uk spectrum policy forum

Explanatory Guide on the Functional Specification for Dynamic Spectrum Access in shared UK mobile spectrum bands

A response to the question from DCMS on general opportunities for DSA spectrum sharing and contribution to Ofcom's initiative to draft a specification for DSA for use in shared mobile bands

December 2019

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1 Purpose

This is a functional specification for dynamic spectrum access (DSA) in mobile spectrum bands in the UK. It expresses the functional requirements for DSA which subsequent technical definition should meet in order to maximise the benefits of DSA for UK citizen-consumers and businesses via innovation on both business models and technology. The intended audience is DCMS and Ofcom. The goal has been to identify the extent of principles that need to be guiding Ofcom's DSA specification activity, their direction, the extent of industry consensus and, where consensus does not exist, help the policy makers understand the alternative views that will need to be reconciled (arbitrated upon) quickly if the work of drawing up a DSA specification is not to be impeded. Areas of disagreement are to be found in section 10 below and in annex 2 (single company positions). All form an integral part of this SPF response.

2 Principles

The principles of a functional specification for dynamic spectrum access (DSA) are set out in the companion document *"Functional Specification – Principles"*

3 Scope

Terms of reference of the *informal* small expert group

1. The group is constituted as a 'coalition of the willing' under the auspices of UK Spectrum Policy Forum Cluster 2. It is not intended to be a representational group, nor an advocacy group. It assumes that there are benefits and a will to implement DSA in the UK and proceeds on that assumption.
2. The core purpose is to create a strawman functional (not technical) specification setting out requirements and use cases for Dynamic Spectrum Access, for debate in SPF Cluster 2 leading to an industry proposal to DCMS, responsive to DCMS' priorities and provided to Ofcom as input to implementing their "Enabling opportunities for innovation" framework for mobile spectrum sharing.
3. The functional specification (FS) aims to:
   - Maximise benefits to citizen-consumers and businesses.
   - Enable innovation opportunities (technological approaches, use cases and business models).
   - Maximise spectrum efficiency, while managing risks of spectrum hoarding.
4. The FS shall be capable of rapid introduction to accelerate the associated benefits. Hence it should build on known approaches where possible with low technical and regulatory risk, avoiding the risks of attempting to create a UK-only ecosystem.
5. The FS shall define the challenge to the research community in terms of broad functionality/capability for the next generation of DSA a decade from now.
6. The FS shall maximise the opportunity for technology to increase spectrum efficiency while ensuring:
   - Appropriate protection of licensed/protected/incumbent users
   - Appropriate assurance of coexistence amongst sharing users

7. The members of the small informal expert group were Google, Commscope, DenseAir, Federated Wireless, Nominet, Rivada, and Wireless Infrastructure Group

***Principle 1**: UK-DSA shall[1] be designed to achieve the following benefits:*

a Support enhanced spectrum efficiency by granting access to spectrum where and when *it is available based on actual usage, whilst respecting the rights of priority assignments, and reusing spectrum in local areas small enough to efficiently reuse it.*

b Support a wide range of existing and new use cases and business models.

c Promote innovation to the benefit of UK citizen-consumers and industry.

d Accelerate and reduced the overheads from of the spectrum assignment process compared with manual assignment, minimising burdens and maximising scalability

d Greater visibility of spectrum availability and rapid access to spectrum.

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Aims

UK-DSA is designed to meet the aims of:

- The market expansion model set out by DCMS in its Future Telecoms Infrastructure Review[2]
- The opportunities for innovation set out in Ofcom's Statement[3]; and
- Ofcom's wider duties in respect of spectrum management, including for spectrum efficiency.

[1] The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119. These are case-insensitive.

[2] Department for Digital, Culture, Media & Sport, Future Telecoms Infrastructure Review, 23 July 2018.

[3] Ofcom Statement: "Enabling wireless innovation through local licensing: Shared access to spectrum supporting mobile technology" 25th July 2019.

Scope - Spectrum Bands

> ***Principle 2:*** *UK-DSA shall be suitable for application to all mobile spectrum* bands nominated *for shared use by Ofcom, including but not limited to 3.8-4.2 GHz, 1781.7-1785 MHz paired with 1876.7-1880 MHz, 2390-2400 MHz, 8 GHz (168 MHz of spectrum between 7.9 GHz and 8.4 GHz), 24.25 GHz to 26.5 GHz.*

The proposed DSA approach ("UK-DSA") shall be applicable to all spectrum bands supporting mobile technology which are made available for shared licenses under Ofcom's "Enabling opportunities for innovation" framework, including currently:

In scope: The bands defined for shared access in Ofcom's December '18 consultation[4]:

- 3.8-4.2 GHz (within 3GPP 5G NR band n77, which spans 3300 – 3800 MHz)
  - Currently used by satellite Earth stations, point-to-point fixed links and FWA by UK Broadband (now Hutchison 3G UK Limited)
  - Suitable use cases[5]: private networks and IoT.
- The 1800 MHz shared spectrum: 3.3 MHz of paired spectrum (uplink 1781.7-1785 MHz, downlink 1876.7-1880 MHz - part of the 3GPP band 3)
  - Currently authorised to 12 Concurrent Spectrum Access (CSA) licensees on a shared basis through an award process.
  - Suitable use cases: voice, text and low data rate applications.
- The 2300 MHz shared spectrum: 10 MHz of spectrum (2390-2400 MHz; part of the 3GPP band 40)
  - Currently used by MOD
  - Suitable use cases: voice, text and low/moderate data rate applications

In scope: The bands added in Ofcom's June '19 update[6]:

- 8 GHz: 168MHz of spectrum between 7.9 GHz and 8.4 GHz
  Suitable use cases: FWA and indoor applications
- 26 GHz: 2.25 GHz of spectrum from 24.25 GHz to 26.5 GHz "to support 5G indoor applications"

While other mobile bands are not specifically considered here, it is intended that UK-DSA should be suitable for adaption to other bands over time.

Out of scope: Bands for which national mobile licences have been awarded.

Scope - Use Cases

> ***Principle 4****: UK-DSA shall have a common approach across all bands, but* with parameters *and rules configured appropriately for the requirements of each band and supporting* the *needs of a wide range of use cases.*

The DSA approach shall enable all plausible use cases for deployment but should exploit

[4] Ofcom Consultation: Enabling opportunities for innovation, 18/12/18
[5] The use cases identified in this section are intended to be exemplary, not restrictive. The UK-DSA process shall be technology and use case neutral.
[6] Ofcom update 5/6/19

simplifications where applicable. Relevant deployment use cases include, but are not limited to:
Indoor deployment

- Outdoor deployment
- Rural deployment (including scope to facilitate shared rural deployments)
- Urban deployment
- Mobile access
- Fixed wireless access
- Both public and private access systems
- Operator deployment - both for public mobile services and for private services.
- Neutral host deployment - both for public mobile services and for private services (see annex for further discussion of this use case).
- Human and machine type communications, including factory industrial automation - low risk of excess demand
- Railway communications, e.g. dynamic backhaul for trains.

