Google's consolidated response to Ofcom's consultations on "Enabling opportunities for innovation: Shared access to spectrum supporting mobile technology" and "Award of the 700 MHz and 3.6–3.8 GHz spectrum bands"

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Summary

In these complementary consultations,[1] Ofcom commendably seeks to promote 5G deployments that support mobile and fixed broadband connectivity as well as industrial, enterprise, and other applications. Google particularly welcomes Ofcom's proposed designation of specific new bands (1800 MHz, 2300 MHz, and 3.8–4.2 GHz) for shared access in the UK. Ofcom further recognizes the benefits of dynamic spectrum sharing, which can multiply options for localized services, including by providing opportunities for 5G deployments in otherwise unused spectrum between 3.6 GHz and 3.8 GHz. It is critical, however, for Ofcom to speed the realisation of dynamic sharing and its benefits in the UK. This is particularly important in the 3.6–3.8 GHz band, where sharing for 5G uses is especially promising due to global harmonisation and the early availability of network and consumer equipment, and where Ofcom has the opportunity to design a new licensing regime from scratch to facilitate sharing.

As explained in the comments below,

- **Dynamic sharing can help make usable spectrum abundant.** Instead of granting exclusive-use licences to a limited set of parties, spectrum can be made generally available for many different types of users, subject to simple technical standards. A simple automated admissions system can determine which spectrum is available at a particular location and almost instantly assign frequencies to systems that seek shared spectrum access, instructing systems to relocate to different frequencies or bands as necessary to avoid harmful interference to protected users. This approach maximises spectrum availability and efficiency, particularly as compared to slower, labour-intensive administrative coordination. Unlike the fixed spectrum allocations that result from administrative coordination, moreover, dynamic sharing systems and models can be updated nearly instantaneously and at low cost, to ensure continuous improvements to efficiency.

[1] Ofcom, *Enabling Opportunities for Innovation: Shared Access to Spectrum Supporting Mobile Technology* (18 Dec. 2018), *available at* https://www.ofcom.org.uk/__data/assets/pdf_file/0022/130747/Enabling-opportunities-for-innovation.pdf ("Sharing Consultation"); Ofcom, *Award of the 700 MHz and 3.6-3.8 GHz Spectrum Bands* (18 Dec. 2018), *available at* https://www.ofcom.org.uk/__data/assets/pdf_file/0019/130726/Award-of-the-700-MHz-and-3.6-3.8-GHz-spectrum-bands.pdf ("Award Consultation").

- **Google and other companies are now deploying sharing systems in which entities that are entitled to protection can register their stations, allowing other users to query these systems and operate without harmful interference.** This is being done most prominently to manage the 3.5 GHz band in the US (3.55 GHz–3.7 GHz), which is vastly more complicated than the sharing environments anticipated in the UK. Initial demonstrations have been promising, and commercial service is expected to begin in a matter of months. Spectrum database systems are adaptable to any band or geography, and simpler UK deployments therefore can be accomplished very quickly in the wake of the US experience. Indeed, it would be a mistake to equate the time needed to implement dynamic sharing in the UK with the time needed to work through all technical and policy issues in the US. Most of the work needed to support dynamic sharing in the UK already has been done in the US and can be applied expeditiously to other markets.

- **The administrative coordination process envisioned by Ofcom is inferior to dynamic sharing and automated admissions.** The administrative coordination process Ofcom envisions will make available less spectrum than dynamic sharing. Under administrative coordination, service permissions are difficult and time-consuming to change once a decision has been made and licences are granted. Spectrum inevitably lies fallow at some places and times, for instance as a protected user builds out its network or adjusts its service area. Incumbent users, moreover, may believe it is in their interest to overstate their need for protection. In such circumstances administrative coordination will be slow, inaccurate, controversial, and costly in comparison to commercial systems that reflect device locations, characteristics, and statuses in near-real time, and apply Ofcom-approved propagation algorithms to identify potential harmful interference and make admissions decisions. Ofcom should make a firm commitment to implement dynamic, automated sharing as soon as possible. Google is ready to work with Ofcom and the industry to assist with this implementation.

- **Extension of sharing to the 3.6–3.8 GHz band is critical.** While use of dynamic sharing and automated admissions should be accelerated in all the candidate bands identified by Ofcom, the 3.6–3.8 GHz band is uniquely suitable for 5G applications—including but not limited to mobile—because of its large, contiguous bandwidth, and because global harmonization and existing industry standards will speed the availability of low-cost hardware. Some hardware is available already.[2] In addition, Ofcom is able to provide for sharing in the upcoming new licences, thus removing any legal or policy questions regarding its regulatory authority. Concurrently providing for flexible shared use in addition to mobile operations would go far to promote 5G fixed broadband, industrial IoT, enterprise systems, and other 5G applications across the UK, inasmuch as 3.6–3.8 GHz licensed mobile services almost certainly will fail to cover much of England, Scotland, and Wales. The 1.8 GHz, 2.3 GHz and 3.8–4.2 GHz bands

[2] *See, e.g.,* Available LTE Hardware for Band 43, 4G LTE, https://www.4g-lte.net/about/lte-frequency-bands/lte-band-43/ (last visited 11 Mar. 2019).

proposed by Ofcom for sharing are variously too narrow or inadequately supported by device manufacturers to meet these needs.

Google is among the leaders in developing technologies for dynamic sharing.[3] We hold a conditional approval to operate our commercial system for CBRS in the US.[4] Through field testing, Google has collected approximately 2 million data points to inform advanced propagation modelling for mid-band spectrum and support dynamic sharing decisions. We generate detailed geolocation data from which increasingly accurate propagation predictions can be made. Google also has extensive experience with associated radio technologies, including experimental deployments of 3.5 GHz fixed and mobile broadband systems. We co-founded the industry associations that are developing solutions to sharing challenges in the US,[5] and we participate actively and collaboratively around the world in regulatory proceedings on spectrum sharing. Google specifically looks forward to contributing substantially to dynamic sharing of the 3.6–3.8 GHz band in the UK.

