Response to Ofcom Consultation "Supporting the UK's wireless future: Our spectrum management strategy for the 2020s"

26th February, 2021

Executive Summary

5G New Thinking strongly supports Ofcom's aims to enable more spectrum sharing. It is our view that:

- Local licences in 4G & 5G bands such as the Shared Access Licence ("SAL") are of particular importance;
- A coming surge in demand for Private Mobile and Fixed Wireless Access 5G networks will necessitate an Automated Spectrum Sharing solution for SALs;
- A lightweight "automated-to-the-engineer" sharing framework based on SALs and immediately compatible with off-the-shelf equipment should be put in place promptly (as defined in detail below);
- This framework can later be expanded into an "automated-to-the-device" sharing framework similar to CBRS when the ecosystem evolves to need it, or when particular users require unscheduled changes to their protection at short notice;
- Further frequency bands and licence-exempt tiers can be readily added to the framework, automated to the engineer or to the device as appropriate;
- Ofcom can better realise its strategic aims by taking a more joined-up and sector-specific approach to reducing the costs of smaller operators deploying rural networks.

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1 About 5G New Thinking

1.1 Background

5G New Thinking is a part-government-funded project run in partnership with the Department for Digital, Culture, Media & Sport. The project commenced in May 2020 with the aim to develop and evaluate a rural network 'toolkit' for enabling sustainable mobile and wireless connectivity, using 5G technologies and strategies in rural areas across the UK. The project builds upon the many achievements and learnings of the 5G RuralFirst project which ran from April 2018 to September 2019 and addressed the many challenges facing 5G deployment in rural areas, including demonstrating the technical feasibility of using neutral hosting and shared spectrum to deliver 5G connectivity for a range of use cases in rural areas.

5G New Thinking's members bring an unparalleled breadth and depth of experience in Automated Shared Spectrum from end to end over many years, including numerous field operations, building and operating a CBRS SAS in the USA, building and operating a TVWS database in the UK and in several other jurisdictions, partnering with equipment vendors, and contributing to numerous regulatory and technical standards documents.

1.2 Aims & Objectives

The project's main ambition is to develop a toolkit that communities and/or local, non-mainstream network operators can make use of in order to design, build, and operate commercially viable and sustainable Mobile or Fixed Wireless Access 5G networks. It targets areas which are served by none of the mainstream MNOs (i.e. full not-spots), areas which are served by some but not all of the mainstream MNOs (i.e. partial not-spots), and areas where home broadband falls well below government minimum guidelines.

The project's objectives are to:

- Investigate the challenges of providing wider coverage of rural areas based on community needs;
- Further develop the strategies of the 5G RuralFirst testbed and use it to test and evaluate technical solutions, new commercial models, and Ofcom's Shared Access Licence and Local Access Licence products;
- Develop a toolkit for the creation of full-coverage mobile and wireless networks for unserved or underserved rural areas, with a focus on Scotland;
- Track and aid the setting up of an initial community network and to take learnings from the community network's commercial operation in order to best inform the toolkit;
- Build rational and sustainable business and commercial models to efficiently and cost-effectively deploy community networks throughout the UK and operate them where possible in concert with incumbent MNOs;

- Work directly with councils, civic partners, and community stakeholders in creating new 5G networks that can be managed, sliced, and structured to address their requirements;
- Work with key industry, social, and welfare partners to demonstrate the applicability and impact of 5G connectivity.

1.3 Motivation

5G New Thinking's principal concern is the application of 5G to serve the general population in rural areas of the UK. We also recognise the important role that 5G will play in industrial and agricultural IoT use-cases, and in commercial use-cases such as private corporate networks. This response keeps all these use-cases firmly in mind when considering the technical and regulatory aspects of the consultation. It is our view that rural connectivity use-cases will deliver the greatest social value, and therefore that any technical and regulatory discussion must be underpinned by a thorough understanding of the civic and social issues which we seek to solve. We count the Orkney Islands Council among our members, and we are conducting field trials around Orkney. Orkney suffers from an unusually severe combination of connectivity difficulties, and so serves as an exemplar for other communities around the UK who experience some or all of the same difficulties.

An estimated 35% of homes and businesses in Orkney are not connected to a network capable of delivering 30Mbps, which is far poorer than an estimated 5% elsewhere in Scotland. Delivering improved connectivity is a high priority for Orkney Islands Council, to mitigate against the effects of distance and isolation, to allow businesses and the public sector to modernise, and to deliver improved quality of living including, improved opportunities for remote learning, healthcare and employment for residents.

The impacts of the COVID-19 pandemic and the subsequent lockdown measures have emphasised the importance of connectivity as never before – suitable broadband and mobile coverage is essential to allow people to work from home, for children to access remote learning from their schools, for people to stay connected with loved ones and for essential services to be delivered. People in places where broadband coverage is inadequate or non-existent have suffered more from disruption to daily living than those with robust connections.

The digital divide poses a serious challenge to inequality and social mobility in Orkney. To date neither the market nor public-sector interventions have managed to bridge the gap. Instead rural areas are playing catch-up as the market moves on to providing the next generation of network innovations to cities. In areas where there is effectively no competition consumer outcomes have often been lacking and the regulatory environment has not been able to incentivise or ensure the necessary investment to maintain or upgrade network infrastructure. As a result, an infrastructure deficit has been created over time, which has resulted in variable availability and quality of service across the country.