4 Terminology

DSA and UK-DSA

- Ofcom's definition of DSA[7] is as follows:

DSA	Dynamic Spectrum Access. This is a technology for a variety of reconfigurable radio equipment allowing it to select the frequency on which it will operate at a given location and over a given period of time to optimise the use of available spectrum and avoid interference with other radios or other systems.

This specification distinguishes:

- "DSA" – a general term for dynamic spectrum access, consistent with Ofcom's definition.

[7] Ref: Ofcom Consultation, Enabling opportunities for innovation", 18/12/18.

- "UK-DSA" - the form of DSA suitable for UK mobile spectrum bands in scope, meeting the requirements set out in this specification.

UK-DSA has the following attributes beyond Ofcom's definition of DSA:

- The essential characteristic of UK-DSA is that it be fully automated, i.e. with no human intervention in the process from equipment requesting a spectrum grant to that grant being assessed and issued if approved.
- 'Dynamic' does not imply a particular timescale for the duration of grants. The appropriate timescale is use-case dependent, and may be anywhere from minutes to years.

Grant
A grant under UK-DSA is simply a licence, issued automatically by an approved Spectrum SharingSystem.

Priority Grant
A priority grant is a class of UK-DSA grant with rights to operate subject to specified grant conditions which take priority over opportunistic grants.

Opportunistic Grant
An opportunistic grant is a class of UK-DSA grant with rights to operate subject to specified grantconditions which take lower priority than priority grants. If a contending priority grant notifies an SSS of intended operation, opportunistic grants will be issued with revocation notices with which they shall comply.

Spectrum Sharing System (SSS)
A Spectrum Sharing System (SSS) is an automated system for issuing grants to devices, complying with contention rules set by Ofcom based on a record of existing licences and existing grants in a database, which it builds in communication with other SSSs.

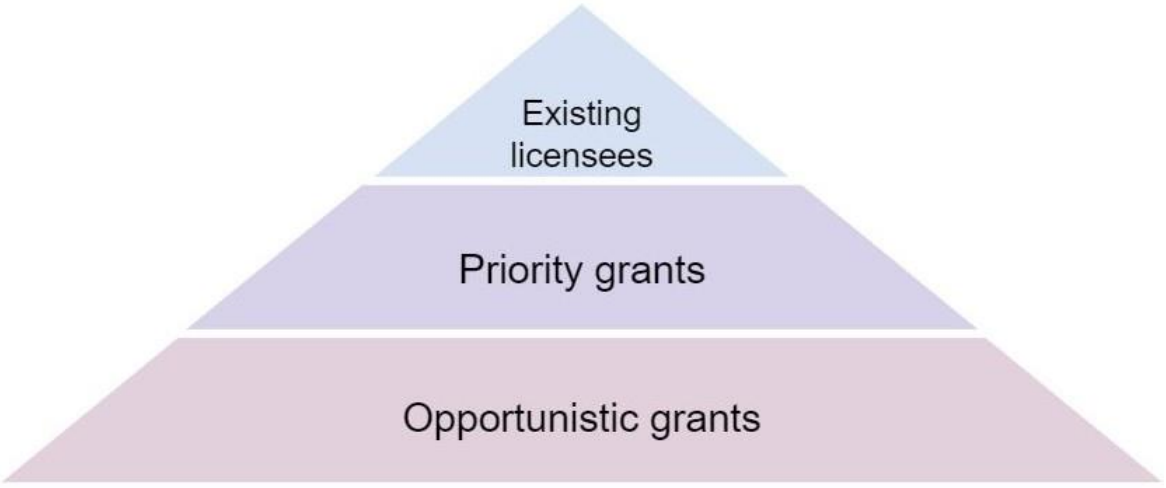
Primary device
A device which directly communicates with an SSS for the purpose of obtaining and maintaining grants, both for itself to transmit in a given band and location and (optionally) on behalf of secondary devices.

Secondary device
A device which obtains grants for itself to transmit via a primary device, rather than directly with an SSS. All grants shall nevertheless always require issue by an SSS.

5 Operation of UK-DSA

Tiered licensing

Principle 8: There are two types of grants (in addition to existing protected licensees), priority *grants* and *opportunistic grants*, both managed by the SSS . Some bands and areas may implement only one of these types, others may use both. In addition, the option to request a short-term priority licence could be considered, similarly to the provision of paragraph 5.10 of Ofcom's Shared Access Licence Guidance Document



There are three tiers of usage in the shared mobile bands:

- Existing licensees, who have previously been granted protection from other users:
  - Users with conventional (not UK-DSA) licences
  - Users with Recognised Spectrum Access.
- Priority grants:
  - Users holding licences issued as UK-DSA priority grants.
  - Holders of administratively-issued shared access licences - which will be transferred into UK-DSA grants.
  - Priority grants may be issued for periods as long as years, providing investment certainty.
  - Holders of priority grants are assured access to the spectrum granted, subject to it not being used by the existing licensees, following a specified notice period.
  - Devices using priority grants must regularly indicate usage to the UK-DSA database.
- Opportunistic grants:
  - Users holding licences issued as UK-DSA opportunistic grants.
  - Provide scope for rapid access to spectrum.
  - Grants may be revoked when a holder of an overlapping priority grant gives notice of intended use.

All tiers are optional, depending on the circumstances for each band. Some bands (or sub-bands) may have no existing licences, so only priority and opportunistic grants are relevant. Some bands may support only opportunistic access. Some bands or areas may support only priority grants.

All grants and existing licences shall be logged in an approved SSS.