General Comments

Like Ofcom, Google "want[s] to see good quality wireless broadband coverage where people live, work and travel across the UK, both now and in the future as the next generation of mobile technologies (5G) becomes available." Sharing Consultation ¶1.1. Ofcom's plan to apply shared access to both newly available and already-licensed bands is a step in the right direction. Ofcom, however, should be more aggressive in setting timelines for dynamic spectrum sharing to allow not only secondary licensing, but also other opportunistic uses on a secondary basis. Primary access to licensed spectrum provides the certainty major operators need to make large, long-term investments in wide-area networks, while broad eligibility for access to licence-exempt and lightly-licensed spectrum fosters widespread contributions to innovation and fast-paced investment in emerging technologies. As a result, licence-exempt and lightly-licensed approaches fulfil a critical role in meeting broader market and consumer needs. Ofcom should consider three-tiered sharing wherever it seeks to implement a secondary licensed tier. In general, the technologies used to protect incumbent users from secondary licensed users could equally well protect secondary licensed users from opportunistic users. Spectrum should be opened to other users in areas where it is not fully used by incumbents or

[3] *See* Google, *Spectrum Sharing*, https://www.google.com/get/spectrumdatabase/ (last visited 11 Mar. 2019).

[4] FCC, *Wireless Telecommunications Bureau and Office of Engineering and Technology Conditionally Approve Seven Spectrum Access System Administrators for the 3.5 GHz Band*, Public Notice, 31 FCC Rcd. 13355 (2016), *available at* https://www.fcc.gov/document/35-ghz-sas-conditional-approval-public-notice.

[5] *See* Wireless Innovation Forum, CBRS WInnForum Standards, https://cbrs.wirelessinnovation.org/ (last visited 11 Mar. 2019) (including information on the Spectrum Sharing Committee). *See also* CBRS Alliance, https://www.cbrsalliance.org/ (last visited 11 Mar. 2019).

secondary licensees. Early indications in the US are that industry interest in such third-tier access is at least as strong as interest in second-tier spectrum.

Today's commercial database systems enable shared access by administering interference management quickly, efficiently, and reliably. Ofcom itself has enabled spectrum sharing between incumbent broadcasters and licence-exempt wireless devices by relying on readily available broadcast operation data. Databases allow devices to share spectrum without causing harmful interference to broadcasters or other protected entities. Given the current state of database management technologies, there is no sound justification for relying solely on centralised administrative coordination, which requires unnecessary agency costs and foregoes the benefits of state-of-the-art technology. Nor is it wise to lock in provider-specific interference management decisions as part of Ofcom's licensing actions, when actual spectrum utilisation continuously changes and related technologies and propagation models constantly improve.

Dynamic sharing with automated admissions soon will be deployed in a geographically expansive and highly complex spectrum sharing environment. In the 3.5 GHz band in the US, multiple competitive Spectrum Access Systems (SASs) will harmonize commercial use by Priority Access licensees and lightly-licensed General Authorized Access users in real time, all subordinate to shipboard radar operations of the US Navy and other government operations. Because the location of US Navy vessels at sea is non-public information, land-based spectrum sensing systems approved by the US Department of Defense will determine whether naval radars are active in the vicinity. If so, the sensing systems will notify the SASs, which in turn will immediately move potentially conflicting commercial uses to other spectrum or shut them down.[6] This vanguard implementation of dynamic spectrum management—with an especially high degree of complexity and criticality due to the need to protect military operations—should provide Ofcom comfort in moving forward quickly with significantly simpler forms of dynamic sharing across multiple spectrum bands in the UK. Developers of dynamic sharing systems need not recreate the time-consuming work done for the US 3.5 GHz band; they need only apply it in the UK, and that application can be done far more quickly. Off-the-shelf dynamic sharing systems are close at hand.

The 3.6–3.8 GHz band should be first on the list for sharing. Ofcom proposes to speed mobile use of this spectrum, but mobile licensing alone falls short of opening the band for 5G. As GSMA explains,

> The ITU has outlined specific criteria for IMT-2020—commonly regarded as 5G—which will support the following use cases:
>
> **1. Enhanced mobile broadband:** Including peak download speeds of at least 20 Gbps, a reliable 100 Mbps user experience data rate in urban areas, and 4 ms latency.

[6] *See generally* 47 C.F.R. Part 96, *available at* https://www.ecfr.gov/cgi-bin/text-idx?SID=248ec1d996ed2b816d423a215e2a7423&mc=true&node=pt47.5.96&rgn=div5.

2. Ultra-reliable and low latency communications: Including sub-1 ms latency and very high availability, reliability and security to support services such as autonomous vehicles and mobile healthcare.

3. Massive machine-type communications: Including the ability to support at least one million IoT connections per square kilometre with very long battery life and wide coverage including inside buildings.

4. Fixed wireless access: Including the ability to offer fibre type speeds in both developed and developing markets using new wider frequency bands, massive MIMO and 3D beamforming technologies.

GSMA further recognizes the 3.5 GHz range as "prime" 5G spectrum.[7] Opening the 3.6–3.8 GHz band for 5G should therefore be a priority of Ofcom and other national spectrum regulators, and this requires the establishment of immediate opportunities for localized IoT and fixed broadband as well as wide-area mobile. The Sharing Consultation in fact notes (at ¶ 1.3) that stakeholders have expressed interest in using newly available spectrum for private networks and rural broadband as well as augmenting localized mobile coverage. And Ofcom rightly observes that "unlocking the benefits provided by 5G for applications beyond consumer mobile broadband, which may not require a national licence," will support innovation. Sharing Consultation ¶ 2.9.