It is clear that there is need for a significant improvement of telecom infrastructure in Orkney as soon as practicable. Previous attempts to improve connectivity in rural areas have failed. 5G New Thinking recognise the importance of cutting-edge telecommunications as covered in this consultation, but it is also important to recognise that many smaller or remote rural communities and businesses are still waiting for more basic levels of connectivity. It is important to address the regulatory issues that have contributed to the digital divide as well as getting the framework right for next-generation connectivity.

2 Automated Spectrum Sharing for Shared Access Licensing

Q10: Do you agree that continued use of our existing spectrum management tools (as set out in sections 4-7) will be relevant and important for promoting our objectives in the future, in light of future trends?

2.1 Summary

1. 5G New Thinking strongly supports the aims of Ofcom's spectrum management strategy for the 2020s to enable more spectrum sharing and to support innovation [1]. We agree that Ofcom's existing spectrum management tools [1] §4-7 are relevant and important to Ofcom's objectives.
2. We strongly support Ofcom's approach of making spectrum available on a localised basis [1] §4.34-4.42 and we believe that careful choices of Automated Spectrum Sharing tools [1] §6.17-6.21 are critical to the success of localised access at an impactful scale.
3. It is our view that an important trend in the short-to-medium term will be industries, communities, and small network providers setting up Private Mobile 5G and Private Fixed Wireless Access 5G networks in highly-localised areas.
4. We strongly support Ofcom's previous introduction of Shared Access Licences ("SALs") and Local Access Licences ("LALs") [15]. A principal aim of the 5G New Thinking project is to investigate innovative means of using these two licence products to deliver mobile and wireless connectivity. We regard these licence products as an important step in applying the principles of shared spectrum to the 4G and 5G bands. Ofcom can further its leading international role in the nimble use of localised shared spectrum access to enable existing mobile device ecosystems to be deployed in new business models outside of the orthodox MNO model.
5. The USA C-band (3.7-4.2GHz) auction raised $81bn in December 2020 [16], and the 3.8-4.1GHz parts of the n77 band were auctioned in Japan in 2019 [17]. There is good reason to expect a surge in demand, and for major OEMs to invest in a healthy ecosystem of carrier- and consumer-grade devices for use in 3.8-4.2GHz.
6. It is our view that SALs are ideally suited to enabling Private 5G networks in the 3.8-4.2GHz band, but we are concerned that the current manual processing of applications will not scale to meet demand. We strongly believe that Automated Spectrum Sharing is the most appropriate solution, and we concur with Ofcom that leveraging existing mobile device ecosystems [1] §§4.35, 4.40, 6.20 will contribute to the success of such sharing.
7. Citizen Broadband Radio Service ("CBRS") in the USA, and TV White Spaces ("TVWS") in the UK and elsewhere, represent the current state of the art in Automated Spectrum Sharing. We recognise Ofcom's leading efforts in TVWS, and we consider both TVWS and CBRS to be excellent stepping-stones towards future Automated Spectrum Sharing

frameworks. In §2.2 we consider in detail what may be learnt from each framework and what must be improved upon at both a technical and a strategy level.

8. It is our view that the limited market impact of TVWS was caused mainly by the need for an entirely new UHF device ecosystem, and unacceptable risk of losing spectrum access without notice. In order for TVWS devices to react to unscheduled changes in spectrum availability at short notice due to higher-priority users, each individual device must run firmware which is specific to TVWS in order to have direct contact with a White Space Database ("WSDB").

9. CBRS successfully addressed the issues with TVWS during its years of development and had substantial up-front investment from major carriers and major OEMs. A licensed tier guarantees spectrum access for 10 years. Band 42/43 LTE hardware can be used with no CBRS-specific firmware, as CBRS permits centralised Network Management Software to contact a Spectrum Access Service ("SAS") on behalf of many devices. While some devices now have CBRS firmware to contact the SAS directly, the support of existing off-the-shelf hardware was key to the success of CBRS.

10. Although CBRS and TVWS have very different hardware ecosystems and have had very different market uptake, the CBRS SAS and the TVWS WSDB have a comparable range of core responsibilities. In addition to responding to device queries for spectrum, a SAS/WSDB is responsible for large volumes of Automated Coexistence Calculations according to regulator specifications, issuing 'permission to transmit' at given frequencies within a licensed or licence-exempt regime, keeping fine-grained records of spectrum usage, managing databases of incumbent and shared-spectrum users, and maintaining the operational relationships with operators. Permitting third-party specialist providers to perform these functions at scale relieves the regulator of the day-to-day burden and expense of administering large numbers of spectrum users, and the capital expenditure of developing complex software and its supporting high-availability infrastructure.

