Study on the characteristics which justify exclusive use of spectrum

A Report Prepared

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About LS telcom

LS telcom is the global leader in spectrum efficiency with customers in over 100 countries worldwide. In an increasingly connected world, we assure that all spectrum users achieve their radio communication objectives in the most optimal and cost-efficient way. We deliver technologies and services to national and international regulatory bodies, to mobile and broadcast operators, to transport, critical infrastructure, defense, PPDR and vertical markets. We optimize spectrum management and spectrum use and enable new business models such as the internet of things (IoT) and 5G.

About the UK Spectrum Policy Forum

Set up at the request of Government the purpose of the Spectrum Policy Forum is to be a pro-active industry-led 'sounding board' to UK Government and Ofcom on future policy and approaches on spectrum and a cross-industry 'agent' for promoting the role of spectrum in society and the maximisation of its economic and social value to the UK. We do this by exchanging news and views on developments in using spectrum, drawing on our industry expertise from around the world. The Forum is open to the full range of UK spectrum users. Our members currently include over 240 companies and organisations with an interest in using spectrum for a diverse range of applications. In this context the term 'spectrum users' is to be interpreted in the widest sense - including all industry sectors which use (or will use) wireless techniques and organisations involved in the entire value chain in these activities. The Steering Board ensure that the work of the Forum is properly framed, work items expedited in the correct manner and suitably resourced, and monitor progress on the delivery of the agreed work packages.

The current members of the Steering Board are:

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Executive Summary

This report has been prepared for the UK Spectrum Policy Forum – it investigates the definitions and characteristics of exclusive use of spectrum and considers what this means in practice. In particular, the report highlights how spectrum authorisation and sharing operates in the context of the existing regulatory framework.

The report addresses and makes recommendations on:

- The definition of "exclusive" in the context of spectrum authorisation where a primary objective is to secure the efficient use of spectrum;
- Whether the current UK spectrum licensing framework provides sufficient flexibility to meet the geographic-based demand of spectrum users;
- Any changes that should be considered to authorisation frameworks for spectrum and the sharing framework currently proposed by Ofcom.

Radio spectrum continues to be in huge demand by a wide range of services and applications such that demands for access to spectrum cannot always be met. Therefore, to be able to satisfy as many demands (users and uses) as possible and to enable efficient use of spectrum, regulators have (amongst other techniques) increased the use of spectrum sharing approaches as exemplified by the recent introduction of new sharing approaches by Ofcom (see section 3.6). However, there is a train of thought that some users and application types considered important to the UK for the provision of key public and private services and applications, justify exclusive access to spectrum. These include mission critical, emergency and safety services, public mobile services, safety of life for aeronautical and maritime. Securing long term (typically nationwide) access to spectrum is imperative to ensure the satisfactory and uninterrupted delivery of these crucial services. Therefore, the licensing framework that is in place provides the certainty for continued access to spectrum, flexibility to deploy networks whenever and wherever needed for these important licensees, certainty for investment in network deployment and the ability to deliver the required quality of service levels to users.

In contrast, there is also concern that exclusive access to spectrum reduces efficiency of spectrum use because some licensees, such as the mobile operators, leave certain areas uncovered, i.e. the licensee does not use the spectrum in all areas covered by the licence and the spectrum is not then available for use by other parties in those areas – this in effect is an unrealised opportunity for sharing and thus is considered inefficient use.

One of the primary considerations of this study is to assess the definition of 'exclusive' in the context of spectrum authorisation where a primary objective is to secure the efficient use of spectrum. We found limited authoritative definitions of exclusive use of spectrum and taking into account our analysis, developed a definition of exclusive use of spectrum as follows:

Exclusive Use: '*User access to spectrum over a defined area which provides a predictable incoming and outgoing interference environment and the ability to deploy services in accordance with the user requirements as and when the user requires*'.

This definition enables Ofcom to achieve its goal of efficient use of spectrum whilst still giving certain types of users/licensees the certainty regarding the interference environment and flexibility to deploy over the defined area that they need.

It is clear from our study that such exclusive access to spectrum is of major importance as it underpins commitment from investors to invest in new mobile networks. For other major spectrum-reliant businesses such as critical and public safety users the most important characteristic that (national) exclusive spectrum offers is reduced harmful interference. We consider that without this exclusive access to spectrum, the benefits that it brings would be lost and determined this could greatly impact deployment of networks and ability to deliver the particular services required by users.

The report also considers whether the current UK spectrum licensing framework provides sufficient flexibility to meet the geographic-based demand of spectrum users and if any changes should be considered to the authorisation framework. We found that the licensing framework is sufficiently flexible to meet geographic-based demand. This is primarily due to the new spectrum access approaches, recently introduced by Ofcom that enable access to a mix of newly identified shared spectrum bands and new local licensing in mobile operator spectrum. It is these new approaches in particular that have increased the flexibility of the framework and enabled access to spectrum bands for new users, that can introduce new services, that would otherwise not have been accessible in certain locations including remote parts of the UK.

We make the following conclusions from our analysis of the three key points of the study:

1. On the definition of “exclusive” in the context of spectrum authorisation where a primary objective is to secure the efficient use of spectrum.

A new and more precise definition for exclusive use of spectrum enables both the regulator and users/licensees to have a common understanding of their usage rights

The key to understanding the definition of exclusive use is to articulate the new definition to industry to achieve a common understanding of the characteristics which justify exclusive use. This includes providing further clarity of how the specific characteristics support a particular use and in turn determine the impact this may have on access to spectrum by other users and ultimately on spectrum efficiency.

We therefore recommend:

The following new definition of exclusive use should be adopted across the industry:

Exclusive Use: *‘User access to spectrum over a defined area which provides a predictable incoming and outgoing interference environment and the ability to deploy services in accordance with the user requirements as and when the user requires’.*

Using this definition, a common understanding of the authorisation framework should be created so that all spectrum users (existing and new) are clear of the pros and cons of the authorisation approaches available. In addition, this could help determine how the primary objective to secure the efficient use of spectrum can be met. Furthermore, the aim would be to minimise any confusion or misunderstandings within industry regarding how spectrum access is authorised.

2. On whether the current UK spectrum licensing framework provides sufficient flexibility to meet the geographic-based demand of spectrum users.

Ofcom's introduction of new spectrum authorisation approaches which includes a new shared access licensing regime and a new local licensing regime - allowing certain types of access to spectrum licensed for mobile operator use - has increased the flexibility of the spectrum licensing framework. These new flexible authorisation approaches being used alongside existing approaches provide significant benefits towards addressing the challenges of realising universal access to spectrum.

We consider that these new approaches provide sufficient flexibility to meet the geographic-based demand of spectrum users. They satisfy the demand of different users and uses including national MNOs and mission critical users, including their requirement for secure long term exclusive spectrum access rights to provide business and operational certainty through to a wider mix of users whose needs vary from remote and rural access and those that can coexist with other users in the same band at the same location. The framework provides both certainty of access with limited risk of interference to deliver a range of different services to a wider mix of defined areas.

Therefore we recommend:

Government, Ofcom and industry continue to work collaboratively and recognise the opportunities for increasing the flexibility of the spectrum licensing framework where and when appropriate. This could include identification of complex and challenging areas where the existing authorisation framework currently does not permit introduction of new services and how developments in Europe and globally (e.g. CBRS) might be introduced to the framework (e.g. determine how could this be achieved, the processes and governance).

3. On any changes that should be considered to authorisation frameworks for spectrum and the sharing framework currently proposed by Ofcom.

We believe no changes are currently needed for the authorisation frameworks for spectrum. The new spectrum sharing approaches can meet demand in the near-term, provide opportunities for the introduction of innovative services, and provide the opportunity to enhance the efficiency of spectrum use. We also consider that these new approaches should be given time so that all users may become more familiar with them and their value proven.

The timely introduction by Ofcom, of new spectrum sharing approaches, provides the facility for new entrants to overcome some of the ongoing limitations of extending mobile coverage into rural and remote areas. The options for new licensees include:

- shared access to three harmonised mobile bands; or
- a new local licence to access mobile operators' spectrum where it is not being used which will help to meet demand, but only at the fringes of mobile coverage.

This new regime may help to overcome some of the barriers new entrants and innovators were facing to access spectrum and could be used to introduce and deploy new services. However, this is a platform on which to build for some of the more challenging and far reaching cases in rural and remote areas (e.g. rail cuttings and remote locations). For example, relaxation of limitations to the power levels (low and medium power) and height restrictions might help to overcome these coverage challenges. Nevertheless, this approach represents a good starting point from which to evolve.

We also believe that the benefits of the new approach could be extended to other bands and should be investigated further.

Therefore we recommend:

Government, industry and Ofcom should create an environment (or support existing programmes for innovation) that will allow testing of the current and future assumptions on exclusive and shared use in spectrum bands that are difficult to share. In particular, determine how future dynamic spectrum access could deliver certain benefits or not, thus informing future authorisation decisions. This could result in enhancements to the licensing framework that support new multi layered and multi-dimensional authorisation approaches, for specific situations and locations. These locations include, for example; indoor (standard indoor, deep indoor/underground, high up indoor), and outdoor (standard outdoor – urban/suburban/rural, transport corridors, special rural locations, business and industrial sites). Furthermore, steps could also be taken to assist with assessing how well these approaches meet other policy objectives around coverage and quality of service.

1 Introduction

1.1 Scope

The UK Spectrum Policy Forum has commissioned LS telcom to undertake a study to address the following key points:

- How spectrum authorisation and sharing operates;
- To study the characteristics that justify exclusive use of spectrum;
- To define “exclusive” in the context of spectrum authorisation where a primary objective is to secure the efficient use of spectrum;
- To determine whether the current UK spectrum licensing framework provides sufficient flexibility to meet the geographic-based demand of spectrum users;
- To consider any changes that should be considered to authorisation frameworks for spectrum and the sharing framework currently proposed by Ofcom.

This study aims to address some key concerns that have arisen over time due to the ongoing use of exclusive access to spectrum which include:

- Government concerns that exclusive use of spectrum has not resulted in universal and ubiquitous coverage;
- Government concerns that exclusive use of spectrum is not leading to optimal outcomes and therefore a desire to understand whether there is a continued need for exclusive use of spectrum;
- Concern from MNOs that access to some of its spectrum may be lost or reduced;

Some of these concerns stem from not having a common understanding of the meaning of exclusive use, i.e. the understanding may differ between regulators and spectrum users.

The thrust of this report is the determination of characteristics which justify exclusive use of spectrum. In particular, it provides information and evidence justifying the circumstances and conditions under which exclusive licences should be issued to a single licensee, in other words when sharing may not be appropriate. Thus, the report focuses on some example applications that utilise the exclusive licensing regime and identifies and articulates the benefits thereof (including mobile, fixed links and business radio). As a consequence of this study, we determine if there is potential room for modification to the current licensing frameworks or for a better understanding of the meaning of exclusive use from both a regulatory and end-user perspective.

1.2 Background

Radio spectrum[1] is a limited natural resource which is of great importance to the economy and society as a whole. Given its importance and scarcity, great efforts are made to ensure that spectrum is used efficiently. It supports a large range of different users, from civil uses such as broadcasting and mobile through to government uses such as defence and security.

Regulators around the world are responsible for assigning spectrum to users and issuing licences granting access rights to spectrum. In Europe, the European Electronic Communications Code[2] (EECC) identifies two main approaches to spectrum authorisation, including:

1. **General authorisation:** authorises the use of clearly identified and delineated spectrum by two or more users – users are granted a general authorisation to access and use the radio frequencies subject to specific technical conditions and types of equipment that are designed to minimise the risk of harmful interference.
2. **Individual authorisation[3]:** Authorising the use of clearly identified and delineated spectrum by a specific identified user over a defined geographic area. Only one individual user is granted authorisation to use the identified radio spectrum;

Individual authorisation of spectrum provides regulators with a tool to enable a user to be the only user of a defined piece of radio spectrum. This has been a mechanism used by regulators for many years - in particular when demand for spectrum was much lower than it is today.