In the UK, the 3.6–3.8 GHz band provides a uniquely suitable home for the full range of 5G applications: It offers as much as 200 contiguous MHz of available bandwidth "to support large numbers of connected devices, and enable higher speeds to concurrently connected devices" (Award Consultation ¶ 2.7); industry standards for 5G in the band are in place (*see* Sharing Consultation ¶ 3.14); and as with the adjacent 3.8–4.2 GHz band (*see* Sharing Consultation ¶ 1.5), mobile phones and other mass-market 5G devices are nearly ready for market (*see* Award Consultation ¶ 2.26). In Europe, spectrum between 3.4 and 3.8 GHz "has been identified as the primary band for 5G" (Award Consultation ¶1.2), and in the US, the shared 3.5 GHz band has been allocated for fixed and mobile 5G applications, with the Federal Communications Commission additionally proposing to allow flexible 5G use in portions of the 3.7–4.2 GHz band.[8] Due to its comparatively large bandwidth, along with international harmonization that supports large investments in developing network equipment and consumer devices (*see* Award Consultation ¶ 1.2), opening up the 3.6–3.8 GHz band to fixed as well as mobile services in the

[7] *See 5G Spectrum: GSMA Public Policy Position*, GSMA, at 2, 3 (Nov. 2018), https://www.gsma.com/spectrum/wp-content/uploads/2018/11/5G-Spectrum-Positions.pdf. *See also* International Telecommunication Union, *Draft New Report ITU-R M.[IMT-2020.TECH PERF REQ]: Minimum Requirements Related to Technical Performance for IMT-2020 Radio Interface(s)*, ITU-R SG05 Contribution 40 (22 Feb. 2017), *available at* https://www.itu.int/md/R15-SG05-C-0040/en.

[8] FCC, *In the Matter of Expanding Flexible Use of the 3.7 to 4.2 Ghz Band, et al.*, Order and Notice of Proposed Rulemaking, 33 FCC Rcd. 6915 (2018), *available at* https://docs.fcc.gov/public/attachments/FCC-18-91A1.pdf.

UK—on a shared basis to maximise availability—would lead to faster fixed 5G deployments at lower cost.

Designating the 3.6–3.8 GHz band for sharing therefore would be consistent with Ofcom's policies of opening "access to spectrum which can be used immediately with existing equipment" and "promot[ing] the development of an equipment ecosystem that would support bespoke 5G equipment." Sharing Consultation ¶¶ 2.25, 3.4. Conversely, restricting the 3.6–3.8 GHz band to mobile-optimised exclusive licences would force fixed applications into non-harmonized spectrum with lesser contiguous bandwidth, thereby raising costs, reducing quality, and slowing speeds for 5G point-to-multipoint (P2MP) broadband, industrial IoT, enterprise systems, and other fixed applications in the UK.

Focusing right now on the 3.6–3.8 GHz band has a legal and policy rationale, too. Whereas the Sharing Consultation identifies the 1800 MHz, 2300 MHz, and 3.8–4.2 GHz bands as spectrum that is not fully utilised by *existing* licensees (Sharing Consultation ¶3), the 3.6–3.8 GHz band provides a home for sharing with *new* licensees as they build out their networks and beyond. Accordingly, provision for sharing can be made in the initial licence awards. MNOs will be on notice that sharing is allowed, and will accept their licences on that basis. Even if sharing of other bands may be slowed by challenges from incumbents who claim exclusive rights even to unused spectrum, no such impediment exists for the 3.6–3.8 GHz band.

Tiered, dynamic sharing thus should be introduced into the 3.6–3.8 GHz band as soon as possible. The band's adjacency to the 3.8–4.2 GHz band, which Ofcom has identified for sharing, ensures that investments in sharing 3.6–3.8 GHz spectrum for 5G will be transferable to that higher band, which to date has not benefited from the same global investment as the mid-3 GHz range.

Google recognizes that, in order to avoid delays in opening the 3.6–3.8 GHz band, Ofcom may find it desirable to employ administrative coordination initially, pending full adoption of automated systems. If so, Ofcom's administrative processes should be supplanted by automated admissions systems as soon as such systems have been configured for this application. A multi-stakeholder process as contemplated by Ofcom (Sharing Consultation ¶2.29) is well-suited to establishing band-specific procedures for interference protection based on input from incumbent and new users. Google would intend to participate actively in such a process.

Using shared 3.6–3.8 GHz spectrum, existing mobile operators, neutral hosts, and enterprise end-users all could develop productive network infrastructure. Both established mobile operators and new players would gain access to more spectrum, more quickly and in more locations than would otherwise be possible. Importantly, allowing fixed use of the 3.6–3.8 GHz band on a shared basis would not reduce the amount of spectrum available to mobile operators as compared to Ofcom's award proposal. Operators securing licences at auction would be protected against interference to their licensed operations, and additionally could access spectrum that has not attracted a licensee, or that is not fully used by another licensee. Such areas of disuse by auction winners are likely to be extensive, as indicated in analysis by the IET

5G Further Faster Group.[9] Sharing therefore can be expected to increase the amount of 3.6–3.8 GHz spectrum available to *every* operator. This approach would help optimise spectrum utilisation and diversify 5G deployments, consistent with Ofcom's duties.

Responses to Specific Questions

A. Enabling opportunities for innovation: Shared access to spectrum supporting mobile technology

Question 1: (Section 3) *Do you agree with our proposal for a single authorisation approach for new users to access the three shared access bands and that this will be coordinated by Ofcom and authorised through individual licensing on a per location, first come first served basis? Please give reasons supported by evidence for your views.*

While Google appreciates Ofcom's recognition that dynamic spectrum management and automated admissions improve the efficiency of spectrum sharing (Sharing Consultation ¶¶ 2.27–2.28), we believe that Ofcom is excessively conservative regarding implementation. Right now, spectrum sharing systems are undergoing final certification testing before their deployment in the US. The sharing Ofcom contemplates presents fewer complexities than the three-tiered CBRS framework for which the US systems have been developed. Accordingly, it will be a straightforward matter to optimise existing automated admissions systems for sharing in the UK.

Ofcom also underestimates the difficulties associated with administrative coordination of spectrum sharing. The administrative process described in paragraph 2.23 of the Sharing Consultation contains a number of potential points of controversy and/or failure, including:

- Reliable and verifiable delivery and receipt of communications between the prospective licensee and Ofcom, and between Ofcom and the incumbent MNO;
- Timely processing of all communications;
- Whether grant of a potentially interfering licence is a reasonable sanction in the event the incumbent MNO is not both timely and cooperative in responding to a sharing request;
- Whether an objection lodged by the incumbent MNO is "reasonable" according to Ofcom's standards (which may be very different from the MNO's standards);
- Whether to provide the prospective shared user and the public access to information provided by the MNO in support of an objection;
- Whether, if the prospective shared user is not invited to participate in Ofcom's deliberations and/or given access to materials supporting the MNO's objection, Ofcom will have any effective mechanism to test the MNO's assertions about its actual usage and future business plans; and

[9] *See* Institution of Engineering and Technology, *5G Further Faster,*, https://www.theiet.org/impact-society/sectors/digital/digital-news/further-faster-with-5g/ (last visited 11 Mar. 2019).

