic and social value it could bring.

The RSPG has suggested that the default form of licensing should be sharing. Ofcom has also published studies and strategies indicating its view that sharing is valuable and should be widely deployed. However, in consultation documents and statements for spectrum awards, the option of sharing is rarely mentioned. Where it is, it is often discounted relatively quickly.

We recommend that when considering the use of a band, and in any consultation on the award of the band, the various possible sharing options are set out clearly and it is shown why any are discounted. We also caution against discounting based on a lack of evidence that the band will be used by the sharer or evidence that it will generate high value – often this evidence is not available prior to the band becoming available (the "chicken and

egg" problem). More generally, given the greater representation that those who prefer exclusive access have with Ofcom we suggest appropriate care in considering options, with a need to seek out input and evidence from those interested parties that might share in the future.

As an example, the 3.4-3.6 GHz and 3.6-3.8 GHz award material does not discuss shared access to the band other than as a mechanism to work with the incumbents during any clearance process (although there was some early discussion in the 2014 consultation). Given the clear possibility of shared access to the band for in-building use (as discussed in Section 4) there should have been full consideration given to this sort of alternative throughout the process.

We have also identified several specific issues during the study where action is required such as DFS for Wi-Fi and more flexible licencing for fixed links and similar services.

Our recommendations are set out below.

5.2 Recommendations

1. In the light of the UK Spectrum Strategy, Government should give further consideration to the approach to spectrum sharing it wishes to see the UK adopt.

2. For new spectrum coming to market, Ofcom should publish a transparent appraisal of its suitability for different access methods ranging from licence exempt through to exclusive national licensing. In particular this should be focused on high value spectrum where there is a high potential to share. Where any method of access is discounted, Ofcom should provide a clear reason why.

3. If there is evidence that mobile operators are not able to provide services, such as in-building and rural services, Ofcom and the wider cellular community including operators and equipment vendors should take action to promote third-party access to spectrum where the said spectrum is not in use by the operators and there is a low likelihood of harmful interference. The optimal way to do this requires further study by Ofcom. We note that approaches that enable licence holders to lease spectrum either directly or to a neutral host might be the most viable. Backstop powers should be retained in the case the licence holders do not give sufficient priority or attention to implementation.

4. Ofcom should review removal or simplification of DFS to increase effective use of the 5 GHz Wi-Fi spectrum, taking into account the sharing constraints with other radio services at 5 GHz.

5. Ofcom should consider options such as a mix of dedicated national (or sub-national) licensing with more flexible approaches for the 26 GHz and other mmWave bands, taking into account potential for enabling viable and sustainable spectrum access to other services in such frequency bands where there is a net benefit to do so (e.g. satellite Earth stations on a geographic basis, noting the inherent geographic constraints on 5G deployments in mmWave bands.

6. Government should consider whether codifying of the technical conditions will be an effective mechanism to facilitate sharing of the public sector spectrum. For example, in the case of sharing with defence spectrum could technical conditions be included in licences issued by Ofcom or general technical access conditions be specified for licence exempt use.

7. To facilitate the necessary dynamic allocation that will be required for fixed links and similar (e.g. 5G small cell backhaul in bands above 100 GHz) it is proposed that Ofcom should consider reducing

timescales for approval to [2 days] or alternatively award block allocations (or a method delivering similar flexibility).

8. When looking to identify additional spectrum for services Ofcom should consider the scope for licence exempt use and review and publish the outcome.

Appendix A Case studies

A.1 Case Study: TV white space

The TV bands are typically considered to extend from 470-790MHz, although in some countries such as the US, they are less extensive, with the upper limit being around 700MHz (and progressively moving downwards as will be discussed). These bands have been used for more than 50 years for terrestrial TV broadcast with transmissions from high mast sites made at high powers and received by millions of households using external rooftop antennas. Typically, transmissions were made using multiple-frequency networks[20] where the same frequencies were not used by neighbouring masts to avoid interference. Instead, there was a reuse pattern of around four, with a quarter of the available frequencies being used on any given mast. For this reason, the TV bands often appeared sparsely populated when observed on spectrum monitoring equipment – there were a lot of "white spaces" between the monitored transmissions.

These spaces appeared suitable for sharing. This was because clearance of the band seemed unlikely given the high levels of terrestrial TV viewing in many countries so changing to a different exclusive usage was problematic. However, the static nature of the TV transmitters and the stable and unchanging TV transmissions made it possible to clearly define the sharing opportunity. These relatively low frequencies were also considered valuable for many applications including Internet of Things (IoT) and rural broadband. This led to high-profile initiatives commencing in the US in 2008 and the UK in 2010.