11. Ofcom should promptly introduce a lightweight "automated-to-the-engineer" sharing framework, whereby an engineer can obtain SALs from an automated SAS/WSDB via a web interface; the engineer is then responsible for manually configuring any devices to comply with the terms of the licence and the assigned frequency range. This approach requires no UK-specific hardware, firmware, or software, and so is ideally suited to the immediate use of existing off-the-shelf 4G & 5G devices and Network Management Software. The incumbent users in the SAL bands do not make unscheduled changes at short notice, so there is no current need for devices to interact directly or indirectly with a SAS/WSDB. The SAL licensing regime and existing licences will not require significant modification. A SAS/WSDB's responsibilities will simply include 'responding to human website requests for spectrum' in place of 'responding to device requests for spectrum' and would otherwise perform the same range of responsibilities as for CBRS & TVWS (¶10). In §2.3 we consider in detail the application of Automated Spectrum Sharing to SALs and the 3.8-4.2GHz band in particular, and in §2.4 we make specific proposals.

12. This framework can later be expanded into an "automated-to-the-device" sharing framework similar to CBRS, whereby the devices directly interact with the SAS/WSDB without human intervention, when there is sufficient market demand, when the ecosystem evolves to need it, or when particular users require unscheduled changes to

their protection at short notice. Many of the components, including a SAS ecosystem, will already be in place, expediting this transition.

13. It is likely that some minor customisation will be needed for existing CBRS device firmware and/or centralised Network Management Software to support a UK automated-to-the-device framework, even if that framework closely mirrors CBRS. Furthermore, other devices and Network Management Software may not already have CBRS support but are nevertheless suitable for SAL bands; manufacturers will need to develop support for the UK from scratch. It is our view that this is a realistic aim, but Ofcom should enable market uptake to grow in parallel with firmware/software support rather than being dependent upon it. We urge Ofcom to introduce an automated-to-the-engineer framework to make the best possible use of spectrum as soon as possible, and to expand it later to also support an automated-to-the-device approach if appropriate.

2.2 Existing Automated Spectrum Sharing: Key Learnings

14. TVWS and CBRS are both Automated Spectrum Sharing frameworks resulting from a significant investment from their respective regulators and stakeholders, and both comprise a considerable level of complexity in their various regulatory and technical components.

15. The development of any future Automated Spectrum Sharing framework must be underpinned by a thorough understanding of the features of these frameworks, why those features were designed as they were, the successes of these frameworks, the factors underlying their market uptake, any shortcomings or difficulties which can be avoided, and any elements which cannot easily be replicated.

16. 5G New Thinking's members bring an unparalleled breadth and depth of experience in Automated Shared Spectrum from end to end over many years, including numerous field operations, building and operating a CBRS SAS in the USA, building and operating a TVWS database in the UK and in several other jurisdictions, partnering with equipment vendors, and contributing to numerous regulatory and technical standards documents.

17. We will therefore give a foundational analysis in this section of what can be learned from TVWS and CBRS, apply it in §2.3 to how Automated Spectrum Sharing can be applied in the UK in future, and conclude with specific proposals in §2.4.

2.2.1 TVWS

18. We recognise Ofcom's pioneering work in establishing the TVWS framework [2]. Many difficult regulatory and technical problems were solved with no precedent. Ofcom's solutions compare favourably with TVWS frameworks in other jurisdictions [3],[4] in many areas, particularly Coexistence and Interference Management, and have been used as the foundation for frameworks for the developing world [5].

19. It is our view that TVWS represents an excellent stepping-stone towards future Automated Sharing frameworks, and that a number of its solutions can be reused with minimal modification. The concept of Automated Spectrum Sharing has been conclusively proved to work in practice.

20. While TVWS has been a regulatory success, it has nevertheless had a limited market impact in the UK and globally. Understanding the reasons for this is critical to the success of any future Automated Sharing framework.

Regulatory Success

21. TVWS has conclusively proved, in the UK and globally, that devices can operate without ongoing human intervention, along with a TVWS Database (WSDB), to use highly-localised gaps of unused licensed spectrum at relatively high power without causing harmful interference to the incumbent licensees.
22. A TVWS framework can broadly be divided into four sections:
    a. Automated Coexistence Calculations;
    b. Interference Management and Regulatory Oversight;
    c. Automated Device Behaviour;
    d. Licensing Regime.
23. It has now been conclusively proved, in the UK and globally, that third-party WSDBs can accurately perform complex Automated Coexistence Calculations [2] (Annex 1-10) for immediate real-world use by devices. Ofcom took the correct approach of delegating the operation of WSDBs to specialist third-party providers.
24. Ofcom kept the most intensive calculations in-house, namely a pre-calculated pixel-by-pixel analysis of coexistence with household TV reception. It is our view that WSDBs and equivalents are capable of performing pixel-by-pixel analysis at scale using sophisticated propagation modelling (e.g. for [5]), and are better placed than Ofcom to do so in an ongoing operational capacity.
25. Ofcom put into place extensive mechanisms for Interference Management and Regulatory Oversight [2] §3.7(ii) & (iv), §3.19-25, Annex 8 part 8. Each WSDB provides a software service which Ofcom can query to identify possible interference culprits, and place restrictions on a culprit's transmissions which will take immediate effect in the field. Ofcom can unilaterally make immediate changes to a number of coexistence parameters. We concur with Ofcom [1] §6.19 that these mechanisms have proven to be extremely useful in practice to effect the 700MHz migration.
26. It is our view that Ofcom's Interference Management and Regulatory Oversight mechanisms for TVWS have been a success, and are sufficiently generic to be applied with minimal changes to any future Automated Spectrum Sharing framework.
27. The Automated Device Behaviour for TVWS in the UK is defined by ETSI [7]. The protocol for communication between a device and a WSDB is not mandated by Ofcom, as is generally the case globally; PAWS [8] is the common standard used in practice.
28. It has been conclusively proved, in the UK and globally, that TVWS devices behave correctly in the field, reacting promptly to instructions to change channel or reduce power. The general approach of radio transmissions taking place without human intervention according to queries to a database is sound.