- Whether Ofcom's sharing decisions will be made publicly available to assist industry's network planning and to help potential users of shared spectrum avoid fruitless requests for shared access.

Resolving issues such as these will be time-consuming for Ofcom. Indeed, similar questions have challenged the industry and the US FCC in the CBRS context. The result of the CBRS process has been a set of industry standards[10] and FCC rules[11] that SAS administrators can apply on an automated basis for access to the 3.5 GHz band, and extend to other, newly shared bands. This process will be refined over time, but will not fundamentally change. By contrast, Ofcom will have achieved little of lasting value by developing a process for centralised administrative admissions because, by Ofcom's own assessment, this is merely a transitional stage in the evolution toward dynamic shared access. Ofcom will have spent substantial time and resources on establishing a process that, by its nature, is neither enduring nor scalable to extensive shared use across the UK. The better approach would be to leverage work already done in the US and convene a multi-stakeholder process in the UK as soon as possible to develop a set of procedures that commercial administrators can implement across multiple shared bands in the long term. Google stands ready to participate.

Question 2: (Section 3) *Are there other potential uses in the three shared access bands that we have not identified?*

An important and valuable feature of spectrum sharing systems is that they can support virtually any use of the available spectrum. This means that regulators need not—and indeed should not—tailor technical rules for shared spectrum closely to particular business models. With automated sharing, market forces and technological developments can drive access to spectrum whenever, wherever, and however it is needed. This flexibility lowers barriers to spectrum access for new entrants and for emerging uses, and greatly lessens the pressure on regulators to attempt the almost impossible task of predicting future industry requirements.

Question 3: (Section 3) *Do you have any other comments on our authorisation proposal for the three shared access bands?*

In order to realise and maximise the innovation potential of sharing of mobile spectrum for 5G uses as well as 4G, Google considers it essential that the spectrum is:

1. Covered by 3GPP standards for 5G;

2. Of sufficient bandwidth to deliver the benefits of 5G and to accommodate the needs of multiple operators in the same geography; and

3. Supported by the full international mobile supply chain including mainstream mobile phones and network technology.

[10] *See* Wireless Innovation Forum, *CBRS Baseline Standards*, https://cbrs.wirelessinnovation.org/standards (last visited 11 Mar. 2019).

[11] *See supra n.6.*

Amongst the bands suggested by Ofcom:

- The 1.8 GHz frequencies, though well supported by LTE phones, are too narrow to support competitive 5G services. It is probable that 5G consumer devices will not be available for these frequencies until well after they are available for 3.6–3.8 GHz;
- The 2.3 GHz frequencies, though supported by LTE phones, are (at 10 MHz) inadequate for 5G; and
- The 3.4–3.8 GHz frequencies, though wide enough for 5G, are years behind the other bands under consideration in terms of the development of consumer mobile devices.

Therefore, while database-managed sharing with automated admissions should be implemented as soon as possible in each band, the 3.6–3.8 GHz band should be particularly prioritized for sharing. Appropriate requirements to enable sharing, such as providing information on actual utilisation of spectrum, should be established in the new MNO licences.

Question 4: (Section 3) *What is your view on the status of equipment availability that could support DSA and how should DSA be implemented?*

The US is seeing substantial growth in DSA-capable equipment as CBRS services near commercial deployment. For example, the FCC has approved equipment from six different companies for operation under the control of 3.5 GHz band SASs. More equipment authorizations are pending. The technology that enables DSA in this equipment, including connectivity to a SAS, is band- and geography-agnostic and could be modified for implementation in hardware used outside the US. Indeed, the baseline specifications are publicly available.[12]

Question 5: (Section 4) *Do you agree with our proposal for the low power and medium power licence? Please give reasons supported by evidence for your views.*

Google agrees that small area licences are appropriate for low-power operation, and through aggregation allow coverage of larger areas when needed. But the licence area should be a square or other polygon that can be geometrically aggregated with adjacent areas, without overlap or gaps. For example, a square with edges of 100 m is a convenient unit and is only about 27% larger in area than the proposed circle of radius 50 m. Licensing medium power systems on a per-base station basis is appropriate.

In both cases, licensees should be required to declare the specific frequencies they are using, and thus enable opportunistic access to frequencies that are licensed but not used. (This requirement should be instituted from the outset for MNO licences in the 3.6–3.8 GHz band.)

[12] Wireless Innovation Forum, *Signaling Protocols and Procedures for Citizens Broadband Radio Service (CBRS): Spectrum Access System (SAS) - Citizens Broadband Radio Service Device (CBSD) Interface Technical Specification (Document WINNF-TS-0016)* (31 Oct. 2018), https://winnf.memberclicks.net/assets/CBRS/WINNF-TS-0016.pdf.

With this information, spectrum sharing systems are readily able to track declared use and associated spectrum availability, as they are doing in the US CBRS band.

In addition to mixed indoor/outdoor licences, Ofcom should offer indoor-only licences. For indoor-to-indoor and even indoor-to-indoor/outdoor licences, spectrum can be re-used within very short distances due to the blocking effect of walls, windows, and floors. Although precise adjacencies would have to be explored based on Ofcom's final low-power licence area geometries as well as propagation estimates,[13] re-use between indoor-only licences may be possible in adjacent licence areas; re-use between indoor and indoor/outdoor in perhaps the 2nd or 3rd adjacent licence areas; and re-use between indoor/outdoor licences in perhaps the 4th or 5th adjacent areas, as an example.