Nearly a decade later there has been very little shared use of the bands and TVWS is broadly seen as a failure. What went wrong? There were two major factors: uncertainty and delay. These are discussed below.

By about 2010 the idea was gaining currency that although the TV bands could not be completely cleared and refarmed, they could be partially cleared. In the US, the 700MHz band had already been cleared and re-purposed for mobile usage and there was discussion of doing the same with the 600MHz band under the heading of the "incentive auction"[21]. In Europe, there was discussion of clearing the 700MHz band. While still leaving enough spectrum for TV transmission these initiatives would reduce the TV white space significantly. There was also uncertainty around the future demands of existing shared use of the band, the so-called programme making and special equipment (PMSE), broadly wireless microphones and cameras widely used for broadcasting, shows and many other applications. Regulators were inclined to be conservative in their rules for transmission powers for users sharing the spectrum further restricting the amount and value of the shared use. Many felt that with uncertainty over the long-term availability of TVWS it was too risky to invest in deploying networks or developing custom chipsets.

The second problem was delay. TVWS became initially available in the US in 2012 after four years of study, and in 2016 in the UK, after six years. These timescales were overly long for the start-up companies formed to innovate in the bands, many of who ran out of funding. They were also too long for the IoT industry which sought alternative spectrum solutions. This was exacerbated by a lack of interest in other countries, preventing a global market. The net result was that trials were not followed by deployment and the interest of the telecoms industry turned elsewhere.

TVWS did leave one important legacy – the development and validation of the concept of using a dynamic database to provide spectrum access. In this approach, often termed dynamic spectrum access (DSA), sharing devices first contact an approved database which provides them with details of the access restrictions in their

[20] In principle, single-frequency transmission is possible with digital technology, but this is rarely used in practice as it complicates regional variations in programming and in any case, cannot be used across national borders.
[21] This subsequently went ahead in 2016/17.

location. Both the FCC and Ofcom developed processes for formulating the rules for these databases, testing and certifying commercial implementations and ensuring an appropriate legal underpinning. The industry considered business cases and technological issues and while not all were solved, much was learnt. This legacy means that, in principle, the introduction of similar sharing approaches in other bands should happen more quickly.

In summary, TVWS was an innovative approach but the regulatory environment failed to provide sufficient certainty or move with sufficient speed. This predominantly appeared to be because regulators were predisposed towards the existing broadcasting uses and new mobile deployments, seeing sharing as a last resort and one that could be dispensed with once the "classic" spectrum management options became available.

A.2 CBRS

The Citizens Broadband Radio Service (CBRS) is a US initiative. Like TVWS, it grew from the observation of a frequency band – in this case around 3.6 GHz (3550-3700 MHz) - where there was little apparent usage. In the US, this band is assigned to defence, predominantly ship-born radars which are only active in coastal regions (however, most of the US population lives in these coastal regions). The CBRS proposal uses DSA to protect the incumbent military in the same manner as in TVWS, however, it adds additional complexity with a three-tier approach. In this approach, the military has the highest level of access, being guaranteed protection from interference. The second tier is termed priority access licensed (PAL) and is intended to provide some certainty both in terms of availability of spectrum and protection from interference. The third tier is termed general authorised access (GAA) and is like the sharing use in TVWS. All users are coordinated through a dynamic database which may be assisted by coastal monitoring stations which can detect whether there is any nearby radar operation. There are many complexities around the number of second tier licenses, their geographical and spectrum extent and much more, which we do not explore further here.

At the time of writing, CBRS was still being debated, with lobbying around the balance of spectrum between the different tiers, the way that the quasi-licenses of the mid-tier were to be awarded and indeed whether clearance and auction should be used instead. There remained high levels of enthusiasm within the industry[22] – but that was also the case for TVWS at this stage in its proceedings. CBRS was given impetus from the fact that these bands had become the major 5G bands in other parts of the world, ensuring good equipment availability. Hence, somewhat perversely, shared use was given assistance from the exclusive use in other regions. However, if this exclusive use is shown to be very valuable it may crowd out the shared usage in the US.

Even if CBRS does succeed it may remain a US initiative since these frequency bands have already been cleared ready for auction in many countries. However, the three-tier concept and some of the other ideas such as monitoring stations are being looked at with interest by regulators elsewhere.

[22] For example, in 2017 Nokia announced a small cell product that could operator in these bands and be deployed by a third party or building owner. There was not the same level of interest from major vendors in TVWS.