29. It is our view that Ofcom took the correct approach by not specifying the protocol for a device to communicate with a WSDB or equivalent, and leaving this protocol for the relevant parties to agree upon continues to be the best approach to take in future.

30. TVWS devices operate under a *de jure* licence-exempt regime. They report to the WSDB their location and other parameters without any human input or tampering. They are not guaranteed to have any spectrum available to them at any time, and any spectrum which is available may become unavailable without notice. Coexistence between licence-exempt devices is left to the devices (e.g. listen-before-talk) or for their operators to agree upon. A response to a device from a WSDB nevertheless has some properties of a *de facto* short-term licence, as it allows the device to transmit legally where it could not do so otherwise.

31. It is our view that 'Automated Spectrum Sharing' need not imply 'licence-exempt' or *vice versa* in the general case, even though TVWS in particular is both. In principle, a response from a WSDB-like service could constitute a *de jure* licence, and in principle that licence could include some guarantees of availability and/or protection from other spectrum users.

32. Ofcom's Manually Configurable White Space Device ("MCWSD") regime [9] already offers a middle ground between fully licence-exempt use and licensed use. An operator purchases a yearly licence from Ofcom to operate MCWSDs. They may then provide the location or other parameters of their devices to the WSDB, after which their devices may communicate with the WSDB and transmit in an automated fashion. The response to the device from the WSDB still does not constitute a *de jure* licence, but unlike fully licence-exempt use the automated behaviour has the legal underpinnings of the operator's MCWSD Licence.

33. It is our view that the MCWSD licensing regime was a successful addition by Ofcom to TVWS in the UK. It has proven that Automated Sharing works in practice outside of a fully licence-exempt regime, and that a part-manual and part-automated approach to spectrum sharing is appropriate in some scenarios. We strongly encourage Ofcom to build upon this precedent when considering future Automated Spectrum Sharing frameworks.

<u>Limited Market Impact</u>

34. TVWS has had a limited market impact in the UK and globally. While it enables a number of use-cases in theory, in practice its primary use is fixed wireless links to provide domestic broadband in rural USA supported by stimulus funding by a large corporation [10].

35. It is our view that this limited impact is due to the intersection of several factors:
    a. TVWS needed an entirely new ecosystem of UHF radios to use the TV frequencies, in particular with a neighbour-friendly over-the-air protocol [11];
    b. TVWS needed entirely new specialised device software/firmware to communicate with a WSDB and operate automatically;
    c. TVWS's licence-exempt nature means there are no guarantees of spectrum availability on any time-frame;

d. Overly-pessimistic coexistence parameters unnecessarily reduce the availability of spectrum;

e. Some minor regulatory details have a disproportionately adverse effect in practice.

36. The lack of an existing device ecosystem, both carrier- and consumer-grade, which was suitable for the UHF band (except as noted below) meant that significant up-front OEM investment was necessary for TVWS to be commercially successful.

37. The lack of any guarantees of spectrum availability means that any operator needs to tolerate the risk that services built on TVWS might need to be terminated at no notice. This risk roughly correlates with the population of a given area, meaning the risk is tolerable only in small target markets. This has proved to be a tenuous foundation upon which to build a business model, particularly for use-cases which might typically include a service-level agreement with the end user.

38. Perhaps as a direct consequence of ¶37, no major OEM invested in bringing carrier- or consumer-grade TVWS devices to market at scale and at affordable prices. A number of smaller OEMs have produced devices in low volumes at high prices. The lack of consumer handsets has pushed the market towards fixed point-to-point and point-to-multipoint links, reducing the number of customers which can be served by a given link. It has proven difficult for operators to find a profitable business model.

39. Each OEM had to develop firmware to interact with the WSDB and control the device's behaviour, and then obtain the necessary certification to operate. This typically added approximately a year to the time-to-market for each device and was typically performed in parallel with similar processes in other TVWS jurisdictions.

40. We concur with Ofcom's comments on more accurate and less pessimistic coexistence calculations [1] §7.57-60. For TVWS the Generic Operational Parameters ("GOPs") are so overly risk-averse as to be unusable in practice, resulting in the unfortunate scenario of a newly-activated device being unable to contact a Master device using low-power GOPs to handshake and obtain the much higher-power Specific Operational Parameters which it could otherwise safely use.

41. TVWS devices are typically attached to high-gain directional antennas. Because any description of these falls outside what a device can feasibly report accurately to the WSDB without human intervention, the effect of antenna directionality and polarisation is neglected in the coexistence calculations, giving an overly-pessimistic result. Given that the MCWSD licensing regime already admits human input, there is no reason in principle why the antenna characteristics cannot be provided manually and included in coexistence analyses.