Typical examples of users that are individually authorised for spectrum use include:

- Mobile operators have individual rights of use to spectrum on a national basis in a range of frequency bands;
- Telecom operators hold national and local fixed links licences in a range of frequency bands;
- Multiple national business radio licences are held by the likes of Network Rail, Airwave and the utilities in certain spectrum bands[4].

As radio technologies evolve and new uses become possible, so demands to access the radio spectrum grow – giving rise to scarcity – and forcing spectrum managers to seek different ways to balance the supply of spectrum with demand. This has resulted in policy makers avoiding the grant of individual usage rights and the adoption of different options for granting spectrum access in order to ensure that the regulatory framework has the flexibility to sufficiently address the needs of the market.

Ofcom has recently confirmed its proposals[5] to rethink current spectrum policies to increase spectrum sharing particularly in mobile bands. For example, Ofcom's has recently extended proposals for:

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[1] For the rest of this report the terms radio spectrum, spectrum and frequency are used interchangeably.

[2] Directive (EU) 2018/1972 of the European parliament and of the council of 11 December 2018 establishing the European electronic communications code(recast), Council of the European Union Dec 2018, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L1972&from=EN

[3] This will be broadly discussed in section 3 of this report.

[4] Wireless Telegraphy Act Licensing Policy Manual A practical user guide to licensing policy, version 7, Ofcom, 2017 https://www.ofcom.org.uk/__data/assets/pdf_file/0025/77209/licensing.pdf

- Sharing of the old Digital Enhanced Cordless Telecommunications (DECT) guard band to allow more users in the 1800 MHz band;
- Shared access to 10 MHz in the 2300 – 2400 MHz band; and
- 400 MHz in the 3.8 – 4.2 GHz band which has been offered for mobile use on a shared basis with existing services.

These solutions provide a potential opportunity for new, innovative services to be created, and can also help improve with the coverage of existing services in remote, rural or poorly served locations. Service providers can access the bands which best suit their needs yet with more certainty of tenure of access and the associated quality of service that can be offered compared to the use of licence-exempt or lightly licensed (see section 2.2) spectrum. The principal goals are on the one hand, to ensure scarce spectrum is utilised efficiently and, on the other hand, to ensure that a lack of access to spectrum is not a limiting factor for the development of innovative technologies.

Against this backdrop it should not be overlooked that important, economically and socially significant services (i.e. public mobile communications, aeronautical, maritime and public safety) have been established on the basis of individual usage rights to access radio spectrum. Careful consideration needs to be given to the extent to which other users are permitted to share spectrum particularly with these users in order not to undermine the basis on which the success of the established services has been built.

In this report, we provide an assessment of the existing regulatory framework and consider the characteristics that may justify individual rights of use of spectrum and in turn determine how enhanced flexibility could deliver benefits in terms of efficient use of spectrum. The report highlights how greater flexibility in the regulatory framework could mean the development of attributes that lead to increased spectrum sharing and hence potentially more efficient usage of spectrum. The study also examines if any changes are needed to the existing regulatory framework to support greater flexibility of access to spectrum.

1.3 Structure of this report

This report is structured as follows:

- Section 2 – How spectrum authorisation and sharing operates

  In this section we provide an overview of the existing licensing frameworks in the UK and consider the rules and regulations under which licenses are issued.

- Section 3 – Assessment of the characteristics which justify exclusive use of spectrum

  In this section, we consider the pre-analysis definition of exclusive use of spectrum and the characteristics used to justify it. We also explore the necessity of exclusive spectrum use in practice for candidate services. Specifically, we consider the regulatory, practical and commercial characteristics under which exclusive licences are justified for individual purposes in practice. We discuss how spectrum sharing would be appropriate to enhanced future access to spectrum and whether the current level of flexibility of the licensing framework is fit for purpose. Consequently,

[5] Enabling opportunities for innovation Shared access to spectrum supporting mobile technology, Ofcom, 2019

we discuss how exclusive use of spectrum differs once we have analysed (post-analysis definition) the characteristics which justify exclusive use of spectrum.

- Section 4 – Conclusions and recommendations

  In this section we summarised our findings and make conclusions and recommendations as to a way forward.

2 Overview of spectrum authorisation and sharing approaches

2.1 Licence definition

A spectrum licence granted by Ofcom authorises the licensee (comprising an individual or organisation) to install and use radio equipment using a specified piece of radio spectrum under a set of defined terms and conditions. A licence specifies that the licensee is responsible for complying with the terms and conditions set in their licence so that no undue harmful interference occurs to other users. Other information such as duration and fees are also included as part of the licence. Civil users of the spectrum must apply for a licence through Ofcom, who assign the particular frequency which the licensee is authorised to use. The assignment approach and decisions are based on licensing policy which can vary depending on the spectrum band and the radio communications services permitted for use in that band. Under specific circumstances, the licence may be permitted to be transferred to other users.

The framework by which spectrum is authorised has evolved in the UK from a command and control regime, which means the regulator determines who is assigned spectrum and for what purpose, to a market-based approach, in which spectrum is offered to the market and those successful in obtaining it choose how it should be used (within the constraints of the terms and conditions of the licence on offer). This has primarily been driven by the growing demand for spectrum (particularly from mobile operators) and the complexities of determining who should have access to the spectrum, whilst striking a balance between ensuring licensees are protected from interference (making frequency assignments) and keeping up with demand.

These pressures have led to a range of different spectrum authorisation approaches including:

- licence-exempt use,
- light licensed use,
- first come first served or direct assignment,
- beauty contests, and
- spectrum auctions.

The approach adopted for the licensing of a particular assignment depends on a number of factors including the types of service, the frequency band being assigned and the demand for access to the spectrum to be licensed; decisions regarding which approach to adopt are made by Ofcom. Ofcom makes its decision in consultation with industry[6] on a pre-defined set of proposals and a final decision (Statement) once all stakeholder feedback has been considered.

In the following section we discuss the attributes and decisions that are made when considering authorisation and award approaches.

[6] It is also driven by European decisions on authorisation

2.2 Licensing frameworks in the UK

The licensing framework in the UK is based on the Wireless Telegraphy (WT) Act Licensing Policy developed by Ofcom[7]. The WT Act 2006 provides the primary legislation which sets out Ofcom's duties including *licensing and exemptions from licensing, the terms and procedures for licensing*.

The use of wireless telecommunications equipment in the UK is illegal unless the use is in accordance with a licence granted to the user by Ofcom – the exception to this is the use of equipment which is specifically exempted. In the case of licence exempt use, the technical characteristics, references for technology and operational mechanisms are specified in other regulatory instruments published by Ofcom.

The secondary legislation (within the WT Act) enables Ofcom to make certain regulations and orders that it believes to be necessary in order for it to discharge its duties. With respect to radio spectrum management, the regulations that can be made vary widely and include enhancements or changes to licence exemption regulations, to the fees for licences to more commercially focused regulations such as trading and competitions for specific awards of spectrum.

There are a number of methods of authorisation (including a range of classes of licences) that Ofcom can grant, these include the following which have been extracted from Ofcom's licensing policy manual:

Type of authorisation	Description
Light-licensed	An 'off the shelf or 'pre-packaged' licence that mostly requires no specific assignment or co-ordination. An example of this is a licence to use a Business Radio (Simple Site) Licence.
Ofcom band-managed (Technically assigned)	This refers to bands where Ofcom issue licences on the basis of individual assignments within the band, often on a first come first served basis, and in many cases through detailed technical coordination.
Block assigned	This refers to bands where licensees manage their own deployments within the band (or act as a band manager for third party access) with a high degree of flexibility. In general, these bands have been assigned via auction. This category includes some longstanding administrative assignments such as the 900 MHz and 1800 MHz mobile network licences[8].
Area defined licences	These are intended for users that need to operate a network over a large geographical area
Licence exempt	This permits the operation of certain transmitting equipment without requiring a specific licence, assuming that certain technical conditions, frequency bands of use and equipment compliance rules are met. There are still certain regulations and compliance requirements that need to be adhered to for using the equipment, this is to avoid causing harmful

[7] Wireless Telegraphy Act Licensing Policy Manual: A practical user guide to licensing policy, Ofcom, 2018

[8] Spectrum attribution metrics Spectrum management strategy, Ofcom, 2013

Type of authorisation	Description
	interference to other users and the acknowledgement that licence-exempt users are not protected from interference from other users. Protection from this type of interference is down to the quality of devices and the performance of the technologies used, which Ofcom does not have the power to regulate beyond compliance with the Radio Equipment Directive 2014/53/EU (RED)[9].

Table 1: Different types of authorisation categories available

Ofcom's licensing policy manual refers to *licence variations* and *transfers* (Section 8) as a mechanism that allows licensees to vary their licences or transfer the rights to another entity. This provides one level of *flexibility* to the market as a licensee can request the change, however Ofcom can also make a change. Although, licence variation can be useful, it is limited to changing the details of the licence with the *current rights holder*. A more useful mechanism is the ability to *trade* and *lease* a licence which is an approach Ofcom permits as part of its licensing framework. This is an exchange or transfer of rights to spectrum access between two parties.

2.2.1 Spectrum trading and leasing

Spectrum trading and leasing present the opportunity to improve spectrum utilisation by permitting a spectrum licensee to lease or sub-let some, or all, of the spectrum, for which they hold a licence, to a third party. Although spectrum trading is available for most classes of licences, it is on a voluntary basis, which may result in licensees not being willing to participate in this approach. Spectrum leasing is currently permitted for very limited type of licences, which reduces the benefit of this approach.

We provide below Ofcom's definition of spectrum trading and leasing from its licensing manual:

Spectrum trading (Sale of spectrum rights)

Spectrum trading allows all or a portion of a licensee's spectrum rights to be transferred through the market to those that can generate the greatest benefits for society and so helps secure optimal use of the limited and valuable spectrum resource. We (Ofcom) introduced spectrum trading in the UK at the end of 2004 as a key element in our programme of market-based reform. Since then, we have progressively extended trading to a broader range of licences.

Spectrum trading is available to most (not all) classes of WT Act licence. Trading can be permanent or time-limited, and is on a voluntary basis with no obligation, with variable level of flexibility from fully flexible and semi-flexible, to restricted[10].

Spectrum leasing

In addition to the outright transfer of rights to another party, provisions introduced in 2011 now enable the leasing and sub-leasing of spectrum for some licence classes. Leasing enables a licensee to

[9] Directive 2014/53/EE of the European Parliament and of The Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC, Official Journal of EU, 2014

[10] Trading Guidance Notes OfW513, Ofcom, 2018

allow others to use all/part of their spectrum without giving up those rights or obtaining a separate licence from Ofcom. Leasing is only permitted for those licensees that have applied for the leasing variation to be included in their licence.

It should be noted that at present leasing is only permitted for certain licence classes:

- Business radio – Area defined[11] and Suppliers Light;
- Spectrum Access - All tradable licences except those licences covered by the Mobile Trading Regulations and Concurrent Spectrum Access licences (CSA) licences (also known as 'DECT guard band' licences).

Block assigned licences are not permitted to be leased under the current regulations. This means that a mobile operator that holds a spectrum licence and who is subject to mobile trading regulations (see below) is not permitted to lease part or all or its spectrum to another user/licensee, as Ofcom states in its Trading Guidance notes[12].

Mobile spectrum trading regulations

Mobile spectrum trading regulations specify certain limitations that apply to mobile operators. Mobile spectrum licences, with one exception[13], specifically do not permit operators to lease their spectrum.

2.3 Spectrum sharing in the UK

It has been possible to share spectrum in the UK for many years. The regulatory framework has enabled access to spectrum on a shared basis across a mix of authorisation approaches. Fundamentally, spectrum sharing is conducted based on three principles:

- **Geographic or spatial sharing**: Users can operate on the same bands, at the same time, but subject to there being sufficient geographical separation between them to avoid interference.
- **Time or temporal sharing**: Users can operate on the same bands in the same location, subject to sufficient time separation (i.e. not simultaneously) which can be beneficial when users have different time requirements.
- **Power**: Users can operate on the same bands in the same location, at the same time. However, there are transmit power constraints for secondary users.