> ***Principle 9:*** *UK-DSA shall adopt a "use it or share it" approach. Devices shall* regularly report *whether they are actually transmitting or about to transmit according to a grant. Even when a priority grant has been made, other devices can request and be* granted opportunistic access *until and unless the existing priority granted user notifies their use of the band.*

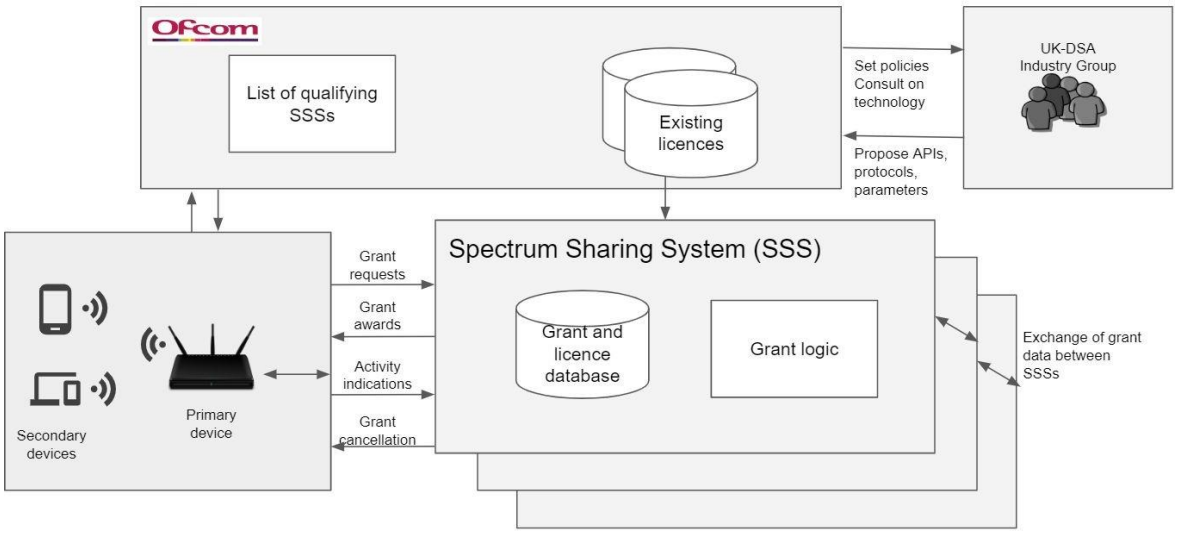
Ofcom considers that the DSA conditions should act to mitigate risks of spectrum hoarding[8]. UK-DSA can mitigate this by adopting a "use it or share it" approach, where priority grants only prevent the issue of opportunistic grants when they are actually in use, or shortly before use according to a specified notification period.

Overall architecture

> ***Principle 5:*** *UK-DSA shall be fully automated, capable of providing spectrum* access grants *(i.e. automatically issued licences) to equipment on request, subject to appropriate rules, without human intervention. Grants are provided by Spectrum Sharing Systems (SSS) which combine a database of existing and proposed grants and other band users with associated grant logic. No requirement for spectrum sensing inputs to SSSs is foreseen (noting devices shall regularly report their transmissions - see Principle 9).*

The architecture of UK-DSA operation is illustrated below.

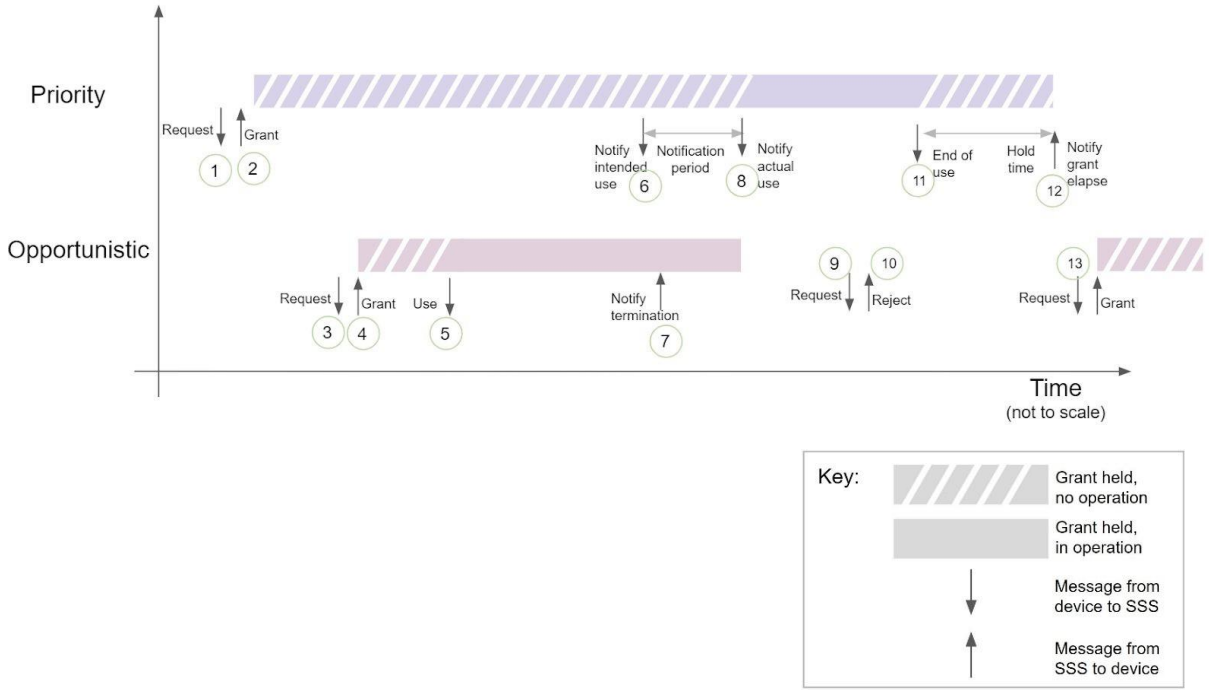
[8] Statement §5.47: "*We do not consider it necessary to set different fees based on bandwidth,* given the amount of *spectrum available in the 26 GHz band and the low risk of interference. We consider it sufficient to rely upon the DSA conditions to mitigate any risk of hoarding* for the 26 *GHz band."*



Spectrum Sharing Systems (SSS) are responsible for issuing grants on request to devices requesting them, in accordance with grant logic set by Ofcom, and respecting existing licences notified and updated by Ofcom.

Example of UK-DSA operation

The following is a purely illustrative example of a particular scenario. It does not give all details of the messages exchanged between devices and SSSs[9].



The following explanation refers to the numbers in the diagram above, e.g. (1).