42. TVWS devices may report their height AGL or AMSL. There is an incentive to do so, because an overly-pessimistic default is applied if not. However, due to the requirement of no human intervention [7] §4.2.11, automated means of measuring height must be used, with the following consequent problems:

    a. GPS is considerably less accurate in the vertical plane than the horizontal [12];

    b. TVWS in the UK requires the device to report its geolocation each time it obtains spectrum [7] §4.2.7.3.4;

c. Spectrum availability in TVWS is highly sensitive to variations in the device's reported antenna height, and the error range of consumer-grade GPS is comparable to the entire 1.5-30m height range supported by the TVWS framework. More accurate units are available (e.g. combined GPS/GLONASS/BD), but further drive up the cost of the device;

d. GPS height 'jitters' from measurement to measurement, meaning that each request for spectrum quoting a fresh GPS measurement may receive significantly different spectrum availability from the previous request, making any link feasibility vary wildly from request to request and making a stable link impossible;

e. Even neglecting any inaccuracies in GPS measurement, a TVWS device with an onboard GPS chip measures the height of the device, not the height of its UHF antenna which may be many metres higher; a human is not permitted to configure the device to apply a correction based on the particular height of its antenna above the device, and devices typically do not support external GPS antennas being mounted beside the UHF antenna.

Taken together, the above problems mean that automated vertical geolocation is practically unusable for TVWS in the UK. Fortunately, the MCWSD regime provides an alternative whereby the device's true height can be accurately measured by a human and used thereafter without jitter effects (in the USA the installer may measure the height of a TVWS device [3] §15.711 (c) (1)).

43. In the event whereby a device is unable to contact a WSDB due to network issues or WSDB downtime (planned or unplanned), it is required to shut down within 15 minutes. Operators typically do not have commercial relationships with more than one WSDB, and devices typically do not support hopping between WSDBs. The WSDB is then a single point of failure for every TVWS network it supports, along with their onward services. This has the needless effect of driving the WSDB provider's operating costs to provide High Availability services; a grace period in the regulations in such scenarios would remove this problem (e.g. in the USA the device may continue transmitting as-is until midnight the following day [3] §15.711 (h)).

Commentary

44. TVWS was an ambitious venture for Ofcom and for other regulators, and has in many ways been a success. Each of the primary difficulties experienced by TVWS (¶35) is surmountable. Ofcom and other parties should not regard the limited market uptake of TVWS specifically as evidence that Automated Spectrum Sharing is not commercially viable in general.

45. By building on TVWS, it can take significantly less time for a new Automated Spectrum Sharing framework to be developed.

46. We concur with Ofcom that leveraging existing mobile device ecosystems [1] §§4.35, 4.40, 6.20 will contribute to the success of future Automated Sharing. It is our view that an existing ecosystem, or the compelling expectation of a new one, is a prerequisite for such frameworks. This will further shorten the timeframe for a new sharing regime to lead to commercial deployments at scale.

47. In our view, the use of TVWS in a commercial research venture *Project Belgrade* [13] showed a promising way forward for Automated Spectrum Sharing in general. The difficultly of no existing device ecosystem (¶35a) was overcome by observing that a small number of LTE bands overlap the 700MHz band, which was available for TVWS at the time. An off-the-shelf LTE base-station was augmented with custom software to communicate with a WSDB and operate automatically according to the response. Off-the-shelf consumer Mi-fi devices were handed out to local households who were unable to afford internet access, and a functioning fixed-wireless broadband network was run for some months. The project was abruptly terminated due to difficulty ¶35c when the relevant frequencies were made unavailable in the area by the 700MHz clearance. The 5G Rural First project also conducted deployments along comparable technical lines [14]. Notwithstanding the R&D nature of the projects, the concept of using off-the-shelf carrier- and consumer-grade devices within an Automated Spectrum Sharing framework for which they were not specifically designed was conclusively proven to be sound.

48. We describe TVWS in the UK as a "fast heartbeat" sharing framework: a device must check a WSDB every 15 minutes to confirm that its spectrum availability has not changed; the underlying PMSE dataset is updated every 5 minutes, and Ofcom may apply changes through various means at any time.

49. In practice, PMSEs tend to be located in urban areas, and TVWS devices in rural areas. As such, the minute-to-minute changes in PMSEs do not generally impact TVWS devices. DTT transmitters seldom change, particularly outside projects like the 700MHz clearance, and never at only 15 minutes' notice. Ofcom seldom apply changes to the various parameters, and it is not essential for doing so to have an immediate effect, especially when the parameters are being relaxed. We can see the benefit of Ofcom's ability to make immediate changes the availability of an interference culprit (a remote 'kill-switch'), but there is no equivalent capability for other culprits causing interference with DTT, and if there are no nearby PMSEs then it is not, in our view, essential for this capability to take effect immediately. It is our view that TVWS is over-engineered for the majority of scenarios it supports.

50. By contrast, TVWS in the USA has a "medium heartbeat", requiring daily checks of availability via the WSDB. While there are some provisions for reacting more quickly to changes in Licensed Low Power Auxiliary Stations (broadly analogous to PMSEs) [3] §15.711 (i), these are the exception rather than the default (and the 'push' method is technically impracticable). In principle the same could be true of TVWS in the UK; there is already a mechanism for changing the heartbeat rate on a region-by-region basis [2] §3.7(ii).