Ofcom established a spectrum sharing framework in its consultation[14] in 2015 which set out key characteristics of spectrum sharing which includes:

[11] An Area Defined licence authorises the use of a frequency(ies) in a defined geographical area. Licensees can make base station deployments anywhere within their defined geographical area (while complying with boundary conditions) without registering these deployments with Ofcom (some exceptions may apply).

[12] Trading Guidance Notes OfW513, Ofcom, November 2018

[13] Ofcom spectrum access licence 3.6 GHz, Ofcom, June 2019
https://www.ofcom.org.uk/__data/assets/pdf_file/0019/83800/SA-3.6-GHz-LICENCE-UK-Broadband-0823615.pdf

[14] A framework for spectrum sharing, Ofcom, July 2015,
https://www.ofcom.org.uk/__data/assets/pdf_file/0032/79385/spectrum-sharing-framework.pdf

- Potential barriers to sharing;
- Identification of the regulatory tools to facilitate sharing;
- Market and technological enablers; and
- A consideration of sharing on a case-by-case basis taking into account the characteristics of both incumbent use and the new use.

The framework has enabled the dialogue with stakeholders on how to get the most out of spectrum sharing. Some examples of spectrum sharing that already takes place in the UK include:

- Static sharing such as between satellite and fixed links;
- Programme Making and Special Event (PMSE) most recently sharing in the aeronautical bands[15] (960 – 1164 MHz);
- Television White Space (TVWS); and
- Shared access to public sector spectrum such as defence and public safety.

In this study, we consider in section 3.6 how new approaches to spectrum sharing that have been developed by Ofcom will facilitate greater flexibility, improve spectrum utilisation and access to spectrum to enable innovation, service creation and generate new business opportunities in areas that until now have been unable to access services provided by a range of spectrum licensees.

[15] New Spectrum for Audio PMSE, Ofcom, March 2016 https://www.ofcom.org.uk/__data/assets/pdf_file/0021/62481/New-Spectrum-for-Audio-PMSE-statement.pdf

3 Analysis of exclusive use of spectrum

3.1 Introduction

In this chapter the general concept of exclusive spectrum use is explained (with respect to individual rights of use of spectrum) and we investigate the characteristics which justify the exclusive use of spectrum. We provide an initial definition of exclusive use of spectrum (pre-analysis) and then explore the regulatory, commercial and practical aspects of exclusive spectrum use for different services. We conclude with a post-analysis definition of exclusive use of spectrum to try and clarify where exclusive licences may or may not fulfil certain policy objectives.

3.2 Pre-analysis definition of exclusive use of spectrum

In accordance with the recently updated EECC, individual rights of use of spectrum can be granted based on taking into account technical implementing measures adopted in accordance with Article 4 of Decision No 676/2002/EC[16]. These technical implementing measures are explained further in section 3.4. In the UK, this is currently translated into the WT Act 2006 *as restrictions on grant of exclusive licence*[17]. In other words, Ofcom may not grant an exclusive licence unless one of the following conditions is met:

1. That it is necessary to grant an exclusive licence in order to protect safety of life service, or;
2. That there are other exceptional circumstances which, in Ofcom's opinion, justify the grant of an exclusive licence in order to ensure the general interest objective

However, Ofcom does not grant spectrum licences that are exclusive because it reserves the right to authorise other (e.g. secondary) users in the spectrum as and when it is needed. As such, licences are granted on a non-exclusive basis but in practice, unless Ofcom and the primary user determines that a secondary use would be possible without impact (to be defined later) to its services, for all intents and purposes the access to spectrum by the primary user is considered exclusive. The notion of exclusive access is based on the practical reality of spectrum usage and the underlying characteristics which are discussed further in this chapter.

Furthermore, there may be a different interpretation of exclusive use of spectrum from the perspectives of Ofcom and industry (uses/licensees). There is a misalignment in both the perceived interpretation of what is meant by exclusive use in practice and the regulatory interpretation which is clearly stated by Ofcom. We also note that there is no formal authoritative and precise published definition of exclusive use of spectrum in the UK (or indeed internationally).

[16] Regulatory framework for radio spectrum policy in the European Community (Radio Spectrum Decision)

[17] WT Act 2006 Part 2 chapter 1 Section 8B, UK Government http://www.legislation.gov.uk/ukpga/2006/36/section/8B

Therefore, we consider the creation of a definition using language that is common to industry and Ofcom which enables both parties to achieve key primary objectives which include:

- **Ofcom**: maximising spectrum efficiency
- **Industry**: necessary certainty for continued, unconstrained use of the spectrum in the locations and under the technical and regulatory conditions under which the licence was granted

We provide below an initial (pre-analysis) definition of exclusive use of spectrum so that we can compare to a 'post-analysis' definition (in section 3.7) of exclusive use of spectrum. This is done once we have analysed the characteristics that justify exclusive use of spectrum. We then refine the definition based on the outcome of the analysis which helps to determine if any changes should be considered to definition and ultimately any changes to the regulatory framework.

Our definition of exclusive use draws from a range of other descriptions and explanations from sources such as WT Act 2011[18], GSMA[19], FCC[20], and OECD[21] and states:

'Access to spectrum on an exclusive basis allows the 'primary' licensee to individually use the assigned frequencies at any time, and within a particular geographical area – either nationally or locally. It implies that there will be no other interfering user(s) operating on the licensed spectrum (based on a presumption of successful coordination with neighbouring countries), and therefore, access to the spectrum as well as performance requirements (e.g. Quality of Service) are guaranteed.'

A licence gives the licensee access rights to the spectrum under certain specified conditions, however these conditions vary for different services and spectrum bands and comprise technical (such as emission masks, frequency band, bandwidth and transmit power) and regulatory (such as licence duration and conditions of breaches) restrictions.

[18] The Wireless Telegraphy (Licence Charges) Regulations 2011 http://www.legislation.gov.uk/uksi/2011/1128/made

[19] Introducing spectrum management, GSMA, 2017 https://www.gsma.com/spectrum/wp-content/uploads/2017/04/Introducing-Spectrum-Management.pdf

[20] Federal Communications Commission Spectrum Policy Task Force Report of the Spectrum Rights and Responsibilities Working Group, 2002

[21] Broadband Policies for Latin America and the Caribbean, Spectrum Policy, OECD, 2016, https://www.oecd-ilibrary.org/docserver/9789264251823-6-en.pdf?expires=1572008929&id=id&accname=guest&checksum=15FEE7A28A479DBAE1A93FEA8F836896

3.3 Bands licensed on an exclusive basis

We identify in the table below some of the different sectors and frequency bands which the user considers are authorised on an exclusive basis in the UK.

Sector licence	Example licensee	Frequency range	Example technology
Nationwide public cellular ("Public wireless network" or "Spectrum Access")	EE, O2, Three, Vodafone	800 MHz 900 MHz 1800 MHz 2100 MHz 2600 MHz 3500 MHz	GSM (2G) UMTS/WCDMA/HSPA (3G) LTE (4G) New Radio (5G)
Nationwide business radio	Network Rail	876 – 880 MHz/ 921 – 925 MHz	GSM-R
Area-defined licence business radio	Construction firms/ Taxi firms / local authorities / security firms / utilities	450 – 470 MHz	Private Mobile Radio, digital Private Mobile Radio, SCADA
Nationwide business radio	Airwave	380 – 385 MHz/ 390 – 395 MHz	TETRA
Spectrum Access	Mobile operators, Airwave, ISPs and broadband providers	10 GHz, 28 GHz; and 32 GHz.	Fixed point to point and point to multipoint

Table 2: Example of area-define and national business radio licences

The sectors listed in the table above consider their particular needs justify exclusive access to spectrum such that the type of licence available aligns with the requirements of the user needs. This could include protection from harmful interference, nationwide access, local specific area access, long term licence and other certainty requirements. Some of the networks that are deployed in these bands are often of critical national importance for uses such as rail operation, utilities (gas, electricity and water), or major distribution networks across a number of different sectors. Further, EE's public cellular network will, in a few years' time, be used by the public safety services police, fire and ambulance for their mobile communications needs. We would emphasise that these sectors either bring significant value to society or commercial value to the economy.

3.4 Justification for exclusive use of spectrum

3.4.1 Characteristics that justify exclusive use of spectrum

As mentioned in section 3.2, there are technical (and regulatory) implementing measures that are used by regulators to justify the decision for authorising spectrum on an individual and exclusive basis. The characteristics that are most commonly used and determined at both a European level (EECC and Authorisation Directive) and national level by Ofcom to justify exclusive use of spectrum typically include the following:

- reduced risk from harmful interference;

- assured spectrum availability to support realisation of planned QoS;
- safeguard efficient use of spectrum and;
- fulfil other objectives of general interest.

Examples of the type of other objectives of general interest in accordance with the EECC include:

- key focus on certainty for investment in networks;
- promote competition in the provision of electronic communication networks and
- promote the interests of the citizens by ensuring connectivity and widespread availability of very high capacity networks (including fixed, mobile and wireless networks)

In the context of this study we focused on four characteristics that justify exclusive use, three from the above common characteristics and also the flexibility for network deployment. This can be considered an outcome of individual exclusive use, however serves as a significant benefit to licensees when linked to certainty for investment in networks.

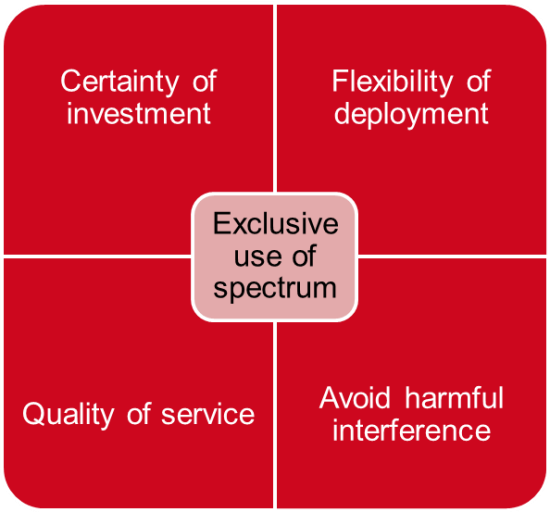

Figure 1: Overview of characteristics that justify exclusive use of spectrum

These characteristics are typically used by regulators to inform decisions about how to authorise a particular spectrum band between a general authorisation approach or individual assignments. If these criteria are met (amongst other economic analysis) when analysing the band and type of use for it then it supports the justification for making individual assignments of spectrum. We explore each of these characteristics in turn and provide a brief coverage comparison between 700 MHz and 26 GHz to tease out some of the nuances of the justification of exclusive use of spectrum.

3.4.2 Reduced risk from harmful interference

Minimal levels of interference have to be accepted as there is no guarantee of total interference free operation. This means the services that are operating on a particular frequency should not suffer (or cause) harmful interference within the practical bounds of equipment operation and professional installation. The use of exclusive licensing therefore ensures that no other (e.g. secondary[22]) services can operate on the same frequency in the same location as the primary user which would otherwise cause interference to the licensed service.

In the table below we provide a summary of the impact to users from increasing levels of interference caused by other users that are co-channel.

Interference mechanism	Description	Severity	Impact to mobile network
Co-channel operation in same geographical location	Secondary user in-band transmitting on the same channel as the user in the same location	High	Can cause overload and blocking of receivers. Potentially causing complete loss of service to the operator in that area
Co-channel operation in adjacent geographical location	Secondary user in-band transmitting on the same channel as the operator nearby the primary user	High – medium	Can cause overload and blocking of receivers in fringe areas, but unlikely to be complete loss of service. Can still cause significant problems to network operation
Co-channel operation distant from the network	Secondary user in-band transmitting on the same channel as the operator at a significant distance from the primary user	Medium	Can cause sporadic and nuisance interference to users at the edge of coverage and receiver in fringe areas, but unlikely to cause complete loss of service

Table 3: Overview of interference impact to mobile networks

3.4.3 Assurance of access to spectrum in all locations to deliver defined quality of service levels

Access to spectrum as and when it is needed, provides the ability to deliver coverage to certain levels of quality to users over a particular area. The ability to deliver defined and varying levels of quality of service means that the service provider has the flexibility to offer a range of services to customers (at least to a minimum acceptable level). This is an imperative characteristic for mobile operators.