1. A device sends a priority grant request to an SSS, specifying the required location, technicalcharacteristics and duration.
2. The SSS determines that there are no existing grants which contend with the grant request, so the grant is issued, specifying the conditions and duration of the grant. From that point, for the duration of the grant, the device has the right to operate compliant with the specified parameters. At this point the device does not start to operate, and indeed may not yet be installed in its eventual location.
3. A second device, requiring only opportunistic access but in the same location and band as the priority grant, sends a grant request to the SSS.
4. The SSS determines that the opportunistic grant would conflict with the already-issued priority grant. However, the priority licensee has not yet commenced operation, so the opportunistic grant is issued. This shows “use it or share it” in operation in respect of the priority licensee.
5. Some time later, the opportunistic device commences operation, and notifies the SSS.
6. The priority licensee has now installed a device in its intended location and issues a notification to the SSS that it intends to commence operation under the terms of the grant issued at (2). This notification initiates a timer for a notification period which was specified when the priority grant was issued.
8. Within the notification period, the SSS notifies the opportunistic licensee that the grant issued at (4) has been terminated and that the device must cease operation within the

[9] In particular, messages between devices and SSSs would likely be acknowledged. Similarly device operation would likely be regularly notified, not just at the start and end of a transmission. These detailed protocol details are a matter for the technical group, but do not affect the principles conveyed in this example.

notification period. This shows that the priority licensee has an expectation of access to the spectrum whenever required within their licence term.

9. The priority device notifies the SSS that usage has commenced.
10. The opportunistic device issues a grant request. However, the request is overlapping with the priority access.
11. The SSS denies the opportunistic request, thereby protecting the priority licensee.
12. The priority device notifies the SSS that its use has ceased. It may recommence operation any time within a "hold time", specified in the original grant notice, while retaining the right to operate. For example, Ofcom has proposed a 6-month requirement for shared access licences to be used. Under UK-DSA Ofcom would have the flexibility to retain this 6-month period or to vary it over time in the light of experience.
13. At the end of the hold time, the priority licensee is informed that the grant has elapsed (optionally, the grant may be converted into an opportunistic grant at this point, giving the licensee the option to restart operation in the future).
14. After the hold time has elapsed, the opportunistic device again issues a grant request. This time the request is granted, as there is no longer contention.

Roles of Ofcom and UK-DSA Industry Group

Principle 18: *The UK-DSA industry group:*

- *a. Shall be independently chaired.*
- *b. Shall be constituted of industry representatives (including SSS* providers) and *an Ofcom observer.*
- *c. Shall set the technical standards for UK-DSA operation compliant with* the *functional*, *service and contention requirements set by Ofcom.*
- *d. Shall remain active through the lifetime of UK-DSA.*
- *e. Shall be consulted by Ofcom when considering changes to* the requirements of U*K-DSA.*
- *f. Shall coordinate the introduction of technical standards into the* market (e.g. GSM MoU-type initiatives).
- *g. Shall liaise with relevant international bodies to further promote economies of scale.*

The UK-DSA industry group provides Ofcom with an important market voice, ensuring the UK-DSA is operated efficiently and in accordance with evolving technical requirements, standards and best-practice.

Principle 14: *Ofcom shall retain the rights to monitor and enforce the appropriate* use of the *spectrum, consistent with their duties and to minimise the impacts of* fragmentation effects *on users.*

Although the UK-DSA industry group plays an important role in the set-up and evolution of the UK-DSA framework, the role of the industry group does not change Ofcom's overarching duties and ability to oversee the spectrum.

Principle 15: *Where necessary for resolving excess demand, SSSs shall share sufficient grant data for the purpose*

It is expected that SSSs will normally share grant data, enabling the calculation of aggregate interference and enabling contention amongst grant requests to be resolved. However:

Grant data shall be shared in accordance with relevant data privacy and security requirements. There could be applications of UK-DSA to bands an environment where the interference risk is low and devices have their own interference-mitigation techniques. In such cases there may be cases where sharing grants is not necessary (especially where priority grants are not applicable in a given band).

Standardised interfaces

> ***Principle 7:*** *SSSs shall communicate with devices requesting grants via* a standardised API, *which shall reuse existing international protocols, with simplifications where possible, to promote and leverage an international ecosystem for DSA. Ofcom should set* the requirements of *these protocols, but the technical requirements should be set by the UK-DSA industry group. Technical implementation is not prescribed, and is a* matter for SSS *providers.*

- The interfaces between SSSs and devices shall use existing standardised interfaces and protocols for device-database and database-database communication, with simplifications where feasible.
    - Justification: Standardised interfaces and protocols already exists and are implemented by manufacturers, so the UK benefits from an existing ecosystem.
- SSS providers shall be required to ensure protection of users at the protection levels consistent with their licences. However the calculation methods shall not be specified by Ofcom.
    - Justification: Enable technical innovation to improve spectrum efficiency over time allowing the market to determine the level of efficiency based on market demand
- Communication of grants between SSS providers is not mandated but is allowed - there are market incentives to do so provided Ofcom specifies that spectrum efficiency is a requirement of the operation of SSSs.
- Ofcom retains the *ex post* ability to review the database market to ensure it is working well.

No spectrum sensing requirement

- Some DSA schemes involve the use of spectrum sensing. Motivations for spectrum sensing may include:
    - The characteristics of existing users are unknown for security reasons
    - Some users are licence-exempt and logging is not required.
    - Some users are unable to access a database, or real-time database connectivity would impose unnecessary cost or delay.
- UK-DSA does not however, use spectrum sensing. Justification:

- While spectrum sensing has a role in some DSA schemes, it introduces risks (e.g. hidden node problems) and implementation complexity.
- UK-DSA requires that all band users are logged in an approved database, removing one motivation for sensing.
- UK-DSA has a class of pre-approved grants, which may be used to avoid real-time database access and provide immediate service.

5 SSS Implementation considerations

UK-DSA supports various implementation options such as:

- Database on public cloud
- Database on private cloud
- Database on device

The SSS provider may select any implementation, provided that the implementation complies with the requirements set by Ofcom.

> ***Principle 16:*** *SSSs shall adopt and implement appropriate data security, integrity* and privacy measures as specified by Ofcom and the UK-DSA industry group.

SSS implementations shall support the relevant security and other requirements independent of its architecture.

7 Grant conditions

Duration

> ***Principle 10****: Longer-term priority grants shall be of sufficient duration to promote investment certainty* while maximising spectrum efficiency*. The appropriate duration will vary with band and use case. Longer-term grants may incorporate a shorter period within which the grant should be used, or may be revoked if not used.*

While UK-DSA provides dynamic, automated access to spectrum, this does not imply that spectrum access is uncertain or short-lived. To promote investment certainty, priority grants should have duration long enough to promote a wide range of use cases applicable to a particular band, potentially as long as years. The duration must cover the expected life cycle of deployment to ensure service continuity, particularly of mission critical applications. Ofcom's "in perpetuity" licence approach offers a model.

One consideration on the grant duration is the need to avoid overheads of radios being connected continuously to databases. Setting the grant duration as long as possible and applying proxies which pass on grants to subsidiary devices should avoid this.

Ofcom has proposed[10] a requirement for usage within six months of issuing a shared access licence in order to retain it. Under UK-DSA given the tiered structure proposed this could be maintained, or adjusted over time in the light of experience.