51. The notion of a device contacting the WSDB and automatically applying the results serves two primary purposes: reacting to unscheduled changes in availability in fast-heartbeat scenarios, and allowing licence-exempt operation by precluding human intervention in the transmissions.

52. We note that the slower the "heartbeat" of a given sharing framework, the greater the feasibility of requiring a human to effect any unscheduled changes in spectrum availability.

53. We further note that the part-manual part-automated MCWSD licensing regime already permits human intervention in a way which affects spectrum availability, and therefore transmissions.

54. We therefore conclude that there are scenarios in which Automated Spectrum Sharing is appropriate and for which automated devices are not necessary, thus removing difficulty ¶35b. We will develop this concept below.

55. Given the complexity of the TVWS framework, it is our view that it was not feasible to expect that no minor issues would arise in practice. Issues such as those in ¶35e often have no impact on coexistence with incumbent users, and instead are 'bugs' whereby the framework is unable to perform as intended. Ofcom should have predefined a process for making surgical changes to resolve such issues as they arise without the need for a wider formal process or public consultation. This is a natural extension of the existing ability of the Policy Team responsible for the day-to-day management of TVWS to make changes to various parameters. It is our view that any future Automated Sharing framework should include such a provision.

2.2.2 CBRS

56. The success of CBRS proves that an Automated Spectrum Sharing approach can simultaneously make more efficient utilisation of spectrum, enable new and innovative uses of spectrum, and provide viable and popular new business models for small and large entities.

57. Since commencing commercial service in January 2020, CBRS has seen over 100,000 deployments as at January 2021. The predominant use-cases are Private LTE Networks for small operators, and additional capacity in urban areas for large operators.

58. The auction for CBRS Priority Access Licenses raised $4.5bn from 228 bidders for a total 20,625 licenses [24], of which approximately 14,500 were purchased by over 200 non-MNOs costing $1.7bn. This is clear evidence that a strong market exists for localised licences outside of the traditional MNO business model.

59. Approximately 100 models of CBRS device ("CBSD") have been certified [23]. CBSD base-stations require either CBRS-specific firmware to interact directly with a CBRS SAS, or for centralised Network Management Software to have CBRS-specific features to do so on their behalf ("Domain Proxy"). In either case the interaction uses a protocol defined specifically for CBRS.

60. CBRS conclusively demonstrates that Automated Coexistence Calculations in mobile bands by SAS operators is technically feasible and gives good results in practice. In particular, CBRS considers the aggregate interference caused to higher-tier users by multiple CBRS devices ("CBSDs").

61. The CBRS band is shared between three tiers of users: Incumbents, Priority Access Licenses ("PALs"), and General Authorized Access ("GAA"). The incumbent users have the highest priority and are mainly Fixed Satellite Stations and military radars in coastal regions. PALs were sold at auction, each covering 10MHz (of the 100MHz available between 3550 and 3650MHz) in one county for a ten-year term, with up to seven PALs operating concurrently with a maximum 40MHz per operator. GAA users are licence-exempt, have the lowest priority, and can use any part of the 3550-3700MHz band not in use by a higher-tier user – including the 50MHz which is not available to PALs.

62. It is our view that making a minimum 80MHz available to GAA users not in the vicinity of the relatively sparse incumbents provides a sufficient guarantee of ongoing usage to enable viable business cases (compare with TVWS ¶37).

63. Given that PAL operators pay more than GAA operators, and PALs receive protection from GAAs, CBRS is a working example of Ofcom's proposal of "charging a higher fee for more protection" [1] §7.98.

64. It is our view that the uptake of PALs by MNOs – typically as additional capacity in urban areas – is a key driver for CBRS support in the consumer handset ecosystem, and *vice versa*.

65. Coexistence between CBSDs in the GAA tier can be managed by a SAS. A nightly process can evaluate whether nearby CBSDs from different operators have overlapping coverage, compute the most efficient frequency allocation, and require devices to change frequencies accordingly.

66. CBSDs must contact a SAS every 5 minutes to confirm that there have been no unscheduled changes to the availability of spectrum. In our terminology (¶48-52) it is a "fast-heartbeat" framework, and the possibility of e.g. a military radar becoming active at short notice necessitates this fast heartbeat in some areas. In practice, many inland deployments have no chance of being affected by changes at short notice, and the heartbeat could safely be 1 day in those areas.

67. Small-cell Category A CBSD's can transmit up to 1W EIRP, and if outdoors at a maximum height above average terrain of 6m. They may automatically measure their own location and height – the latter to ±3m accuracy. Large-cell Category B CBSD's can transmit up to 50W EIRP at unlimited height and must be installed by a Professional Certified Installer, who can enter the location and height. Both categories report location and height once to the SAS during registration, and do not subsequently report their location; this avoids the issue of 'jitter' (¶42d). Both categories permit only fixed devices, which may communicate with many movable end-user devices (typically handsets). In practice, >75% of CBSD installations rely on the manual Professional Certified Installer method, with <25% having automated geolocation. More than 1700 Professional Certified Installers are now certified [23].