For example, it could be argued that without exclusive access to spectrum it would be challenging for mobile operators to offer a broad range of ‘guaranteed’ bit rates defined within the mobile operators’ network specifications. In Annex C, we provide an extract from one of the Next Generation Mobile Network Alliance’s (NGMNA) specifications which defines a range of Quality of Service Channel indicator (QCI) codes to measure traffic performance.

[22] Note that the use of the terms ‘primary’ and ‘secondary’ in this context refers to the main licensee and anyone who may wish to use the same spectrum, and not the definition provided by the ITU in the Radio Regulations.

Airwave Solutions manages the network for the UK's emergency services and delivers an (almost) guaranteed level of nationwide voice communications (and some limited data) to police, fire and ambulance users. Airwave does not hold national 'exclusive' rights of access to the 380-385 and 390-395 MHz spectrum, but Ofcom is unable to (and would not) authorise other users due to a European mandate for public safety use of the band. This situation is in some ways similar but also at odds with the case for exclusive access to spectrum for mobile operators as it suggests that exclusive licences are not needed and yet a public safety service can be delivered.

However, there are similarities between the Airwave case, and that of the mobile operators in that any secondary use would not be permitted by Ofcom (on the basis it will impact delivery of the minimum level of service) or accepted by Airwave as it would limit their flexibility in deploying and operating their network which could risk responding to public safety incidents. For mobile operators, having secondary users in their band would also limit their deployment options and ability to deploy their network as and when they saw fit.

3.4.4 Key focus on certainty for investment in networks

Since the introduction and increase of market-led approach to spectrum authorisation, the wireless telecommunications sector has developed an understanding of the economic value of spectrum. Thorough market mechanisms it is argued that spectrum, as a state asset, will be licensed to whose companies that value it most, and can make best and most economically efficient use of it. There is an opportunity cost of using the spectrum this way (from the denial of access to other users) and Ofcom has continued to consult on this, prior to deciding whether spectrum auctions should be the mechanism that will deliver the most optimum outcome in terms of mobile spectrum efficiency.

This decision creates a commercial dependency between acquisition of spectrum from the private sector and the need for network investment. Securing spectrum at auction is only the first step for MNOs, what follows is the additional need to finance the roll out of the network. This can often match or exceed the costs of the spectrum[23] which is dependent on the frequency band and the speed of network roll-out. Mobile operators, in this case, require certainty before they will invest in new networks and access to exclusive spectrum (along with other conditions) provides this required level of certainty.

Other commercial considerations include certainty of tenure, which means licensees have a defined minimum duration of exclusive rights of access to spectrum which allows them to produce a business case which will allow them to make a return on investment. Other commercial aspects the regulator considers include:

- National licences are typically awarded in harmonised mobile spectrum resulting in higher perceived value, this is based on the estimated value of mobile spectrum of £273 billion over ten years (2012 – 2021) (See Annex C for details) ;
- High demand for harmonised mobile spectrum below 6 GHz from mobile operators, combined with:
  - Perceived scarcity of spectrum
  - Potential high value placed on spectrum by the mobile market given associated demand

[23] Assuming £2 billion spent on network upgrades and expansion per year over the first five years of the licence

Furthermore, we show below how harmonised mobile spectrum achieves high value at auction and benefits to consumers but also delivers high value to society such as that demonstrated by TETRA and GSM-R networks.

Spectrum band	Total auction value	Total spectrum assigned	Main benefits
380 – 385 MHz/ 390 – 395 MHz	Not applicable	10 MHz	Harmonised spectrum for TETRA technology to support the deployment of secure and resilient public safety voice services nationwide
876 – 880 MHz/ 921 – 925 MHz	Not applicable	8 MHz	Harmonised mobile spectrum for GSM-R technology to support the deployment of secure and resilient railway voice and signalling services over national rail routes
800 MHz & 2600 MHz	£2.367 billion[24] (2013)	250 MHz	Nationwide indoor and outdoor 4G population coverage Commitment and obligation (for Telefonica) to extend coverage to 98% of UK households MBB services for consumers Introduction of new services (e.g. Wi-Fi on trains)
2100 MHz	£22.5 billion[25] (2000)	120 MHz	UK wide outdoor 3G population coverage Kicked off further expansion of national mobile networks
2300 MHz & 3500 MHz	£1.37 billion[26] (2018)	190 MHz	Continued expansion of UK wide outdoor 4G coverage (2300 MHz) Introduction of new 5G services Fixed Wireless Access and enhanced MBB

Table 4: High value of UK harmonised public and private mobile spectrum

We also consider, for example how certainty for investment can be impacted without clear unconstrained access. For example, in Concurrent Spectrum Access (CSA) licences, there is a regime which requires degrees of coordination between operators to access the spectrum. It could be

[24] Award of the 800 MHz and 2.6 GHz spectrum bands – Publication of final results of auction under regulation 111 of the Wireless Telegraphy (Licence Award) Regulations 2012, Ofcom 2012, https://www.ofcom.org.uk/__data/assets/pdf_file/0031/74893/4g-final-results.pdf

[25] The Auction of Radio Spectrum for the Third Generation of Mobile Telephones, NAO, Oct 2001 https://www.nao.org.uk/wp-content/uploads/2001/10/0102233.pdf

[26] Award of 2.3 and 3.4 GHz spectrum bands- Publication under regulation 111 of the Wireless Telegraphy (Licence Award) Regulations 2018 of results of auction, Ofcom, 2018 https://www.ofcom.org.uk/__data/assets/pdf_file/0018/112932/Regulation-111-Final-outcome-of-award.pdf

argued that this concurrent access limits the certainty to for wide-scale investment (*CSA licensees have deployed systems to provide private mobile phone networks for organisations*[5]*)* in networks.

The regulatory and technically focussed characteristics discussed in the previous section do not alone justify exclusive use. The top priority for mobile operators (as informed by stakeholders) and supported by the GSMA and other mobile industry groups, is the certainty required to make network investments at a national scale.

We discuss these characteristics and the ability to flexibly deploy networks in the following sections.

3.4.5 **Flexibility to deploy networks**

Exclusive rights of access to spectrum provide telecom operators (fixed wireless and mobile) the flexibility to plan and deploy their networks as their business or operational need dictates. This characteristic is also linked to certainty for investment because the certainty for network investment enables a choice which in turn can align with whatever business plan the operator has developed.

The business plans of MNOs are typically focused around coverage being deployed in areas which deliver the best economic return on investment which is predominantly populated areas but may also include more remote areas where the business case stacks up or where partnering with other MNOs reduces the costs sufficiently. Private operators with nationwide coverage requirements have the flexibility within their licence to deploy networks and provide coverage where it is needed for operational purposes. In the case of fixed links, operators can use their national licence to deploy sites when and where they wish.

Exclusive access to spectrum also enables telecom operators the flexibility of network deployment when it is right for them to do so. For example, MNOs can deploy networks whenever or wherever the need arises without requiring individual authorisation or assignment from Ofcom which may otherwise slow down the process. A national licence provides this flexibility which means demand for consumers can readily be met. Flexibility in network deployment promotes competition within the mobile market as it does not constrain operators from taking individual decisions on where to provide service.

However, there is an ongoing policy issue which government has been trying to address for many years: how to extend mobile coverage to more remote and rural areas, i.e. where it is not commercially viable. Given the fact that mobile operators have the flexibility to deploy networks wherever and whenever they like, there is an on-going opportunity through licensing (as discussed in section 3.3) to fulfil the geographic coverage of the UK, however government intervention has been necessary to encourage and support wider roll out by MNOs to more remote areas. Exclusive access does not help address this situation as it does not permit other parties to use the spectrum to provide services in the remote areas where the mobile operators consider it unviable.

3.4.6 **Coverage related criteria to justify exclusive use: 700 MHz versus 26 GHz**

We consider the physical characteristics of the 700 MHz band compared to the 26 GHz, both of which will be used in mobile networks in the next few years and what regulations or conditions can be put in place to secure certain outcomes.

The 700 MHz band is an ideal band for wide area coverage due to its good propagation characteristics and once deployed by operators will contribute towards filling many of the remaining

coverage holes (not-spots). The wide-area coverage characteristics and relatively small quantity of spectrum means there is limited opportunity for authorising secondary users.

In the 700 MHz band there is relatively limited available bandwidth for MNO licensees (with only 2 x 30 MHz being made available across four MNOs). Given the current share of mobile spectrum, the maximum that any one operator can hold is likely to be 2 x 10 MHz which will not provide extremely high bit rates but rather provide wide area and deep indoor coverage.

By comparison, the 26 GHz band will predominantly be used for delivering ultra-high capacity in 5G networks using very wide channels but much smaller cell areas. The re-use distance is much smaller at 26 GHz compared to 700 MHz, which opens up the opportunity for sharing the spectrum. The UK Spectrum Policy Forum recently published a report[27] on the 26 GHz band and indicated its technical characteristics would suit local area applications and therefore could be shared both outdoors and indoors.

The UK Spectrum Policy Forum report provides details of the particular role 26 GHz will play for mobile operators in locations of 'high and exceptionally high' traffic demand. Thus, as stated in the report[27]; "*there will not be a well-defined roll-out or start point of large-scale deployment, rather the band will be utilised as aggregate demand across 5G bands increase".*

The report identifies, for reasons of high risk of interference, that individual licences (exclusive access to spectrum) would be the most compatible solutions for this band to give assurance of access to large blocks of spectrum which will be needed to support the high capacity or congested areas the networks will be deployed. However, the report does not recommend a particular option but further identifies a range of policy proposals for authorisation of the 26 GHz band which include:

- Exclusive national licences;
- Mixed spectrum release model;
- National priority zones of exceptionally high demand (e.g. Hong Kong model);
- Club spectrum (e.g. Italian model);
- Technology and innovation driven sharing model and;
- Tiered model.

In the context of this study, the UK SPF report points to exclusive national licensing as *a conventional model that has proven effective in competition, supporting investment in networks at scale, development of devices ecosystem and delivered good outcomes for consumers.* However, the physical characteristics at 26 GHz suggest that spectrum sharing is possible and may also bring spectrum efficiency gains.

In other words, Ofcom has to make a decision which balances the commercial imperatives of operators, and their obligations with regards competition against the very clear physical signal propagation characteristics of 26 GHz which potentially indicate that a sharing approach to spectrum access would be the most suitable and supportive of the spectrum efficiency benefits trying to be achieved by Ofcom.

[27] Report on the principles for the release of the 3rd 5G 'pioneer' band at 26 GHz and shared spectrum access within the band (and potential model for release of subsequent mobile bands above 26 GHz), UK Spectrum Policy Forum Cluster 2, August 2019

3.5 Pros and cons of exclusive use

As discussed above, there are some clear justifications for exclusive use of spectrum. In this section we discuss the pros and the cons of exclusive use of spectrum with respect to understanding the impact of whether the benefits are lost with shared access to spectrum, by which we mean other users have overlapping usage rights.

The example benefits of exclusive use of spectrum include:

- The ability to secure and operate safety of life networks (i.e. for air travel and maritime)
- The certainty required to enable the continued evolution and expansion of mobile networks
- Ability to secure and operate critical national infrastructure for railways, public safety and utility networks
- In the case of spectrum auctions, the ability to secure higher licence revenues for treasury

The following table looks at the benefits of using exclusive spectrum and considers whether these benefits would be lost, if that same spectrum was shared with other users.

Benefits of Exclusive use	Do you lose the benefits with shared access to spectrum?
Ability to secure and operate safety of life networks for air travel and maritime	Yes – due to the potential for interference into these services in the areas they are used
The certainty required to enable the continued evolution and expansion of mobile networks	Yes - due to reduced uncertainty of access to spectrum for a mobile operator overlapping usage rights could undermine the business case and impact network roll-out.
Ability to secure and operate critical national infrastructure for railways, public safety and utility networks	Yes - due to the potential for interference into these services in the areas they are used which is widespread and could be nationwide
In the case of spectrum auctions the ability to secure higher licence revenues for treasury	Yes – as much of the value of the spectrum in auctions comes from its ‘exclusive’ availability

Table 5: Risk to benefits of exclusive use of spectrum arising from sharing

The cons of exclusive use of spectrum include:

- The challenge and potentially prohibitive cost to deliver full ubiquitous mobile coverage across the UK;
- Denies access to other users in the context of spectrum efficiency;
- Locked into specific long term technology family limited opportunity for innovation with respect to different types of use and users.