Grant technical conditions

Principle 12: Grants shall specify the technical conditions of the grant (power, bandwidth, duration etc) so as to protect existing licensed users and other grants as appropriate. Grants may change over time to accommodate additional users or changes in conditions specified by Ofcom. Devices are required to comply with grants as issued, amended and revoked.

- Grants provide permission to transmit with specified technical characteristics, such as:
  - Radiated power [dBm]
  - Directions, beamwidths and off-beam characteristics of antennas.
  - In-band power emission mask [dBm/Hz]
  - Out-of-band power emission mask [dBm/Hz]
  - Duty cycle (TDD uplink/downlink configuration)
  - Duration
  - Location area
  - Transmit antenna height [m AGL/ASL]
  - Indoor or outdoor deployment
- Grants allow transmission while minimising risk of interference towards non-DSA services
- Grants may:
  - provide protection from interference from other grants; or
  - provide implicit assurance of protection from interference based on the grant assignment process.
- There are multiple classes of grant, relating to differing technical characteristics. A grant request shall specify the class of grant required.

[10] Ofcom Statement §1.9.

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Access to bandwidth: contention for spectrum

> ***Principle 11:*** *UK-DSA shall implement contention rules, set by Ofcom, to resolve* cases of excess *demand, striking a balance between incentivising deployment and avoiding hoarding. Contention rules shall adopt the following generic scheme:*
>
> *a* *The first devices to request a grant in a given area and band will be able* to use *the whole of the band (or the maximum bandwidth requested) in that area.*
>
> *b* *Subsequent requests will be granted up to some maximum to* avoid oversubscribing*the band. Existing users may be required to reduce their bandwidth (or may not depending on the conditions for that band) to accommodate new granted users, subject to a minimum bandwidth (or number of users) appropriate to the band.*
>
> *c* *Additional requests once the appropriate maximum has been* reached will still*be granted if existing grants are not being actively used,* but as opportunistic grant*s. Once priority grants become active, contending opportunistic grants will be revoked.*

This section considers the rules for assigning bandwidth when there is excess demand, i.e. where there are grant requests which total more than the available spectrum in a given location. These rules impact on the incentives for deployment, the support for various business plans, and the fairness of the assignments. Ofcom identifies that these conditions should provide safeguards to mitigate hoarding risks[12].

When devices use DSA to access spectrum it is clear that they must not interfere with any primaryusers. Less clear is whether they should be allowed to interfere with each other. Some approaches, such as TV white space, allow an unlimited number of devices to access the spectrum, leaving it to the devices to handle any interference. This is also how licence exempt spectrum is typically configured, for example the 5GHz band used for Wi-Fi. Other approaches, such as the PAL licenses in CBRS, provide for protection from interference from other DSA users (but not from the primary user).

There are arguments for both approaches. There will be some bands where it is better not to offer protection and other bands where protection is beneficial. Hence, the optimal approach

[12] Statement §5.47: "*We do not consider it necessary to set different fees based on bandwidth,* given the amount *of spectrum available in the 26 GHz band and the low risk of interference. We consider it sufficient to rely upon the DSA conditions to mitigate any risk of hoarding for the 26 GHz band."*

will be selected on a band-by-band basis, typically by the regulator. It is likely that this decision will be made on the basis of:

1) Whether there will be excess demand for the spectrum. Where there is not excess demand, for example in rural areas or in bands with significant bandwidth, then there is no need to offer protection to DSA users.
2) Whether there is likely to be a service deployed that requires substantial investment, for example in multiple base stations. Where this is the case, then some certainty of prolonged access to spectrum free of harmful interference may be needed to reduce the risk of deployment.

In the case that there is no protection then DSA assignments can be readily provided across multiple uncoordinated databases.

In the case that there is protection then this implies that if there are multiple databases available to provide the same service, then they need to coordinate with each other. This specification does not set out the mechanism by which this should happen. Database providers seeking certification for their operation in bands where protection is to be provided will need to show how they will inter-operate in order to deliver the scheme set out by the regulator.

Where protection is to be provided this implies that there may be a need to turn away some requests. With conventional spectrum management, this is typically done through an auction, where those not willing to pay a sufficient fee do not gain access to spectrum.
However, auctions are complex to arrange and are one-time events where those who subsequently want access cannot partake. Auctions generally do not align well with the aims and benefits of DSA.

If an auction is not used, then there needs to be some mechanism to prevent abuse of the system. For example, a company might request multiple grants with no intention of actually using them in order to block others from doing so. Alternatively, applicants might request more spectrum than they need because there is no penalty in doing so.

Multiple alternative approaches could be envisaged to deciding who gains access to spectrum.

Our preferred approach is as follows.

The first devices to request a grant in a given area and band will be able to use the whole of theband (or the maximum bandwidth requested) in that area. This ensures that where there is little demand, there are few restrictions on usage. For purely an illustrative example, the 3.8-4.2 GHz band might be divided into four 100 MHz wide blocks and the first user can use all four blocks. If subsequent requests are made, they will be granted a block of 100 MHz and so on up to some maximum, in this example, four. The maximum number will be set by Ofcom to ensure all those who are granted requests have sufficient spectrum to provide a viable service. Existing users may be required to reduce their bandwidth (in the example given, reducing the number of channels being used from 4 to 1,2 or 3) to accommodate the new granted users as needed. But they would never be asked to reduce the bandwidth below some minimum or anchor value. (in the example 100 MHz). This ensures that one user cannot monopolise a band but that there is absolute certainty of continued operation on the minimum or anchor bandwidth for those early into the band, regardless of the level of demand. The actual numbers used in a data base system can, of course, be far more granular than the numbers quoted in the illustrative example

However, this approach does not prevent multiple users applying, few of whom intend to actually use the spectrum. To overcome this, once the appropriate maximum has been reached additional requests will still be granted if existing grants are not being actively used, but they will be granted as opportunistic grants. User's equipment will be required to periodically

send information on their usage of the band so that the SSSs are aware of which grants are actually in use. Once priority grants become active, contending opportunistic grants will be revoked. If priority grants remain unused for aprolonged period (e.g. a year) then they will be revoked.

This approach strikes a good balance between curtailing abuse, allowing access to all the spectrum and allowing a fair degree of certainty of tenure at an assured quality of service. Deploying opportunistic bandwidth can meet the needs of short duration events and for longer term services will facilitates lower congestion in busy periods, higher quality of service and lower latency. It maximises spectrum efficiency. It does no harm.