Question 6: (Section 4) *Are there potential uses that may not be enabled by our proposals? Please give reasons supported by evidence for your views.*

Ofcom proposes to licence medium power base stations in the shared access spectrum strictly on a fixed geographic basis, "at a given location." Sharing Consultation ¶4.21. It is not difficult, however, to imagine uses for a medium power base station that travels along a fixed route such as a railway line or roadway, or for one that can be deployed anywhere within a predetermined geographic area such as a large hospital site, stadium grounds, or university campus. With automated admissions—and potentially even with manual coordination in some instances—it would be possible to verify non-interference to incumbent licensees throughout such defined areas. Accordingly, Ofcom should allow applications for licensing of a specified number of medium power base stations within specified geographic boundaries. While in practice such area licences may be more difficult to secure for shared use because of the larger geographic area involved, there is no technical or logical reason why they should be categorically unavailable.

Question 7: (Section 4) *Do you agree with our proposal to limit the locations in which medium power licences are available? Please give reasons supported by evidence for your views.*

Ofcom's proposal to initiate medium power licensing of shared access spectrum in rural areas is a means of introducing shared use across substantial geographic portions of the UK with very low risk. This initial rural licensing, however, should be done with a view to confirming admissions processes and propagation models that ultimately can be used for medium power shared access across the UK, including in urban areas where spectrum is in particularly short supply.

Question 8: (Section 4) *Do you have other comments on our proposed new licence for the three shared access bands?*

Intentionally blank.

[13] Google's measurements show an approximate average indoor-to-outdoor loss of 15 dB at 3.5 GHz.

Question 9: (Section 4) *Do you agree that our standard approach to non-technical licence conditions is appropriate? Please give reasons supported by evidence for your views.*

A cardinal advantage of mid-band spectrum is that it can be used efficiently by low cost, low and medium power devices for localized service. Financial barriers to entry are relatively low, small cell equipment has a shorter useful life than macrocell equipment, and the range of potential uses and operators is far greater than for sub-2 GHz spectrum. For these reasons, spectrum such as the 3.6–3.8 GHz and 3.8–4.2 GHz bands invite experimental uses and require less investment than traditional MNO bands. In this environment, licences of indefinite length are unnecessary to incentivise investment, as well as dramatically out of sync with the lifespan of network equipment (which is likely to be 5–10 years or less). Furthermore, the fact that deployments in shared mid-band spectrum will be disproportionately new efforts rather than updates to existing networks makes it likely that there will be a significant number of failures. Having a set licence term that is not too long may be administratively convenient in the case of operators that cease operations without notification to Ofcom. Accordingly, for the 3.8–4.2 GHz shared band an appropriate licence term would be in the same 5–10 year range as the upper-bound lifespan of small cell equipment, rather than the indefinite duration proposed by Ofcom. Sharing Consultation ¶ 4.24. Licences should, however, be automatically renewable on request for licensees that request an extension of the same duration as the initial licence, are in good standing with Ofcom, and are using their licensed spectrum. Alternatively, the shorter term for secondary licences in awarded mobile spectrum could be applied to the 3.8–4.2 GHz band as well. *See* Sharing Consultation ¶ 8.25.

Question 10 (Section 4): *Are you aware of any issues regarding numbering resources and Mobile Network Codes raised by our proposals which we have not considered here?*

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Question 11: (Section 5) *Do you agree with the proposed technical licence conditions for the three shared access bands? Please give reasons supported by evidence for your views.*

The proposed power levels for 3.8–4.2 GHz equipment are very low. The 3.8 GHz low power device (24 dBm for up to 20 MHz) is almost 8 times less powerful than the lowest-power 3.5 GHz CBRS device, and 16 times less powerful than 2.4 GHz Wi-Fi. The base is only 1 dB more powerful than the mobile unit, even though it will typically be transmitting several times as many resource blocks.

Question 12: (Section 5) *Are there other uses that these bands could enable which could not be facilitated by the proposed technical licence conditions? Please give reasons supported by evidence for your views.*

Reliable rural broadband coverage in the 3.8–4.2 GHz band will require more than the proposed 42 dBm base station power and much more than the proposed 23 dBm customer premise equipment (CPE) power. The US FCC is working to authorize 3.5 GHz CPE that can transmit at

47 dBm back to the 47 dBm base station,[14] as those are the power levels that the rural operators have determined are needed for effective service. 23 dBm EIRP is likely not sufficient as a CPE power level.

Question 13: (Section 5) *Do you agree with our proposed coordination parameters and methodology? Please give reasons supported by evidence for your view*s.

Ofcom's proposed administrative coordination methodology may serve a useful temporary role in the transition to automated admissions, but it is not a long-term solution. With geolocation databases and automated admissions systems, admissions decisions can be made faster; spectrum can be put to the best possible use quickly; and voluntary agreements can be facilitated.

Ofcom compares its proposed administrative coordination process to privately negotiated sharing and acknowledges that a centrally administered process "may result in spectrum being used a little less efficiently." Sharing Consultation ¶ 5.77. This inefficiency is justified, Ofcom suggests, because "coordination negotiations between users could be lengthy and with no guarantee of success, and the likelihood of local coordination failure increases when there are multiple users in the vicinity." Sharing Consultation ¶ 5.77. This analysis highlights the importance of introducing automated sharing systems as soon as possible. Automated systems using powerful data centre computing are better able than administrative coordinators to take account of detailed local data, such as the presence of trees or buildings, that can greatly affect the interference potential of transmissions, especially in mid-band spectrum. Precise, localized sharing decisions can be made without having to rely on manual coordination.

Automated sharing systems also can provide computational support for voluntary user coordination. Interested parties quickly can obtain predictions regarding potential interference from a trustworthy third party. This facilitates privately negotiated solutions that, in turn, can be registered in spectrum databases.

In the development of CBRS in the US, the importance of accurate propagation prediction has become apparent, both in avoiding over-protection of incumbents and in predicting coverage of new entrants. Clutter such as buildings and foliage is a particularly critical factor. Google's real-world propagation measurements show that some standard models, such as Longley-Rice, underpredict losses by as much as 40-60 dB on paths shorter than approximately 5 km. Standard models that incorporate clutter loss on a statistical basis, such as the extended Hata or ITU-R P.452 models, still underpredict losses on shorter paths by tens of dB. Ofcom therefore should encourage industry to develop refined propagation models that utilize the best-available clutter data, and such models should be used for all spectrum sharing scenarios.