The following table looks at the negatives associated with exclusive spectrum and considers whether these would be rectified if that same spectrum was shared with other users.

Cons of Exclusive use	Do you fix the cons with shared access to spectrum?
Operators unable to deliver full ubiquitous nationwide mobile coverage due to economic constraints	No – as there is no incentive or requirement for existing or new operators to roll out nationwide or in a timely manner that will satisfy all mobile subscribers at every location
Operators unable to deliver full ubiquitous nationwide mobile coverage in a timely manner	
Denies access to other users and uses in the context of spectrum efficiency	Yes – other users and uses could be introduced but may have to be implemented in carefully coordinated and predictable interference environment
Locked into specific long term technology family with limited opportunity for innovation with respect to different types of use and users	Yes – shared access would allow introduction of new technologies and potentially create new ecosystems for frequency bands that have been traditionally used for single technologies or services

Table 6: Cons of exclusive use of spectrum

It can be seen that the pros of exclusive use would mostly be lost if we were to instead consider shared access to spectrum. Similarly, not all the cons of exclusive use will be fixed when we consider shared access to spectrum. This suggests therefore, that depending on the perspective of the user or type of use, the case of satisfying certain requirements for protection from interference or certainty for investment and over a defined area, the benefits of exclusive use are important for ongoing business operations and network expansion. Unless an alternative approach is developed that can satisfy those requirements without using exclusive use of spectrum then we consider that exclusive use is a necessary approach to address demand and operational needs of certain users.

However, we acknowledge that a primary objective of the regulator is to secure efficient use of spectrum. It can be argued that some of the cons can be fixed by carefully managed shared access to spectrum and hence the need for a spectrum sharing framework and newly introduced approaches to sharing as recently set out by Ofcom.

3.6 New and existing spectrum sharing approaches help address consumer demand

3.6.1 Geographic demand for mobile spectrum

All mobile operators provide 99% 4G population coverage[31] and 4G coverage is being extended into rural and remote areas, however, there are many rural, remote and deep indoor locations in the UK where national operators' coverage does not reach. The chart below extracted from Ofcom's 2018 Connected Nations report highlights the extent of outdoor 4G geographic coverage for all mobile operators in the UK.

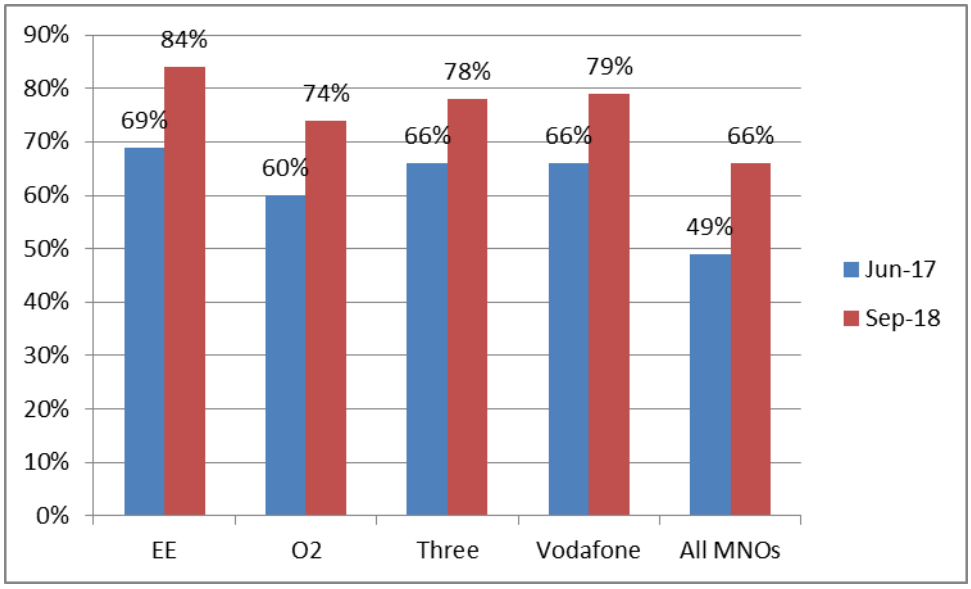

Figure 2: Outdoor area geographic coverage of 4G mobile services in the UK. Source: Ofcom[28]

It can been that there has been good growth of coverage over the 15 months from June 2017 to September 2018, however this rate of coverage growth may not be maintainable as it becomes harder and takes longer to deploy infrastructure in the remaining remote and rural areas.

It is, however, reasonable to assume the next Connected Nations report from Ofcom will show an increase in outdoor 4G coverage as mobile operators continue to extend networks and build new sites in rural areas as exemplified below.

Mobile operator	Example of MNOs extending mobile coverage
EE	Rural UK Landowners Seek Guarantees in Rural 4G Mobile Rollout [29]
O2	O2 to Extend 4G Mobile Coverage to 250000 Rural UK Residents UPDATE [30]
Three	Rural UK Landowners Seek Guarantees in Rural 4G Mobile Rollout[29]
Vodafone	Vodafone installs fast 4G in phone boxes on Polzeath and Sennen Cove beachfronts [31]

Table 7: Examples of UK mobile network roll outs

[28] Connected Nations report, Ofcom, December 2018,
https://www.ofcom.org.uk/__data/assets/pdf_file/0020/130736/Connected-Nations-2018-main-report.pdf

[29] Rural UK Landowners Seek Guarantees in Rural 4G Mobile Rollout, ISP Review, June 2019
https://www.ispreview.co.uk/index.php/2019/06/rural-uk-landowners-seek-guarantees-in-rural-4g-mobile-rollout.html

[30] O2 to Extend 4G Mobile Coverage to 250000 Rural UK Residents UPDATE, ISP Review, Oct 2019
https://www.ispreview.co.uk/index.php/2018/10/o2-to-extend-4g-mobile-coverage-to-250000-rural-uk-residents.html

[31] Vodafone helps customers surf the internet in Cornwall , Vodafone web site, April 2019
https://mediacentre.vodafone.co.uk/news/vodafone-cornwall-4g-phone-boxes/

The table above highlights how all four mobile operators have committed to extending coverage of their networks, which is being driven by an initiative for rural shared network between the MNOs and government[32].

We provide some examples that demonstrate how extended coverage could meet certain geographical demands, including:

- Full mobile coverage of the UK Strategic Road Network and other major roads;
- Full mobile coverage of UK rail networks;
- Coverage in remote and rural villages including enterprise, tourism, travel, small businesses, farming, and agriculture.

Mobile usage inside vehicles and need for full coverage of UK Strategic Road Network

Access to mobile services whilst on the move has become an essential part of everyday life. This is driven by a number of factors; one in particular is the mandate for all new vehicles to have an e-Call[33] unit, which requires mobile connectivity. This initiative will subsequently support additional mobile services such as the usage of smartphones, or streaming of video by passengers inside vehicles. This is not a metric that is widely published, however, we consider growth by car manufacturers with the inclusion of e-Call as a standard feature will lead to increased growth in demand – examples include:

- Tesla[34] has embedded SIM for interactive maps, and over the air software updates;
- Ford now offers an in-vehicle connectivity package to enable a range of services[35];
- Vauxhall OnStar[36] is a connectivity service offering a range of safety and security features.

With regards to coverage along the roads, according to Ofcom's 2018 Connected Nations report[28] '*Over a third of all Motorways and A-roads do not have good in-car 4G coverage from all operators.*' This presents an opportunity to extend coverage along UK's roads for ubiquitous connectivity.

Demand for mobile coverage of UK rail networks

The demand for mobile services on trains is slightly different to that of demand in vehicles. The concentration of users (i.e. user density) is greater on trains compared to cars and users can spend time on trains working, surfing the internet or shopping. The method of delivery on-board trains is similar to vehicles which is via an on-board gateway providing Wi-Fi backhauled over the cellular

[32] £1 billion deal set to solve poor mobile coverage, DCMS, October 2019, https://www.gov.uk/government/news/1-billion-deal-set-to-solve-poor-mobile-coverage

[33] E-Call is the European initiative to include an automated emergency call whenever a vehicles is involved in an incident that requires emergency services response

[34] Telefonica connects Tesla cars in Europe, Fierce Wireless, April 2014, https://www.fiercewireless.com/europe/telefonica-connects-tesla-cars-europe

[35] "The new FordPass Connect modem makes your journeys easier", Ford web site accessed October 2019 https://www.ford.co.uk/shop/research/technology/connectivity/fordpass-connectivity

[36] Vauxhall Onstar connectivity system pricing announced, Autocar web site, June 2015 https://www.autocar.co.uk/car-news/industry/vauxhall-onstar-connectivity-system-pricing-announced

network. Depending on the route, mobile coverage varies and is often patchy or non-existent on remote/rural parts of the route for long distance rail journeys. Commuter lines often have better mobile coverage (as they run through urban and suburban areas) but run through cuttings and tunnels making it difficult to serve trains on a number of routes.

Network Rail, the Department for Transport (DfT) and industry have been trying to improve connectivity from the trackside to trains for a number of years for passenger and operational uses, with the latest Government policy[37] seeking to ensure '*connectivity for passengers on all mainline routes could be dramatically improved by 2025'*. This work will continue to evolve as technical solutions and deployments (trackside fibre and sites) become clearer and the safety and commercial barriers continue to be overcome. However, it could be argued that if coverage obligations were somehow placed on MNOs licences for coverage along rail routes this issue could have been resolved.

Demand for mobile connectivity in remote and rural areas

There has been concern over the growing digital divide in the UK in which consumers in urban and suburban areas receive better, faster and enhanced broadband services whilst consumers in rural and remote areas have very poor or no services at all. The demand does not change in these remote and rural areas but translates into a frustration by consumers due to limited access in their location[38] on the basis that new technologies do not reach them either at all or many years after they have been introduced elsewhere.

In Ofcom's consultation on enabling opportunities for innovation[5], it identifies a number of markets that will benefit from better connectivity in remote and rural areas, including:

- IoT such as smart meters;
- Industrial automation;
- Robotics;
- Fixed Wireless Access.

Some of these opportunities could also benefit from using 5G meeting the connectivity requirements for a range of proposed use cases particularly in industrial automation. These demands point to a need for extending mobile coverage in some form or another and we discuss below how flexibility in the licensing frameworks can help support this.

We discussed the flexibility of the current licensing framework and found that some aspects could be enhanced to enable new innovating opportunities for sharing. Ofcom's recently adopted proposal for "three-shared access bands" (as shown below) provides a novel way to introduce sharing in certain mobile related bands:

- 2 x 3.3 MHz in the 1781.7 – 1785 MHz paired with 1876.7 – 1880 MHz;
- 10 MHz in the 2390 – 2400 MHz shared with MoD use;

[37] Better mobile and Wi-Fi connectivity for rail passengers, DfT, 2017 https://www.gov.uk/government/news/better-mobile-and-wi-fi-connectivity-for-rail-passengers

[38] Three-quarters of UK consumers frustrated by their internet connection, Inews, July 2018, https://inews.co.uk/news/technology/three-quarters-of-uk-consumers-frustrated-by-their-internet-connection-270487

- 400 MHz in the 3.8 – 4.2 GHz band shared with satellite earth stations and fixed links.

The aim of this shared spectrum approach is to enable access to mobile bands on a time and location limited basis in areas that are not always well served by mobile operators particularly in rural areas, campuses, large enterprise parks and indoors. The bands are harmonised for mobile use which for 1800 MHz and 2300 MHz bands could be used immediately given these bands are widely supported in devices today. Two types of access have been proposed:

- Low power licence for local connectivity (per area licence) which allows transmission from base station to both fixed and mobile terminals with desired number of base stations but within a 50 metre radius, with a maximum antenna height of 10 metres.
- Medium power licence for longer range connectivity (i.e. higher transmit power per base station licence). Due to potential risk of interference, these are initially limited to rural areas and allow connections from base stations to fixed terminals only.