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8 Timescales for UK-DSA introduction

Principle 2: *To maximise these benefits, UK-DSA shall be introduced as rapidly and* as widely as *practically possible. The introduction should not be predicated on the level of demand observed for administratively-issued licences.*

- Ofcom has indicated[11] that it prefers to transition towards dynamic spectrum access after initially introducing shared access licences via administrative allocation.
- DSA introduction should be as early as possible, and should not be predicated on the demand for administrative assignment.
    - Justification:
        - Significant use cases require rapid, low cost spectrum access which is not supported by administrative assignment, so the demand for administrative assignment is a poor indication of the overall demand.
        - To the extent that DSA brings spectrum efficiency gains, these should be implemented as soon as feasible, consistent with Ofcom's duties.
        - The demand and supply arrangement are inextricably linked - the innovative approach to supply of spectrum licences is expected to stimulate innovative usage.
- Specification of the business requirements and technical specification for DSA should proceed in parallel with the introduction of administrative allocation.

Principle 13: *Once UK-DSA is introduced in a band, existing administratively* issued shared*access licences shall be recognised by SSSs and administered as DSA grants.*

[11] Ofcom Statement §1.25.

- Once UK-DSA is ready to operate, all existing administratively issued shared access licences shall be replaced with DSA grants, with closely equivalent conditions. This is necessary to ensure the efficient and consistent operation of UK-DSA.

- An example timetable is as follows:
  Q3'19: 25th July 2019: Ofcom publishes Statement.
  Q4'19:
    - Draft functional specification issued (this document).
    - Ofcom introduces administrative assignment of shared access licences.
    - Functional specification approved by UK SPF WG2.
    - Technical specification commences.
    - Demonstrator system created.

  Q1'20:
    - Technical specification v1 approved.
    - Demonstrator system implements v1 tech spec.
    - Regulatory implementation (e.g. condoc)

  Q2'20:
    - Regulations in place.

  Q3'20
    - DSA operation commences.

9 Band-specific Considerations

This section contains considerations regarding the application of UK-DSA to specific bands.

<u>26 GHz</u>

Spectrum Policy Forum has published seven principles for the release of 26 GHz in a shared fashion[12], leading to differing approaches to allocating and assigning spectrum in different areas of the country determined by foreseen levels of traffic density.

These principles for 26 GHz are consistent and compatible with the principles of UK-DSA. UK-DSA shall support these, including:

1) To provide priority (on a first come first served basis) or opportunistic (club spectrum) grants to any users requesting access to 26.5-27.5 GHz in less dense traffic areas.
2) To provide priority or opportunistic grants to any users in the 24.25 - 26.5 GHz range for 5G indoor applications while providing the relevant coordination with incumbent users.

[12] Ofcom Statement §1.25.

10 Areas of industry divergence for DCMS and Ofcom to settle

Issue 1 - Multiple Spectrum Sharing Systems

Principle 6x: *To promote rapid innovation and enhance efficiency over time, multiple* SSSs shall be *permitted. Ofcom, in consultation with the UK-DSA industry group, shall set* the functional r*equirements and service levels of SSSs and approve and monitor SSS providers for compliance with the requirements. To avoid disincentivising the emergence of commercial providers, Ofcom should not operate an SSS itself. SSS requirements* shall be *common across bands wherever possible, reducing the cost of compliance.*

- DSA implies the use of databases to log and track grants, plus associated logic to assess the compatibility of grants against the rights of existing licensees and grant holders.
- The combination of a database and associated grant logic is here termed a Spectrum SharingSystem, SSS.
- Most requirements for SSSs shall be consistent across bands, and the certification process should cover all core requirements. SSS providers may apply for certification in as many or as few bands as they desire, and shall be required to meet
- band-specific requirements only in the applied-for bands.
- Justification: By minimising the overhead of supporting multiple bands, the opportunity for SSS providers is maximised.
- While all spectrum access in a given band should be logged in a SSS, this need not imply a single database. SSSs may be distributed and share data.
- SSS providers shall be approved by Ofcom.
- SSSs shall not be operated by Ofcom, but by multiple 3rd party providers.

Justification: Enable technical innovation to improve spectrum efficiency over time.

Principle 6y: A single SSS operated by Ofcom (or on Ofcom's behalf), would benefit from economies of scale to achieve low cost-based fees and would be compatible with Ofcom's unique duty to grant licences. It would avoid unnecessary complexity of multiple SSS systems that would implement the same rules but would need to exchange latest assignment data with each other.

The DSA operation should be a function of Ofcom and not commercial Spectrum Sharing System (SSS) providers. This does not preclude Ofcom from contracting-out to private companies the building of a Spectrum Sharing System and running it under contract from Ofcom.

Justification: Spectrum is a public asset and administration has been delegated by the State to be a function of Ofcom; there would need to be a justification for control of such an asset to be ceded to a competitive third party, e.g. that choice of SSS on a per-application basis yields a benefit that justifies the complexity of multiple SSSs. Other reasons include scale economies,

avoiding the need for relatively sensitive data having to be shared between different Spectrum Sharing Providers to avoid radio interference and a greater assurance of cost-based pricing.

> ***Principle 6z:*** To provide service and cost based pricing certainty there should be an SSS run by Ofcom offering a basic DSA service at a price to cover administrative costs but with an open API to their data base that allows other SSS's to enter the DSA market with offering differentiated through their innovations and/or quality of service.

Justification: To ensure a basic DSA offer at a price related to covering administrative cost but providing the freedom for private DSA providers to enter the market with innovative offers or ones more tailored to specific operational needs.

Observation: The issue hinges on the confidence that an effective competitive market in "DSA operation" can be established for an embryonic spectrum sharing market that will start in non-mainstream mobile bands.

Issue 2 - Grant Fees

> ***Principle 17x:*** *Fees charged for administering grants are a commercial matter for the* SSS providers, not *set by Ofcom. Ofcom retains its role as a competition authority to ensure the market is functioning appropriately.*

Justification - UK-DSA is likely to be more efficient than administrative assignment of local access licences, enabling a wide range of charging options

> ***Principle 17y*** Fees charged by Ofcom for administering grants shall be set to cover the costs involved. Were multiple SSS's to be the preferred policy route and a fully competitive market does not result, or where the SSS provider has not paid to acquire rights over the spectrum and the opportunity cost of the assignments is in aggregate substantial, then Ofcom should regulate the prices to avoid windfall gains and to ensure that the cost of grants does not become a barrier to access shared spectrum

Justification: To avoid windfall gains and to ensure that the cost of grants does not become a barrier to access shared spectrum, particularly to those extending coverage in areas of the country (or within buildings) of marginal viability. The very significant change in the price of spectrum from DSA spectrum sharing may well have unintended consequences. This is a further reason for Ofcom to administer the grants, as it can make policy fine-tuning adjustments to maintain the intended policy trajectory.