Finally, Ofcom does not address important questions regarding the proposed administrative coordination. To make this process workable, Ofcom proposes to adopt simplifying

[14] *Cf.* Office of Engineering and Technology Laboratory Division, *Draft Laboratory Division Publications Report: Citizen Broadband Radio Service Frequently Asked Questions*, FCC (22 Feb. 2019), https://apps.fcc.gov/eas/comments/GetPublishedDocument.html?id=441&tn=983380.

assumptions—such as the proxy base station approach (Sharing Consultation ¶¶ 5.55–5.59)—that may not reflect actual conditions. Will parties who fear harmful interference from a new licensee have an opportunity to challenge the assumptions as insufficiently protective in their particular case? Will prospective entrants have the ability to show that the assumptions are too conservative in their situation? Automated admissions systems minimize these problems due to their superior computational power, which can take into account a greater number of relevant factors. For instance, the actual locations of all base stations can be considered. Thus, although the design of automated admissions systems may be more complex than the design of Ofcom's administrative admission models, they are ultimately not only easier to use but also less likely to create disagreement among users.

Regardless of the admissions system used, the coordination process should be designed to encourage rather than constrain sharing. In particular, Ofcom contemplates that sharing should be licensed for a minimum of three years in awarded mobile spectrum. Sharing Consultation ¶ 8.25. Under that approach, MNOs predictably will reject sharing proposals and block efficient use whenever they have—or merely can imagine—a plan to use even some of the spectrum at issue within three years. A better approach would be to licence shared use for any period of time proposed by the applicant, provided that the MNO does not raise a reasonable objection.

Question 14: (Section 5) *What is your view on the potential use of equipment with adaptive antenna technology (AAS) in the 3.8–4.2 GHz band? What additional considerations would we need to take into account in the technical conditions and coordination methodology to support this technology and to ensure that incumbent users remain protected?*

Intentionally blank.

Question 15: (Section 5) *Do you agree with our proposal not to assign spectrum to new users in the 3800–3805 MHz band and the 4195–4200 MHz band?*

Intentionally blank.

Question 16: (Section 6) *Do you agree with our fee proposal for the new shared access licence? Please give reasons supported by evidence for your views.*

Cost-based licensing is a sound approach to testing the attractiveness of shared spectrum and supporting innovative uses of the newly available shared frequencies. Ofcom, however, correctly identifies a risk of non-use when spectrum is licensed at low cost (Sharing Consultation ¶ 6.18). The shorter licence term Google suggests in response to Question 9, above, with renewal dependent on actual use of the licensed spectrum (ideally verified by spectrum management system registrations), would be a straightforward way to address this concern. As compared to indefinite licensing, fixed licence terms also would facilitate adjustment of the fee arrangements if, over time, demand for shared spectrum clearly exceeds supply.

For some use cases, the proposed level of fees is too high. In particular, a femtocell deployment in tens or hundreds of thousands of homes could bring significant consumer benefit, but

Ofcom's fees would be too high to support a femtocell business case. Such low power indoor cells create little risk of interference, so coordination procedures should be significantly simplified to reduce cost.

Question 17: (Section 7) *Do you agree with our proposal to change the approach to authorising existing CSA licensees in the 1800 MHz shared spectrum? Please give reasons supported by evidence for your views.*

Intentionally blank.

Questions 18 & 19 (Section 8):

- *Do you agree with our proposal for the Local Access licence? Please give reasons supported by evidence for your views.*
- *Do you have any other comments on our proposal?*

Local Area licensing is a sound concept for increasing the availability and use of spectrum in the UK. Giving MNOs what amounts to a veto over shared licensing, however, threatens to nullify this concept. Licensed MNOs tend to view with scepticism the proposition that other providers can use portions of their spectrum without impairing the MNOs' own current or future operations. That is one reason why, as Ofcom observes (Sharing Consultation ¶ 8.7), spectrum leasing has generated limited interest. In the US, where spectrum leasing generally is allowed, nearly 90% of secondary market transactions have involved purchases of spectrum by the largest national carriers to consolidate their spectrum holdings, instead of transfers of spectrum rights to smaller operators that would use them more intensively.[15] In addition to interference concerns, major MNOs may also believe that divesting small amounts of excess spectrum is simply not worth their time or—more disturbingly—that divested spectrum could provide footing for potentially competitive or disruptive services that the MNO would rather block.

Accordingly, adopting Ofcom's proposal to require consent from all affected MNOs (Sharing Consultation ¶ 8.12) could doom Local Area licensing. This is particularly true given Ofcom's proposed three-year minimum lease term for awarded mobile spectrum. As explained in response to Question 13, above, asking MNOs to acquiesce to sharing for a minimum of three years will likely lead those operators to reject sharing altogether, whereas leaving open the option of licensing for shorter periods of time would create greater opportunities for negotiated sharing agreements, while also making it more likely that a sharing applicant could present a proposal to which the MNO, even if not supportive, could not reasonably object.

In the long run, transaction costs could be vastly lower with automatic admissions. The most efficient approach would be to allow sharing of unused spectrum, subject to the MNO's priority rights, and administered through systems that recognize where and when spectrum is in use, and where and when complementary uses are possible. If a sharing applicant seeks to use available spectrum in a non-interfering manner, then admission would be granted subject to the MNO's priority right of use. Ensuring immediate and effective termination of permissions to share has been a particular focus of the US FCC in the CBRS context, where incumbent military use requires absolute protection. The automated solutions developed there are readily transferable to the UK to protect MNOs' ability to deploy throughout their licensed spectrum without harmful interference.

[15] *See FCC Spectrum Auctions and Secondary Market Policies: An Assessment of the Distribution of Spectrum Resources Under the Spectrum Screen*, Mobile Future, at 19 (Nov. 2013), https://mobilefuture.org/wp-content/uploads/2013/11/Paper-Distribution-of-Spectrum-Resources.pdf.