One major aspect of the approach Ofcom has introduced is the opportunity both for new entrants and existing (non-mobile) telecom operators to apply for local licences in existing awarded mobile spectrum. This is a totally new approach and perhaps provides the access to mobile spectrum that users in remote and rural locations have been seeking.

Essentially a new local licensing regime will permit 'secondary users' access to mobile operator's national spectrum on a short term but cost effective basis[39]. However, the following conditions have been applied:

- Local licences will be issued with a proposed minimum term of three years with options to extend depending on agreement with incumbents;
- Must be for a single location or areas;
- Licences can only be issued in locations where the spectrum assigned to the mobile operator is not being used;
- The MNO has not used the spectrum for some time and has no plans to in future.

To summarise, this new flexible approach supports the mix of spatial and temporal spectrum needs of users and services but does not guarantee that spectrum can be utilised by other parties exactly when or where needed. It provides an opportunity to introduce new technologies (or variants of existing technologies) to other bands and provides limited flexibility in the technical limitations in terms of transmit power, antenna height, and indoor or outdoor use. It is an innovative and promising step towards efficient utilisation of spectrum and provides a solution for potential new licensees in rural and remote areas, as well as in small but densely occupied areas (such as campuses and hospitals) to deliver innovative services.

[39] A local licence has a cost-based one-off fee of £950 per licence

3.7 Post analysis definition of exclusive use of spectrum

In this chapter we have assessed the characteristics which justify exclusive use of spectrum but also considered how sharing increasingly plays a role in the approaches to spectrum access. In addition, we understand that there are differences in perspectives with regards exclusive use from a regulator's perspective and a user/licensee perspective. To resolve this, we propose a definition of exclusive use which addresses the concerns of both parties.

Subsequent to our analysis we propose that exclusive use of spectrum is defined as:

> *'User access to spectrum over a defined area: which provides a predictable incoming and outgoing interference environment and the ability to deploy services in accordance with the user requirements as and when the user requires'.*

This definition provides the certainty which operators need to deploy services with a defined QoS due to the predictable interference environment, it aligns with the new sharing options proposed by Ofcom and the ability to roll-out services on an as needed basis. It also provides regulatory clarity on users' expectations without using terms which limit the regulator's flexibility in licensing the spectrum in innovative or novel ways. The 'defined area' could be nationwide, or could be smaller.

The characteristics which justify why certain sectors (mobile, mission critical) require exclusive access to spectrum do not change and will remain essential in future. This is because the needs of these users will not change unless:

- The specific business models of telecom operators change drastically and certainty for investment is no longer required
- The technology and methods over which critical and business services are delivered change such that they can meet the required levels of resilience and availability without guaranteed access to clean spectrum
- Managing harmful interference (from a secondary user) is done automatically without the need for dedicated spectrum as the main physical differentiator

In the medium to long term we do not foresee significant changes in the requirements of users of exclusive access to spectrum, or their business models which means the existing framework is fit for purpose in this context. However, we observe that changes in technology such as dynamic spectrum sharing, self-organising networks and 5G will increasingly play a role in how existing operators and new entrants can deliver innovative services and access newly identified frequency bands. This is exemplified with Ofcom's new proposal for enabling innovations[5] through more spectrum sharing and the emergency services shifting connectivity from a private narrow-band network with dedicated spectrum to a public network i.e. no longer requiring exclusive access to spectrum for its own network, and this may evolve over time for other sectors such as rail and possibly utilities.

Overall, from a practical perspective exclusive access to spectrum remains a viable approach so that major businesses and organisations can continue to invest in networks, provide certainty for the future and function properly as the single primary users. This ensures they meet both the commercial/market needs of investors and consumers and operational needs of mission and business critical services.

4 Conclusions and recommendations

The scope of the study is to address and make recommendations on:

1. The definition of "exclusive" in the context of spectrum authorisation where a primary objective is to secure the efficient use of spectrum;
2. Whether the current UK spectrum licensing framework provides sufficient flexibility to meet the geographic-based demand of spectrum users; and
3. Any changes that should be considered to authorisation frameworks for spectrum and the sharing framework currently proposed by Ofcom.

With respect to the above we conclude the following:

1. On the definition of "exclusive" in the context of spectrum authorisation where a primary objective is to secure the efficient use of spectrum.

A new and more precise definition for exclusive use of spectrum enables both the regulator and users/licensees to have a common understanding of their usage rights

The key to understanding the definition of exclusive use is to articulate the new definition to industry to achieve a common understanding of the characteristics which justify exclusive use. This includes providing further clarity of how the specific characteristics support a particular use and in turn determine the impact this may have on access to spectrum by other users and ultimately on spectrum efficiency.

We therefore recommend:

The following new definition of exclusive use should be adopted across the industry:

Exclusive Use: *'User access to spectrum over a defined area which provides a predictable incoming and outgoing interference environment and the ability to deploy services in accordance with the user requirements as and when the user requires'.*

Using this definition, a common understanding of the authorisation framework should be created so that all spectrum users (existing and new) are clear of the pros and cons of the authorisation approaches available. In addition, this could help determine how the primary objective to secure the efficient use of spectrum can be met. Furthermore, the aim would be to minimise any confusion or misunderstandings within industry regarding how spectrum access is authorised.

2. On whether the current UK spectrum licensing framework provides sufficient flexibility to meet the geographic-based demand of spectrum users.

Ofcom's introduction of new spectrum authorisation approaches which includes a new shared access licensing regime and a new local licensing regime - allowing certain types of access to spectrum licensed for mobile operator use - has increased the flexibility of the spectrum licensing framework. These new flexible authorisation approaches being used alongside existing approaches provide significant benefits towards addressing the challenges of realising universal access to spectrum.

We consider that these new approaches provide sufficient flexibility to meet the geographic-based demand of spectrum users. They satisfy the demand of different users and uses including national MNOs and mission critical users, including their requirement for secure long term exclusive spectrum

access rights to provide business and operational certainty through to a wider mix of users whose needs vary from remote and rural access and those that can coexist with other users in the same band at the same location. The framework provides both certainty of access with limited risk of interference to deliver a range of different services to a wider mix of defined areas.

Therefore we recommend:

Government, Ofcom and industry continue to work collaboratively and recognise the opportunities for increasing the flexibility of the spectrum licensing framework where and when appropriate. This could include identification of complex and challenging areas where the existing authorisation framework currently does not permit introduction of new services and how developments in Europe and globally (e.g. CBRS) might be introduced to the framework (e.g. determine how could this be achieved, the processes and governance).

3. On any changes that should be considered to authorisation frameworks for spectrum and the sharing framework currently proposed by Ofcom.

We believe no changes are currently needed for the authorisation frameworks for spectrum. The new spectrum sharing approaches can meet demand in the near-term, provide opportunities for the introduction of innovative services, and provide the opportunity to enhance the efficiency of spectrum use. We also consider that these new approaches should be given time so that all users may become more familiar with them and their value proven.

The timely introduction by Ofcom, of new spectrum sharing approaches, provides the facility for new entrants to overcome some of the ongoing limitations of extending mobile coverage into rural and remote areas. The options for new licensees include:

- shared access to three harmonised mobile bands; or
- a new local licence to access mobile operators' spectrum where it is not being used which will help to meet demand, but only at the fringes of mobile coverage.

This new regime may help to overcome some of the barriers new entrants and innovators were facing to access spectrum and could be used to introduce and deploy new services. However, this is a platform on which to build for some of the more challenging and far reaching cases in rural and remote areas (e.g. rail cuttings and remote locations). For example, relaxation of limitations to the power levels (low and medium power) and height restrictions might help to overcome these coverage challenges. Nevertheless, this approach represents a good starting point from which to evolve.

We also believe that the benefits of the new approach could be extended to other bands and should be investigated further.

Therefore we recommend:

Government, industry and Ofcom should create an environment (or support existing programmes for innovation) that will allow testing of the current and future assumptions on exclusive and shared use in spectrum bands that are difficult to share. In particular, determine how future dynamic spectrum access could deliver certain benefits or not, thus informing future authorisation decisions. This could result in enhancements to the licensing framework that support new multi layered and multi-dimensional authorisation approaches, for specific situations and locations. These locations include, for example; indoor (standard indoor, deep indoor/underground, high up indoor), and outdoor (standard outdoor – urban/suburban/rural, transport corridors, special rural locations, business and

industrial sites). Furthermore, steps could also be taken to assist with assessing how well these approaches meet other policy objectives around coverage and quality of service.

5 Annexes – Supplementary information

5.1 Annex A - Overview of national and international authorisation frameworks

5.1.1 Ofcom

As specified in the Communications Act and Wireless Telegraphy (WT) Act, the following points from the licensing provisions are highlighted as criteria for justification of exclusive use:

A licence is a regulatory instrument enabling regulatory bodies to grant rights of access to the radio spectrum thus allowing a named service provider to use spectrum in a clearly defined way and under a set of general terms and conditions. Users of spectrum are assigned certain frequencies (and a given power/modulation) that they can use within the appropriate allocations so that the spectrum is used efficiently. The licence states certain service criteria that need to be complied with so that no interference occurs to other users. Under section 3 of the Communications Act 2003 (the "Act")[40], Ofcom's principal duty in this matter is to further the interests of consumers, where appropriate by promoting competition. Of particular relevance to authorising spectrum, is to secure the optimal use for wireless telegraphy of the electromagnetic spectrum.

Importantly, Ofcom is clear when granting licences (including awards following beauty contests and auctions) that the right to use spectrum is on a 'non-exclusive' basis and Ofcom retains the rights to authorise other users in the spectrum, with appropriate safeguards to appropriately manage the risk of interference. In this context it is important to recognise that there are some limitations placed on Ofcom in granting licences. In WT Act 2006[17] (Part 2 Chapter 1 Section 8B), which states that Ofcom may not grant an exclusive licence unless it ensures a general interest objective (highlighted below) and exceptional circumstances which, in Ofcom's opinion justify the grant of an exclusive licence:

- When it is necessary to grant an exclusive licence in order to protect safety of life services access to spectrum that is heavily used or used to provide critical/ safety of life services may be problematic, especially in populated areas. If non-exclusive access to one of these frequency bands is needed, then it would be worth considering a location where the use may be limited
- The promotion of social, regional or territorial cohesion
- Avoidance of inefficient use of frequencies: Exclusive access should not lead to inefficient use of the part of the electromagnetic spectrum available for wireless telegraphy
- The promotion of cultural and linguistic diversity and media pluralism
- Fulfilment of a requirement under the ITU Radio Regulations
- The WT Act restricts Ofcom to only include those provisions that are necessary for example to avoid undue interference (protection will be given from harmful interference received from

[40] Review of the authorisation regime for spectrum access, Ofcom, 2017
https://www.ofcom.org.uk/__data/assets/pdf_file/0019/108604/Review-of-the-authorisation-regime-for-spectrum-access.pdf

other authorised services), ensuring technical quality of service. The equipment must not cause harmful interference to any other authorised services. Interference is harmful if[41]:

- "it creates dangers, or risks of danger, in relation to the functioning of any service provided by means of wireless telegraphy for the purposes of navigation or otherwise for safety purposes; or
- it degrades, obstructs or repeatedly interrupts anything which is being broadcast or otherwise transmitted: by means of wireless telegraphy; and in accordance with a wireless telegraphy licence, regulations under section 8(3) or a grant of recognised spectrum access or otherwise lawfully".

It is stated that the regulatory framework, including competition rules, would allow exclusive use only when duly justified. Furthermore, *Block edge masks* contained within licences or interface requirements are considered to minimise the risk of interference.