11 Other issues that are valuable to note

- It is not clear that there is a legal basis for an entity other than Ofcom to issue or control spectrum licencing. This is currently a statutory power of Ofcom. There may be

workaround such as approved SSS providers acting as Ofcom's agent, or, if not, primary legislation would be needed.

- There are some terms such as "Dynamic Spectrum Access" and "Grants" that have a different meaning in another context. There could be merit in Ofcom reviewing the best terminology with the industry it involves in its DSA specification writing.
- A need to communicate with Ofcom's spectrum authorisation database that materially impact the technical radio requirements of licensed equipment needs to be done in a way that does not cut the UK off from the benefit from global economies of scale of the radio equipment.

- Whilst the scope of the report is limited to the mobile bands identified by Ofcom for shared use, it would be useful for any SSS not to be precluded from providing data base spectrum sharing services in other service sharing scenarios

- Whilst technical issues are out of scope of this functional specification, there are some "technical principles" that qualify to be included in this functional specification:

    - The technical specification activity needs to be open to finding optimal "local" solutions as this can make a real difference to the sharing capacity of the bands. A fully centralised approach, lacking knowledge of the topology, building data, attenuation in walls and how this varies over time as well as door openings, antenna patterns, position relative to windows etc., will result in excessive safety margins reducing sharing opportunities. The way technical specifications are applied needs to allow for local agreements.
    - This might take the form of power levels not to be exceeded at a common border in much the same way that "setting maximum interference level at the border" is a well-established approach for the management of spectrum between nation states. This again can enhance both the spectrum sharing capacity as well as quality of service. (Note: Local flexibility will need to be handleable in the DSA automation).

- Ofcom must always govern directly the protection of incumbent services and this must allow for future changes in their characteristics

Annex 1 – Process and list of entities that have taken part in this work

Process

The work of Cluster 2 is to respond to questions on spectrum sharing put to it by DCMS. They are turned into projects with a deliverable. An acknowledged thought leader in the field is invited to form a sub-group of experts sharing the same goals. The group needs to be small enough to be creative and able to draft together a high quality output. In this case the question from DCMS were the general opportunities from DSA in shared bands. Prof Simon Saunders (Google) was a widely acknowledge thought-leader invited to lead this small informal team.

The output of the small informal group is presented as a "strawman" to an open meeting of Cluster 2. Other companies and individuals can also make written contributions and given co-equal status as input documents. The Cluster 2 meeting on 13th November had over 40 attendees. The short document from the small informal group listing the 18 proposed principles and two documents from members were given co-equal status and debated at the open meeting. The companion explanatory document from the informal small group was put out for consultation with a 2nd December deadline for comment. At the conclusion of the open meeting the Chairman of Cluster 2 assumed editorial responsibility for drawing up the final documents. He has taken into account the balance of the debate at the open Cluster 2 meeting and any subsequent written comments. There were written comments received by Ericsson, Huawei, Nokia and Vodafone. The Steering Board is responsible for the overall integrity of the process and final sign-off.

Subsequent Written Comments

The following guideline was agreed at the Cluster 2 meeting for the handling of subsequent written comments:

- Editorial responsibility will pass to the Cluster 2 Chairman, who will make "best effort" to accommodate drafting change proposals (but not more than that)
- The Explanatory Note will go out for comment with deadline December 2nd
- Comment will be accepted from those not able to attend the Cluster 2 meeting (same deadline)
- Comments of substance must be in-scope, specific and include alternative texts for both documents
- Substantive changes supported by two or more companies will go into the main documents. Comments from a single company or individual will go in an annex

Written comments received and how they were handled

Written comments were received after the meeting from Nokia, Ericsson, Huawei and Vodafone. A mixture of the editing guidelines and a lot of good will has resulted in agreement on how to reflect the contributions into the documents in an appropriate way. In particular some very good supplementary points have been brought together in section 11 above.

List of entities that have participated:

1. Access Partnership
2. BBC
3. BT Group
4. CGI IT UK Ltd
5. Commscope,
6. DenseAir
7. Digital TV Group
8. Disruptive Analysis

9. Electronic Media Service Ltd
10. Federated Wireless
11. Google UK Ltd
12. Hewlett Packard Enterprises
13. Huawei Technologies (UK) Ltd
14. JRC
15. LS Telecom Ltd
16. MoD
17. Nokia (UK) Ltd
18. Nokia Networks
19. Nominet
20. Plumb Consulting London LLP
21. Policy Tracker
22. QuinetQ Group
23. Real Wireless Ltd
24. Rivada Networks
25. Ruckus Wireless Ltd
26. Smith Institute
27. Sony Europe
28. Tango Networks
29. techUK
30. Telefonica O2 UK Limited
31. University of Bristol
32. University of Surrey 5G IC
33. Viatec Associates Ltd
34. Webb Search
35. Wireless Infrastructure Group
36. WSO2
37. Vodafone UK

Annex 2 – Single company positions

Editor's note: Placeholder for Huawei summary case for two-tier "first come first served" model without opportunistic use of unused spectrum. To be added before Steering Board sign-off

Annex 3: Use cases for UK-DSA

This contains further information on the nature of various potential use cases and how they could be supported by UK-DSA.

Neutral host indoor mobile

Access to local licenses in the 2.3 GHz and 3.8-4.2 GHz Innovation Bands will enable neutral host networks to drive indoor mobile coverage across the UK's Enterprise market

One of the biggest market failures in mobile coverage is within larger buildings across the UK. It is estimated that there are over 20,000 premises with between 50,000 and 300,000 sq. ft. including offices, factories, hotels, hospitals, educational facilities and other public buildings. Delivering signal into buildings of this size, globally referred to as the Enterprise market, is widely recognised as one of the toughest industry challenges.

Poor Indoor Coverage affects UK productivity

The National Infrastructure Commission highlighted in its "Connected Future" report[13] that "recentresearch by the CBI found that 81% of firms see more reliable mobile connectivity as essential".

According to a recent study on behalf of Commscope[14] nearly half of UK workers can't make calls or use data inside the office, and nearly half of all workers in the UK are forced to make calls or access data on mobiles outside an office due to poor connectivity. According to the research, 44% of the participants said they had to leave the office to use data or make a phone call with 23% having productivity hindered once a week. Almost three quarters (73 per cent) of people pointed to poor connectivity as a reason for affecting work efficiency.
As data rates increase, higher licensed frequencies get deployed and modern building materials get better at retaining heat - and repelling mobile signal - and the problem of indoor connectivity in larger buildings is set to get worse.