Question 20: (Section 8) *What information should Ofcom consider providing for potential applicants in the future and why would this be of use?*

The information needed to administer an effective dynamic sharing regime should be made available to database administrators on a confidential basis, under Ofcom's supervision. This includes a unique identifier for the registered device, the operator's contact information, horizontal and vertical location, maximum EIRP, antenna characteristics, centre frequency, and channel bandwidth. This information can be anonymized as appropriate, although in fact much of the information already is available online.[16] With this information, admissions decisions can be made quickly, confidently, and neutrally, with full protection of new entrants as well as incumbent MNOs. In establishing the regulatory criteria for admission, Ofcom can ensure the same substantive results envisioned in the Consultation. That is, admission rules can be set conservatively so that if there is a "reasonable" basis for fearing harmful interference to MNO operations, shared access will be denied. Sharing Consultation ¶¶ 8.12, 8.17. Should the MNO expand its active operations into currently shared spectrum, the authorization for sharing would terminate. Sharing Consultation ¶ 8.23.

As recommended below in Google's response to Question 12 of the Award Consultation, Ofcom should anticipate the information it will need from MNOs and require the provision of such information upon demand as a condition of the initial 3.6–3.8 GHz licences.

Question 21: (Section 8) *Do you agree with our proposal to have a defined licence period and do you have any comments on the proposed licence term of three years?*

As explained in response to Question 13 above, most MNOs are likely to react unfavourably to requests to share their spectrum for three years or more—whether or not the MNO is likely to use the spectrum. Therefore, rather than setting a three-year minimum licence period, Ofcom should issue a licence for any period of time proposed by the applicant, provided that the MNO either affirmatively consents or else raises only unreasonable objections. While licences of less than three years may be unattractive to some potential applicants (*see* Sharing Consultation ¶ 8.25), that will not always be true. For example, a trade show organizer or exhibitor might wish to use off-the-shelf small cell equipment to provide local connectivity during the show, and private small cell networks might be useful for major but time-limited events like the Olympics or sporting championships.

Looking beyond the transitional approach Ofcom proposes and to a time when automated admissions systems are fully operational in the UK, opportunistic admission on a secondary basis, subject to the MNO's priority rights, provides the most promising path to shared use. Should an entrant require greater certainty for its operations than opportunistic use affords, it can enter into an agreement with the MNO as contemplated by Ofcom (Sharing Consultation ¶ 8.23), or look to other spectrum.

[16] *See*, *e.g.*, Mast Data mobile telecoms base station resource tool, https://www.mastdata.com/ (last visited 11 Mar. 2019).

Question 22: (Section 8) *Do you have any other comments on the proposed Local Access licence terms and conditions?*

Intentionally blank.

Question 23: (Section 8) *Do you agree with our fee proposal for the new local access licence? Please give reasons supported by evidence for your views.*

The assumption underlying a cost-based fee structure—"that where there is high demand to use the spectrum the incumbent licensee would have likely already deployed"—is sound. Sharing Consultation ¶ 8.33. Given the potentially transient availability of MNO-licensed spectrum for secondary use, moreover, fees should be kept as low as possible to encourage productive uses of otherwise vacant frequencies.

B. Award of the 700 MHz and 3.6–3.8 GHz spectrum bands

Question 1: (Section 4) *Do you agree with our proposals on the coverage obligations as set out in this section? Please give reasons supported by evidence for your views.*

Build-out requirements of the sort proposed by Ofcom can be effective in spurring new and improved service to unserved and underserved communities and locations. They are an imperfect solution, however. First, operators perform better when the expectation of profit, rather than regulatory mandate, motivates their network deployment. Second, the mandates contemplated by Ofcom will leave large areas of the UK unserved or underserved. Third, ascertaining compliance or non-compliance with build-out obligations is difficult.

A strong spectrum sharing policy can help address each of these difficulties. Localized sharing opportunities enable small and non-traditional operators to attempt successful entry where national licence-holders do not see an opportunity for profit consistent with their business model. For instance, a rural community unserved by major MNOs might bring service to its own downtown area using inexpensive small cell equipment. Or a large farm or industrial site might establish an enterprise network for its own operations. Such uses of otherwise fallow spectrum provide a market-based means of improving the availability of broadband in the UK, at no cost to the national licence holder.

Dynamic sharing technologies also can help with enforcement of licence holders' build-out obligations. With a database-managed admissions system, MNOs and other protected operators will register the locations and characteristics of their transmitters in order to secure non-interference. Potential shared users can test actual coverage both in the field and by querying the spectrum management system. If a licensee's actual coverage does not match the full extent of its database registrations, then there is an opportunity for shared use, and the potential entrant will have an incentive to secure correction of the incumbent's excessive registrations. Market forces and automated systems thus do the hard work of measuring compliance with build-out mandates. With automated admissions, Ofcom will be able to rely on the spectrum sharing infrastructure both to check that MNOs are making satisfactory progress toward meeting their obligations, and to verify ultimate compliance.

For these reasons, dynamic spectrum sharing using automated admissions systems is complementary to the build-out policy and licence obligations Ofcom envisions for the 3.6–3.8 GHz band.

Questions 2 & 3 (Section 5):

- *Do you agree that we have identified the correct competition concerns?*
- *Do you agree with our assessment of these competition concerns, and our proposed measure for addressing them? Please give reasons supported by evidence for your views.*

Ofcom correctly notes that in mobile services, "barriers to entry are high," with access to spectrum being a particular obstacle, *see* Award Consultation ¶¶ 5.19, 5.28–5.60. Allowing access to unused spectrum on a shared basis is a way to lower these barriers. Rather than having to make huge outlays for a national licence, a shared user can acquire rights for a smaller geographic area or subset of frequencies that meets its unique needs. As discussed in the Sharing Consultation, cost-based fees are likely to be appropriate. Lower spectrum acquisition costs allow shared users to pursue business models different than those of major MNOs, including fixed and hyper-local mobile uses. Due to its propagation characteristics and the ready availability of off-the-shelf equipment, harmonized mid-band spectrum such as the 3.6–3.8 GHz band is ideal for such innovative, low-cost deployments that can supplement the offerings of the national MNOs.