68. The USA is a very large market, and the CBRS framework, ecosystem of entities (SAS, ESC, Installers etc.), and ecosystem of major operators and major OEMs took a number of years of careful collaboration to establish.

2.2.3 Key Learnings for Automated Spectrum Sharing in General

69. In this section we will consider Automated Spectrum Sharing in general, and how to build on the successes and learnings from TVWS and CBRS to significantly improve the chances of success of a new sharing framework. Any issues around device ecosystems are specific to each band and we will not consider them in this section.

70. Both TVWS and CBRS adopted a strategy of deriving measures which are appropriate to the most complex scenario and applying them throughout, even for scenarios which were (and are) years away from being realised, are relevant only in some geographic areas, or are relevant only in a mature ecosystem. It is our view that a nimble strategy should be preferred, first introducing lightweight measures appropriate to simpler scenarios which

exist now or in the near future, and including a clear pathway to more complex measures to support more complex scenarios as they become relevant later.

71. Licence-exempt use is not an essential part of an Automated Spectrum Sharing framework (¶¶30-33, 61), and either a licensed or a part-manual part-automated licensing regime (e.g. MCWSD) may be a more appropriate choice.
72. On a point of terminology, it is our view that 'database' does not adequately describe the purpose of a WSDB and equivalent services. We will use CBRS's term 'Spectrum Access Service' ("SAS") hereafter.
73. It is our view that in the general case the three most difficult aspects of Automated Spectrum Sharing are:
    a. Automated Coexistence calculations as performed by a SAS;
    b. Devices automatically requesting spectrum from a SAS and transmitting accordingly;
    c. Licensing regime.

Automated Coexistence Calculations

74. Automated Coexistence calculations are the defining feature of Automated Spectrum Sharing. Each band will have specific issues due to its propagation characteristics and the incumbent users which require protection. The general principle common to all bands is to find a set of frequencies and power limits at which a particular device can transmit without causing harmful interference to incumbent users (and, potentially, to each other), and without exceeding emission limits at international borders.
75. CBRS shows that the principle of a SAS performing Automated Coexistence calculations in mobile bands is proven to work in practice. Other bands and jurisdictions may differ in details as needed. It has also been proven that SAS providers are capable of performing computationally-intensive point-to-point propagation modelling at scale (¶¶23-24, 60).
76. Accurate and fine-grained data on incumbent deployments and/or coverage is necessary for Automated Coexistence calculations. Where the necessary data is not in the public domain, sufficient contractual protections should be put in place so that such data can be shared in full with SAS providers to be used privately, and solely as an input to the calculations.

Automated Devices

77. We describe TVWS and CBRS as being "automated to the device", which we define as the devices autonomously querying the SAS and configuring themselves to transmit accordingly – or centralised Network Management Software doing so on their behalf. While there may or may not be human input in the setup of the device and its parameters (e.g. antenna height AGL), there is no human intervention in the day-to-day operation and reaction to unscheduled changes in spectrum availability.
78. For spectrum availability to be calculated, the geolocation of the radio must be known. Supporting automated-to-the-device sharing with mandatory on-board automated geolocation raises the cost of devices (particularly if consumer-grade chipsets are not

accurate enough) and precludes the use of off-the-shelf devices which lack this capability (particularly base-stations). Furthermore, it has experienced severe difficulties in practice (¶42), which have been mitigated by manual or part-manual geolocation (¶¶32-33, 67). There may be specific use-cases where mandatory automated geolocation is both workable and necessary (e.g. base-stations on outdoor movable platforms at a known fixed height), but for the fixed base-stations typically used for TVWS and CBRS this is not the case. It is our view that in general an Automated Spectrum Sharing framework must not mandate automated geolocation, and should partly or wholly rely on human input in some or all cases.

79. As we discuss in ¶48-54, TVWS has shown that automated-to-the-device sharing is excessive or unnecessary in many scenarios. It is our view that being automated-to-the-device is not an essential characteristic of an Automated Spectrum Sharing framework.

80. We introduce the notion of "automated to the engineer" sharing. Under this approach, a human interacts with a SAS via a web interface to obtain available spectrum, and manually configures the devices (directly or via centralised Network Management Software) to transmit accordingly. In cases of unscheduled changes to the available spectrum (e.g. from changes to incumbent users), the engineer is notified, and is required by the terms of the underlying licence to implement any changes within a defined period.

81. The automated-to-the-engineer approach makes it significantly easier to use off-the-shelf carrier- and consumer-grade devices, without the need for custom firmware or Network Management Software which is specific to a UK sharing regime. This has the twin benefits of greatly expediting the initial uptake of a sharing regime, and facilitating deployments at large scale.

82. If the incumbent users in a given band and region change infrequently and with plenty of notice, then the "heartbeat" (¶48-52) of the framework can be one week or even one month. Such "slow heartbeat" scenarios are well-suited to automated-to-the-engineer sharing.