Addressing the problem needs dedicated indoor wireless infrastructure

Delivering mobile signal into larger buildings almost always requires dedicated wireless infrastructure to be deployed inside the building. Licensed spectrum is currently the only option to address the problem and given the challenges of macro dominance from outdoor networks interfering with any indoor infrastructure, the solutions have focused on high quality distributed antenna systems (DAS). Many of the UK's largest buildings (i.e. buildings > 300,000 sq. ft.) have signal delivered by DAS and the majority of these systems are provided by neutral host operators. This ensures a single high-quality infrastructure can be deployed that is fairly accessible to all operators.

Whilst DAS infrastructure is effective at counter-balancing outdoor macro signals it also requires a large investment and is only economic in the largest of buildings. A number of cheaper options have been explored for Enterprise buildings under 300,000 sq. ft. however these have failed to address the twin challenge of i) sufficient quality of infrastructure to enable high quality signal; and ii) affordability.

[13] National Infrastructure Commission, *Connected Future*, December 2016.
[14] Mobile News, *Poor indoor mobile coverage hinders productivity in UK offices*, April 2018.

For enterprise indoor networks, the affordability of solutions will be key to success. Only with licensed spectrum can we avoid the delivery of indoor connectivity through multiple RF sources which, even with improvements in coordination with macros, will remain more expensive than a single RF source route enabled by spectrum. The release of affordable local licensed spectrum in other jurisdictions, such as the CBRS model in the US, has seen a range of solutions developed which can offer multi-operator capability in a single cell.
Coupled with the emergence of a new business model where neutral host operators deploy infrastructure into Enterprise buildings, paid for by the building owners under an IAAS (Infrastructure as a Service) model, the Innovation Band offers a transformational opportunity to resolve the indoor coverage challenge.

Annex 4 - Government and Ofcom policy statements on Dynamic Spectrum Access

DCMS Future Telecommunications Infrastructure Review *July 2018*

213. Ofcom has set out a plan for releasing 5G spectrum in line with the timeframe for development of 5G standards and technology. This includes the 3.4 – 3.6 GHz auction which concluded in April 2018 and the plan to auction spectrum in the 700 MHz and 3.6 – 3.8 GHz bands in 2019. Ofcom is also considering a more flexible approach for the future licensing of the 3.8 – 4.2 GHz band and spectrum above 20 GHz.

214. The Government wants Ofcom to complete the award of the remaining 5G spectrum bands of 700 MHz and 3.6 – 3.8 GHz in a timely manner. We are also mindful, however, that the development of a set of innovative 5G services and new investment models may require more flexible approaches to spectrum licensing. This was also a key recommendation of the NIC's 5G report.97 215. Ofcom has indicated plans to extend shared access to 3.8 – 4.2 GHz, allowing for coordination arrangements between new and existing users. However, this band is used by satellite earth stations and the Government understands that it may be a number of years until this band is widely available in consumer handsets and other 5G equipment, compared with the 3.6 – 3.8 GHz band and other bands harmonised for 5G in Europe.

221. The evidence this Review has received indicates that there are various potential shared access models that merit consideration, including:

- Light-licensing models, which permit coordinated use of spectrum across the country by multiple operators through a registration process and database. This could be through localised or pay as you go licences. Having some 5G spectrum set aside for light-licensing would ensure that there would always be some spectrum available for shared access, to create investment certainty for new entrants, even in urban areas where MNOs are likely to deploy these frequencies.104 Access to this block could be controlled by database access in order to provide future flexibility. This could support use cases including indoor coverage for factories, office buildings and event venues in urban areas; neutral hosts for mobile network densification; and road and rail corridors. Future Telecoms Infrastructure Review 66
- Dynamic spectrum access (DSA), which uses a database to identify spectrum that is unused at any time and location by the licensed incumbent and make it available to other users without causing interference. This model would provide opportunistic access to spectrum to existing and new players by making available unused 5G spectrum, and would give priority to the principal licensee. DSA techniques are already used in so-called TV White Space, which is unused spectrum in the frequency bands used for Digital Terrestrial Television broadcasting. This method is likely to be particularly useful to enable the provision of wireless broadband services in rural areas that are less likely to be covered by 5G mobile networks.

223. We would, therefore, encourage Ofcom to assess the feasibility, costs and benefits of potential flexible licensing models, and also consider the trade-offs involved, as part of its continuing consultation on the planned release of spectrum in the 3.6 – 3.8 GHz band, in addition to its work on the 3.8 – 4.2 GHz band.

Ofcom consultation: Enabling opportunities for innovation Shared access to spectrum supporting mobile technology *December 2018*

1.25 We note that a DSA approach could provide users more flexible access to spectrum as devices would automatically connect to a central database and be assigned spectrum based on availability at that time and location. From a spectrum management perspective, this

would also ensure an efficient use of shared spectrum but a DSA solution would likely take longer to develop and test.

1.26 We will, however, explore the potential for introducing DSA in the three shared access bands. We would like to work with industry to define the appropriate specification for both DSA equipment and database capability that would enable future transition to DSA.

DCMS Statement of Strategic Priorities to Ofcom *July 2019*

- Enabling of spectrum sharing generally (esp in the whole of 3.6-4.2 GHz
- Reporting on geographical utilisation of spectrum by band
- Supporting new business models and new players
- Enabling secondary markets for spectrum

Ofcom Press Release *June 2019*

We also intend to make 2.25 GHz of spectrum from 24.25 GHz to 26.5 GHz available. We are planning for this spectrum to support 5G indoor applications, sharing access with the existing fixed-wireless services and satellite earth stations that operate in the band.

Ofcom statement: Enabling opportunities for innovation Shared access to spectrum supporting mobile technology *July 2019*

1.25 We are commencing work to consider whether it would be appropriate in the future to transition towards a dynamic spectrum access (DSA) approach supported by a fully automated central database in the bands outlined under our spectrum sharing framework. We would like to work with industry in developing our approach and encourage interested parties to get in touch with us at SharedSpectrumAccess@ofcom.org.uk
What we proposed

3.179 We want to ensure that the shared spectrum is used effectively and efficiently so that we can accommodate as many users as possible. We indicated in the December consultation our intention to consider a move towards an automated Dynamic Spectrum Access (DSA) approach which would ensure that access to spectrum is only authorised when equipment is transmitting. We want to achieve greater spectrum management flexibility and encourage the development of frequency agile equipment.

3.180 We indicated our aim to work towards a fully automated dynamic spectrum assignment approach whereby equipment communicates directly with a spectrum assignment database to be granted access to spectrum at the location and time required on frequencies unused by others (i.e. automatic spectrum assignment). This could facilitate more efficient sharing because frequencies would be available for new users when no longer required by previous users.