5.1.2 International Telecommunication Union (ITU)

"Exclusive allocation is defined where the frequency band concerned is allocated to a single radiocommunication service. The national regulatory administration assigns licences to users giving them the exclusive right to operate on a specific frequency in a specific location or geographic area and under specified technical conditions (power, antenna height, etc.). Exclusive allocations are favoured in cases that involve broad international use of equipment and practices, which imply the need to harmonise relevant operational procedures and technical material in a larger international context.[42]"

"The granting of exclusivity rights generally increases government revenues from privatization and licensing transactions. Maintaining monopolies can limit sector growth and reduce licensees' efficiency to the detriment of consumers. Whatever policy is adopted on exclusivity, it should be clearly reflected in the licences of new licensees in order to provide certainty to them, their investors and lenders. It is of critical importance to ensure that the licensee is financially and technically able to meet its licence obligations. Otherwise, the licensee may fail to meet important licence conditions, such as those related to network roll out, service coverage and quality. The process of enforcing licence compliance or revoking and re- tendering a licence in the case of default is time consuming, costly and disruptive for consumers.[42]"

5.1.3 EU Authorisation Framework[43]

The Radio Spectrum Decision lays the foundation for a general EU radio spectrum policy and is binding on all Member States[44]. The objective of the Radio Spectrum Decision is to ensure

[41] Innovation and Trial licensing Guidance notes for applicants, Ofcom, 2018
https://www.ofcom.org.uk/__data/assets/pdf_file/0014/53105/ofw357nonopguide.pdf

[42] Background paper: radio spectrum management for a converging world, ITU, 2004

[43] Directive 2002/20/EC of the European parliament and of the Council of 7 March 2002 on the authorisation of electronic communications networks and services(Authorisation Directive), European Commission, 2002

[44] We note there may be some uncertainty in adopting European spectrum policy once the UK has withdrawn from the EU.

coordination of radio spectrum policy approaches by facilitating harmonized conditions for the availability and efficient use of radio spectrum.

Authorisation is considered the process by which users gain access to the spectrum resource. This may involve assigning specific frequencies to users, allotting certain frequency bands or sub-bands to specific users who may or may not be able to transfer such spectrum rights to others or it may mean simply authorizing the use of specific equipment or categories of equipment.

"Spectrum Regulatory Authorities (SRAs) emphasised that General Authorisation is the default option for assigning frequencies to communication services. It is only under specific circumstances that Members States may find it necessary to make an exception to the general authorisation and grant individual exclusive licensing to certain bands". The exceptions to general authorisation include the following, as indicated within Authorisation Directive[43]:

- **Avoid harmful interference**
  For users and potential users of spectrum, it is important to know their rights and obligations with sufficient precision to allow them to make plans and avoid interfering with one another's activities. Except in the case of unlicensed spectrum, this is done at the stage of assignment of frequencies which thus becomes a key aspect of spectrum regulation especially if licences are granted for a long duration. This is particularly important when licensees transfer, lease or trade rights and the licensee is required to either seek approval from the regulator for the change or simply provide notice of the change.
- **Ensure technical quality of service**
  This criterion is considered based on the type of the application and corresponding characteristics. MNOs strongly favour exclusive licensing, as they recognise mobile spectrum as the key differentiator to serve their customers and a strategic asset of significant value and see it as commercially harmful to share it with others. Quality of service and high spectral efficiency are further arguments brought forward by MNOs to justify a continued need for exclusive individual licensing. As opposed to verticals that concur in their assessment that as long as the Quality of Service agreements, particularly in the transport and energy sectors can be guaranteed at all times, any approach to licensing is feasible.
- **Safeguard efficient use of spectrum**
  For efficient use of spectrum at the basic level, the fullest possible use of all available spectrum is encouraged. Exclusive use of spectrum should not lead to spectrum underutilisation at specific time and locations for any type of service. Some metrics of technical efficiency are needed to help regulators and users determine the degree of improvement in technical efficiency comprising spectrum utilisation/occupancy and data rate. Occupancy, for example, can be used as a measure of technical efficiency; in the sense of how constant or heavy the usage of spectrum is over time. Data rate means how much data and information can be transmitted for a given amount of spectrum capacity.
- **Fulfil other objectives of general interest as defined by Member States in conformity with Community law**
  It should be possible for exceptions to the principle of service neutrality which require the provision of a specific service to meet clearly defined general interest objectives such as safety of life, the need to promote social, regional and territorial cohesion, or the avoidance of inefficient use of spectrum to be permitted where necessary and proportionate.

A number of key recommendations related to spectrum authorisation are contained in the European Commission 2007 Review concerning spectrum management and these include:

- Increased Use of Market Mechanisms:
- Technology and Service Neutrality
- Freedom of choice
- Spectrum User Rights

5.1.4 European Commission study on Spectrum Assignment in the EU[45]:

A study conducted by LS telcom on behalf of the European Commission examined spectrum assignment in the EU.

This study considered individual exclusive licensing for mobile communication system namely 5G. Individual rights of use are often granted on an exclusive basis to users such as mobile operators. This is because spectrum in the lower frequency bands (e.g. sub-1 GHz) is limited (relative to frequency bands which have more available bandwidth) and exclusive access to specific frequencies ensures protection from interference.

There are other examples of network deployments using a range of different technologies where operators prefer individual rights of use for spectrum access. For example, frequencies are typically assigned to Fixed Wireless Access (FWA) network operators on an individual basis. This is to ensure protection from interference and coordination between many individual licensees. Similarly, private mobile radio systems require individual licences so that many different users can coexist in limited geographical area. Each service has a distinct set of technical and operational requirements and parameters that have historically led to a decision by SRAs to adopt individual rights of use instead of general authorisations. This is because these systems require protection from interference from other users.

5.1.5 Federal Communications Commission (FCC)[20], Spectrum Policy Task Force, 2002:

“Exclusive use” model is referred to as a licensing model in which a licensee has exclusive and transferable rights to the use of specified spectrum within a defined geographic area, with flexible use rights that are governed primarily by technical rules to protect spectrum users against interference. Under this model, exclusive rights resemble property rights in spectrum, but this model does not imply or require creation of “full” private property rights in spectrum.”

5.1.6 Radio Spectrum Policy Group (RSPG)[46]:

A report from the RSPG defines individual licensing where the spectrum manager issues a licence to an individual user for the use of a certain frequency band. The licence includes effective guarantees for protection of the licence holder (primary user) against potential harmful interference from other users.

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[45] Study on Spectrum Assignment in the EU, LS telcom on behalf of the European Commission, 2017 https://op.europa.eu/en/publication-detail/-/publication/2388b227-a978-11e7-837e-01aa75ed71a1/language-en

[46] Radio Spectrum Policy Group Report on Assignment and Pricing Methods, RSPG, 2009

The Radio Spectrum Policy Programme (RSPP) gives strategic policy objectives to ensure a more efficient usage of spectrum considering the needs and characteristics from various sectors. These include but not limited to; high emission power devices, technology and business environments that are not rapidly changing; service and technology dependent (e.g. mobile broadband requires access to specific bands such 2.1 GHz with favourable propagation properties), a large number of users in the same area is not possible without the need for coordination among the users.

5.1.7 Summary of authorisation frameworks

We found from our research that the various definitions of approaches to authorisation of spectrum from a range of national and international authorities are similar, this includes definitions of "exclusive" spectrum use. We observe from our findings that the fundamental reasons, criteria and conditions for justification of exclusive use of spectrum from the regulatory authorities within all licensing frameworks are almost identical, as follows:

- Where protection from harmful interference is strictly required;
- Where QoS provision to users is required to be assured for the application/use;
- Where full occupancy of spectrum is more likely and is necessary (to avoid spectrum underutilisation); and
- To retain certainty for investors in the competitive market, to deploy their network.

Moreover, there is a recognition from the regulatory authorities that spectrum scarcity is a serious issue that will negatively affect deployment of new technologies and within the UK licensing framework there is a keen need to explore other potential flexible spectrum licensing mechanisms, besides exclusive use of spectrum (unless necessary).

5.2 Annex B - Characteristics of flexibility of existing licensing frameworks

Ofcom has introduced mechanisms and regulations that offer degrees of flexibility within each licensing framework. In the table below, we summarise, for each type of authorisation mechanism, an initial consideration to support flexibility in the licensing framework.

Licensing framework	Characteristic that supports flexibility	Restrictions that may limit flexibility
Light-licensed	Trading	✓
	Leasing	✓ (but not for all services)
Ofcom band-managed (Technically assigned)	Trading	✓
	Leasing	✓ (but not for all services)
Block assigned	Trading	✓
	Leasing	X

Table 8: Flexibility of existing licensing framework

In the case of light-licensed and Ofcom managed, we consider there is a reasonable degree of flexibility based on the ability to trade and lease rights of the spectrum licence but not for all services. In the case of block assigned licences there is a slightly lower degree of flexibility due to the ability to simply trade the spectrum rights and cannot currently lease.

It is also noted that all spectrum licences are technology and service neutral which implicitly means that there is flexibility to use 'any' technology or service for the particular licence so long as the technical conditions and obligations are not unduly affected.

Holding a licence requires the user to ensure certain obligations and responsibilities are met and these are set out in the licence as part of the schedule section. The technical conditions and limits are particularly important as these set out the specific frequencies, bandwidths and powers which are permitted to be used by the licensee.

5.3 Annex C – Additional supporting evidence of demand

The following characteristics are used to justify exclusive use of spectrum from a regulatory perspective:

- Reduced risk from harmful interference;
- Assurance of access to all spectrum in all locations deliver certain quality of service levels; and
- Apecified coverage related criteria.

These characteristics ensure particular sectors (e.g. mobile and business radio) have the ability to deliver certain levels of service to their customers at certain locations. In particular, it enables these different sectors to provide added benefits on the basis these characteristics are supported. One key industry that benefits from these characteristics is the mobile sector. The mobile sector is important to the UK economy with one report for the UK Spectrum Policy Forum[47] estimating the value of spectrum use over a 10 year period (2012 – 2021) to be worth £273 billion. In addition, mobile operators are a significant user of spectrum with almost 1000 MHz of licensed spectrum held across all mobile operators in the UK as shown in the diagram below.

[47] Valuing the impact of spectrum use on the UK economy, Plum, March 2019, https://www.techuk.org/images/documents/March_2019_-_Valuing_the_impact_of_spectrum_use_on_the_UK_economy_-_UK_SPF.pdf

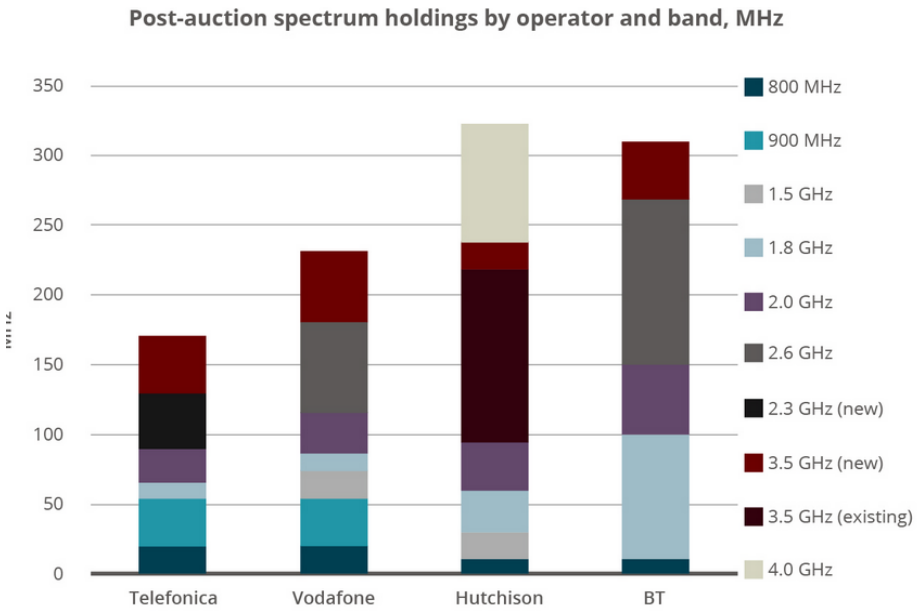

Figure 3: UK Mobile operator spectrum holdings. Source: Connectivity Business[48]

The other sectors, such as public safety, rail and utilities which also rely on exclusive access to spectrum are important from a mission critical or business operations point of view. This is because any reduction to the operational service caused by interference or reduced quality of service levels that are delivered from these private radio networks can cause:

- Safety of life implications
- Security concerns
- Impact on day to day society (i.e. blackout)

It can be argued that without exclusive access to spectrum the service levels required could not adequately be delivered.