Question 4: (Section 6) *Do you agree with our proposal to proceed with a conventional assignment stage?*

The availability of comparatively large bands of contiguous spectrum is one characteristic of mid-band spectrum that makes it particularly suitable for 5G broadband deployments. Ofcom's tentative decision to rely on market transactions to achieve defragmentation of 3.6–3.8 GHz spectrum highlights the importance of facilitating such transactions. Spectrum sharing systems can play a role. By collecting and making available granular, up-to-the-minute information on actual usage of licensed spectrum, spectrum management databases can provide MNOs and other service providers data and interference analysis that support spectrum trades and sales. Network information can be made available on an anonymized basis, or shared through spectrum database managers on a confidential basis as allowed by the relevant providers. Spectrum database managers should be permitted to provide such transaction-facilitating services on an optional basis, in order to promote liquid secondary markets for spectrum and add flexibility to the licence assignments Ofcom contemplates.

Question 5: (Section 7) *Do you agree with our proposal to use a CCA design for this award?*

Intentionally blank.

Question 6: (Section 7) *Do you have any comments on the proposed detailed rules for our CCA design?*

Intentionally blank.

Question 7: (Section 8) *Do you agree with our proposed approach to coexistence in the 700 MHz band?*

Intentionally blank.

Question 8: (Section 8) *Do you have any comments on the proposed licence obligation and guidance note (annex 19)?*

Intentionally blank.

Questions 9, 10, & 11 (Section 9):

- *Do you agree with our proposed approach to managing interim protections for registered 3.6–3.8 GHz band users?*
- *Do you agree with our 3.6–3.8 GHz in-band restriction zone proposals?*
- *Do you agree with our view that we do not need to include any specific conditions in 3.6–3.8 GHz licences to mitigate the risk of adjacent band interference?*

The challenges of coexistence between new MNO licensees and legacy satellite and fixed service operators in the 3.6–3.8 GHz band are similar to those in the US 3.5 GHz band, where CBRS service is being introduced. Although Ofcom has chosen to clear satellite and fixed service operators out of the 3.6–3.8 GHz band, the US CBRS framework shows how dynamic sharing can facilitate coexistence in the long run. Exclusive licensing, while highly valuable, is not realistic in many bands due to the time and expense required to displace existing users. Furthermore, if a clearing policy has been adopted, dynamic sharing systems provide the optimal way to manage coexistence during the transition.

Regarding existing users of the 3.6–3.8 GHz band, Ofcom acknowledges both that its administrative coordination process likely will lag behind marketplace conditions, and that Ofcom will be unable to timely accommodate the station-by-station coordination filings that may be most convenient for some MNOs. Award Consultation ¶¶ 9.12–9.14. Likewise, Ofcom has adopted a radius approach to protecting satellite earth stations that for simplicity does not take account of either the orientation of the satellite antenna or obstructions (like buildings and terrain) that lie between the potential source of interference and the satellite dish. These factors are highly relevant to actual interference potential. *See*, *e.g.*, Award Consultation ¶¶ 9.33–9.34 (discussing Ofcom's interference modelling). For instance, an MNO base station located behind rather than in front of a satellite dish, with a wooded hill and buildings between them and no line-of-sight visibility, presents no risk of harmful interference to the dish even if the calculated signal level at the earth station location using free space path loss exceeds the proposed signal level threshold of -43 dBm/5 MHz.

Automated admissions systems avoid these kinds of inefficiencies because they use algorithms designed for large-scale application, advanced propagation models that have been confirmed through real-world testing, and detailed device and geography information. Accordingly, quickly establishing dynamic sharing as an available option in the UK will enable Ofcom to manage coexistence challenges like those discussed in the Award Consultation across the full range of

spectrum bands, both to phase out incumbent uses in favour of more efficient uses and to introduce new opportunities for shared commercial use.

Question 12: (Section 10) *Do you agree with the non-technical conditions that we propose to include in the licences to be issued after the award of the 700 MHz and 3.6–3.8 GHz bands?*

Ofcom identifies three reasons why it is disinclined to adopt a use-it-or-lose-it requirement for new 3.6–3.8 GHz licences:

> • Such conditions are very difficult to make workable in practice because of the problem of defining what constitutes 'use' and therefore what the trigger for an enforced trade or revocation would be;
>
> • There may be entirely legitimate reasons for spectrum remaining unused – the licensee may be holding back until it sees a suitable commercial opportunity or until the technology it wishes to use is ready;
>
> • Imposing such an obligation also has the potential to distort and/or chill the incentives to invest in the spectrum, and so reduce the benefits for consumers and citizens which the award would otherwise create.

Award Consultation ¶ 10.19. Dynamic sharing of unused spectrum achieves most of the benefits of a use-it-or-lose it regime, without these difficulties. Instead of requiring Ofcom to adopt and apply an abstract definition of "use," spectrum sharing databases—by means of data analysis within the contours of all of Ofcom's relevant decisions—can answer the concrete question whether a particular proposed use would cause harmful interference to any protected registered use. Sharing puts fallow spectrum to productive use when the licensee is holding back on its own deployment. And because sharing of unused, licensed spectrum does not diminish the licensee's rights of use, it should not discourage MNOs and other primary licensees from investing in spectrum. In short, a use-it-or-share-it policy offers a compelling alternative to use-it-or-lose-it.

It therefore is wise for Ofcom to include a licence condition requiring licensees to provide information regarding their equipment and use of frequencies, on Ofcom's request. Award Consultation ¶¶ 10.26–10.28. Such information is a critical input for automated sharing systems. In addition, after dynamic spectrum sharing frameworks have been adopted, detailed information on any harmful interference can be used to refine individual regulatory frameworks. The proposed condition thus is essential to enable quick deployment of automated sharing.

Question 13: (Section 11) *Do you agree with the technical licence conditions we propose?*

Ofcom is correct to identify harmonization of technical requirements between the 3.4 GHz band and 3.6–3.8 GHz band as an important objective. Harmonization enlarges the potential market for new network hardware and consumer devices, and thereby encourages manufacturers to make equipment available sooner and at lower cost.