5.4 Annex D - QCI code notes

The table below provides the Quality Channel Indicators used to be able to quantify traffic on a network and determine what services can be delivered under particular channel quality conditions. The QCI codes comprise the following.

QCI (see annex for notes)	Resource type	Priority	Packet delay budget (ms)	Packet error loss rate	Example services
1 (Note 3)	Guaranteed Bit Rate	2	100	10^{-2}	Conversational voice
2 (Note 3)		4	150	10^{-3}	Conversation voice (live

[48] Strong demand for UK spectrum auction highlight 5G strategic necessity, Connectivity Business 2019
https://www.connectivitybusiness.com/insights/strong-demand-uk-spectrum-auction-highlights-5g-strategic-necessity

	(GBR)				streaming)
3 (Note 3)		3	50	10^{-3}	Real-time gaming
4 (Note 3)		5	300	10^{-6}	Non-conversation video
5 (Note 3)	Non-GBR	1	100	10^{-6}	IMS signalling
6 (Note 4)		6	300	10^{-6}	Video, TCP-based (web, email)
7 (Note 3)		7	100	10^{-3}	Voice, video (live streaming)
8 (Note 5)		8	300	10^{-6}	Video TCP based
9 (Note 6)		9	300	10^{-6}	Video TCP based

Table 9: Standardized QCI characteristics" from 3GPP TS 23.203 version 8.6.0 – Table 6.1.7. Source: NGMN[49]

The above table is an example of how the mobile industry defines different types of traffic services that can be delivered. The key point in the table refers to the Guaranteed Bit Rate which means that in order to deliver the particular service the quality channel criteria must be met in order to deliver, for example voice, such that the bit rate must be guaranteed to do so. Exclusive access to spectrum, in part, has enabled the mobile industry to develop these types of traffic profiles and quality indicators.

The table below provides the notes associated with the Quality Control Codes in section 3.4.3.

Notes	Description
1	A delay of 20 ms for the delay between a PCEF and a radio base station should be subtracted from a given PDB to derive the packet delay budget that applies to the radio interface. This delay is the average between the case where the PCEF is located "close" to the radio base station (roughly 10 ms) and the case where the PCEF is located "far" from the radio base station, e.g. in case of roaming with home routed traffic (the one-way packet delay between Europe and the US west coast is roughly 50 ms). The average takes into account that roaming is a less typical scenario. It is expected that subtracting this average delay of 20 ms from a given PDB will lead to desired end-to-end performance in most typical cases. Also, note that the PDB defines an upper bound. Actual packet delays - in particular for GBR traffic - should typically be lower than the PDB specified for a QCI as long as the UE has sufficient radio channel quality
2	The rate of non congestion related packet losses that may occur between a radio base station and a PCEF should be regarded to be negligible. A PELR value specified for a standardized QCI therefore applies completely to the radio interface between a UE and radio base station
3	This QCI is typically associated with an operator controlled service, i.e., a service where the SDF aggregate's uplink / downlink packet filters are known at the point in time when the SDF aggregate is authorized. In case of E-UTRAN this is the point in time when a corresponding dedicated EPS bearer is established / modified.
4	If the network supports Multimedia Priority Services (MPS) then this QCI could be used for

[49] Integrated QoS Management, NGMN Alliance, December 2012

	the prioritisation of non-real-time data (i.e. most typically TCP-based services/applications) of MPS subscribers
5	This QCI could be used for a dedicated "premium bearer" (e.g. associated with premium content) for any subscriber / subscriber group. Also in this case, the SDF aggregate's uplink / downlink packet filters are known at the point in time when the SDF aggregate is authorized. Alternatively, this QCI could be used for the default bearer of a UE/PDN for "premium subscribers"
6	This QCI is typically used for the default bearer of a UE/PDN for non-privileged subscribers. Note that AMBR can be used as a "tool" to provide subscriber differentiation between subscriber groups connected to the same PDN with the same QCI on the default bearer

Table 10: Quality control codes for mobile networks

5.5 Annex E - Views from stakeholders

In discussion with a range of stakeholders with regards to the characteristics which justify exclusive use of spectrum, we summarise the views across a range of sectors including:

- Ofcom
- Mobile
- Media and broadcasting
- Satellite
- Transport
- Utilities

Ofcom provided us with feedback confirming that:

"when granting licences (including awards) is done on a non-exclusive basis and Ofcom retains the rights to authorise other users in that spectrum."

Although there are references to exclusive use of spectrum in many Ofcom documents, consultations and papers there is no specific definition of the term. This is open to interpretation by licensees who, for all intents and purposes believe their licences are exclusive in practice.

We consulted with a limited group of stakeholders on this issue to attain their viewpoints. The views from other stakeholders were mixed with the likes of transport and utilities concerned about ensuring their services were protected from interference given the critical nature of the services they provide. In particular, it is essential that no interference is caused to GSM-R networks which can have safety of life implications for the operation of the railways. Similarly, for utilities, network availability and reliability is essential for operations and therefore exclusive licences (and in future additional dedicated spectrum for future energy distribution) are needed to ensure a very high quality of service can be delivered. This perspective could readily be translated as exclusive use of spectrum in practice, such that Ofcom cannot and would not licence a secondary user on the grounds supplied by the primary licensee.

The mobile operators confirmed that exclusive licences provide significant reduction to the risk of harmful interference to the point where they can deploy networks with sufficient certainty and thus secure investments in infrastructure at a national scale.

In other sectors including broadcast and satellite, there was a view that there is either no exclusive access to spectrum or the concept is becoming outdated and instead quasi-exclusive approaches (such as hierarchy-based priority access between primary and secondary) should be more commonly used. This approach enables secondary users to gain access to the spectrum subject to interference to primary users with defined spectrum masks, and restrictions on duration of licence, power, height (of transmitter), polarisation, signalling and class of emission are imposed. PMSE as a secondary service utilises spectrum under this approach.

Thus some stakeholders were optimistic about spectrum sharing approaches such as temporal or spatial dynamic access, subject to risk assessment and clear statements of objectives.

More details of specific responses from stakeholders can be found in the annex.

5.5.1 Ofcom

Ofcom does not have a precise definition of exclusive use of spectrum and in fact they state that:

> "*when granting licences (including awards) on a non-exclusive basis and Ofcom retains the rights to authorise other users in that spectrum.*"

There are references to exclusive use of spectrum in many Ofcom documents, consultations and papers but no specific definition of the term.

5.5.2 Mobile sector

The term "exclusive basis" is considered as where rights (i.e. authorisation or licence) to use a given range of frequencies on a nationwide (or some other defined wide area) are held by a single party, as is currently the case for assignments held by UK national mobile network operators. Ofcom has noted that such licences do not guarantee future rights to exclusively use spectrum in all places, in the sense that Ofcom has the ability to issue additional licences in a given band/location. We would expect that in practice any such shared use would only be authorised if, amongst other things, Ofcom were satisfied that harmful interference will not occur.

5.5.3 Satellite sector

In the satellite sector, no one entity has exclusive use of the spectrum i.e. a particular quantity in a particular area. It is generally a matter of perception of exclusive use which means some spectrum is used by satellite and not by terrestrial services in UK, but even then it is not exclusive to a particular satellite operator Satellites themselves are not licensed in the UK but rather the earth stations/terminals that use satellite have licences or are licence exempt. For example, a ship or aircraft would have a radio licence that permits its use to connect to the satellite service. The licence is held by the ship or aircraft operator and is not an exclusive licence. The service itself can be provided by any of the satellite operators, Inmarsat, Iridium etc.

The ship or radio licence would determine what equipment should be used, the particular standard to be adhered to and technical conditions under which the licence has been issued.

Land mobile satellite terminals (such as ESIM and L-band MSS terminals) are exempt from individual licensing, and the exemption regulations allow the user to operate with any available satellite system provided that the terminal meets certain technical requirements.

One slightly different example is for S-Band (MSS) licences. This situation is unusual in that there has been a European selection process that chose one operator for each of two bands of 2 x 15 MHz. Under the European regulations, any alternative use of these bands can only be on a non-interfering non-protected basis. In the UK, there are Complimentary Ground Component (CGC) stations which are licensed to use the MSS 2 GHz band. These are issued on a per base stations basis and not explicitly limited to a particular operator. However, the scope for use by a user other than the MSS operator is severely limited by the requirement to not cause interference to the MSS/CGC service. Furthermore, end user devices are licence-exempt for use in the UK for S-Band MSS and not restricted to a particular operator.

Ofcom could authorise someone else in the S-Band so long as it is compatible with the conditions set out by the EU for CGC i.e. offers protection in line with the use designated for MSS and CGC, even though for technical reasons there is little scope for other uses. Media and telecommunications

For broadcasting services, the term “exclusive use” is said to be a rather outdated concept and is not used. Instead, quasi-exclusive approaches (hierarchy-based priorities of access, i.e. primary-secondary) are applied. This approach enables secondary users to gain access to the spectrum subject to interference to primary users with defined spectrum masks, and restrictions on duration of licence, power, height (of transmitter), polarisation, signalling and class of emission are imposed. PMSE as a secondary service utilises spectrum under this approach.

They are optimistic about spectrum sharing approaches such as temporal or spatial dynamic access, subject to risk assessment and clear statements of objectives.

5.5.4 **Business radio and critical services sector**

‘Exclusive’ use implies that the use of a given frequency band, in a given geographic area, over a given time period, is reserved for the exclusive use of a specified use / application. In practice, the frequency block allocated has to be governed by a percentage time and location availability; and the block has to be governed by the field strength of potentially interfering co-frequency signals for a percentage of time, and by a block edge mask for out-of-band emissions.

Thus the degree of ‘exclusivity’ of service depends on how often communication is likely to be successful / guaranteed and is as much a function of the characteristics of the network design as well as the spectrum deployed. This may vary from PMR assignments obtained from Ofcom which are designed to 50% of time and 50% of locations to 99.999% for carefully planned fixed links.

For example, in utility applications, the required availability (or exclusivity required) of the communication systems varies with the application, with 50% acceptable for meter data systems, to 90% for mobile, 99.9% for SCADA and fully redundant 99.999% available systems for high voltage transmission protection. In essence the critical operational telecoms capability needs to be as available as the energy system is resilient to power outage.

From a SCADA spectrum usage perspective the electricity and gas utilities have benefited from exclusive use of 48 x 12.5 kHz narrow band channels (450 – 470 MHz channels) to facilitate grid monitoring and control on a UK-wide basis. In this context a single 12.5 kHz narrow band channel enables system data exchanges utilising the full 9.6 Kbit/s across an individual service area of typical radius 30 km on a 24 x 7 x 365 basis which is repeated over the whole country as opposed to other communication systems which may have busy periods during the day and periods of little if any active as per mobile communications networks.

5.5.5 **Transport sector**

In transport, particularly rail, there is spectrum already assigned in the 876 – 880 MHz paired with 921 – 925 MHz for GSM-R which is exclusively used for rail purposes.

In future, it is expected this frequency range will be extended to include an additional 2 x 1.4 MHz for migration to the next generation technology known as Future Railway Mobile Communication System (FRMCS). It will be aggregated to create a total 2 x 5.4 MHz which can only be used for FRMCS exclusively.

The reason spectrum has been and will continue to be used exclusively for railway purposes is due to the safety critical nature of the services. A guarantee of no interference to the service means that the risk of impacting the operation of services is greatly reduced.

We were informed that in high density areas such as junctions and hub stations train signals can become congested and often causing connection failure, exclusive spectrum is needed to be able to manage these situations.

In terms of the potential for sharing spectrum used for safety critical services within railway one key point raised was that if these services stop the railway stops and if it is shared then the sharer would need to carry the liability for it. There is a low likelihood many sharers would be prepared to take on the liability.

In principle, the definition of exclusive use spectrum applies such that it should be ‘harmonised for the exclusive use by the railway’.