83. If the incumbent users in a given band and region change frequently and without notice, then a fast heartbeat is required and the automated-to-the-device approach is indeed essential. Similarly if any protected user, whether incumbent or shared-spectrum, is movable (e.g. ship-mounted) then a fast heartbeat may be appropriate. There is no need in principle for an entire band to have the same heartbeat across the entire jurisdiction, and the concept of a "variable heartbeat" allows each band and region to have the most appropriate heartbeat, defaulting to a slow heartbeat unless there is a specific need for a fast heartbeat.

84. An automated-to-the-engineer framework may be a desirable endpoint in itself. It may also be used as a temporary bridge towards an exclusively automated-to-the-device framework, or towards existing side-by-side with an automated-to-the-device approach with each used for different scenarios (e.g. urban vs rural) using a variable heartbeat.

Licensing Regime

85. For the purposes of Automated Sharing, the licensing regime has three key areas: guarantee of ongoing spectrum usage, protection from other users, and the trustworthiness of human-reported parameters.

86. Licence-exempt TVWS in the UK has no guarantee of ongoing spectrum usage, offers no protection from other users, and disallows human-reported parameters.
87. A MCWSD operator for TVWS in the UK is licensed, but their devices operate on a licence-exempt basis. A MCWSD device similarly has no guarantee of ongoing spectrum usage and no protection from other users, but the underlying licence permits human-reported parameters to be trusted.
88. Licence-exempt GAA CBRS use has no guarantee of ongoing spectrum usage, offers no protection from other users (but does offer some coordination), and allows human-reported parameters by certified (i.e. trusted) installers.
89. Licensed PAL CBRS use guarantees spectrum usage for the duration of the licence, offers protection from other users, and similarly allows human-reported parameters by certified (i.e. trusted) installers.
90. Where no guarantee of ongoing spectrum usage is available, operators must assess the risk of losing the spectrum access they need according to their specific needs. CBRS GAA users have a sufficiently low risk of losing access that licence-exempt use is proving popular (¶62). This is not the case for TVWS in the UK (¶37).
91. It is our view that any future Automated Spectrum Sharing relying, wholly or in part, on licence-exempt use must ensure that the risk of losing ongoing spectrum availability is low enough to be attractive commercially.
92. We concur with Ofcom that tiered levels of protection with differential pricing is an appropriate solution in some cases [1] §7.98. We note the success of this approach for CBRS, in which the PAL and GAA tiers are licensed and licence-exempt respectively.
93. It is our view that future Automated Spectrum Sharing regimes can rely on a tiered model, and that different tiers may have different licensing regimes and different pricing.

2.3 Future Automated Spectrum Sharing

94. In §2.2 we conducted an analysis of how learnings should be taken from TVWS & CBRS into a new Automated Spectrum Sharing framework in the general case.
95. In this section we will apply those learnings to Ofcom's existing non-automated sharing framework. We will then make specific proposals in §2.4.

2.3.1 Shared Access Licences & Local Access Licences

96. We strongly support Ofcom's introduction of Shared Access Licences ("SALs") and Local Access Licences ("LALs") [15]. A principal aim of the 5G New Thinking project is to investigate innovative means of using these two licence products to deliver mobile and wireless connectivity. We regard these products as an important step in applying the principles of shared spectrum to mobile bands.
97. It is our view that LALs provide a unique opportunity for small operators to roll out 4G mobile networks in remote areas in a neutral host model, collaborating with the MNOs to use their fallow spectrum and to extend their coverage, ultimately serving communities which are still waiting for more basic levels of connectivity.

98. An LAL Applicant should engage with the incumbent MNO licensee prior to submitting an application [15] §4.78. To respond to an LAL request, Ofcom must engage with the incumbent MNO licensee [15] §4.100-102. Whether an application is successful depends on whether the MNO currently uses, or has plans to use, their licensed spectrum in the area in question. It is feasible for accurate and fine-grained data on current usage to be shared with Ofcom for the purposes of Coexistence calculations, but it is not feasible to also do so for planned usage. Coexistence analysis is conducted on a case-by-case basis without a formally-codified procedure. For these reasons we do not regard LALs as a strong candidate for expansion into an Automated Shared Spectrum approach, and we shall not consider them further here.

99. It is our view that an upcoming surge in demand for SALs will be driven by uptake of 5G (we will cover 5G in more detail in §2.3.2). Ofcom's current manual application process will quickly become impracticable, and an automated approach will be necessary.

100. An SAL Applicant fills out an application form and emails it to Ofcom, who perform a coexistence analysis based on a codified process [15] Annex 4. SAL licences are provided on a first-come-first-served basis [15] §3.1, so an existing SAL user does not need to react to the appearance of new SAL users nearby. The incumbent primary users in the SAL bands are various Satellite Earth Stations, Point-to-Point Fixed links, MOD facilities, PMSE, and UK Broadband's licence [22]; none of these users requires frequent or short-notice unscheduled changes to the protection they require from secondary users – i.e. the SAL bands have a "slow heartbeat" (¶¶48-52, 82). The SAL licence terms have provision for Ofcom to request (by email) that a licensee manually makes changes to spectrum usage within a specified timeframe [15] §3.187(a). SAL licensees are trusted to provide human-reported parameters (¶85-89).

101. It is our view that SALs are ideally suited to an automated-to-the-engineer approach as defined in ¶77-84, and that this represents an ideal level of complexity to support current and near-future scenarios (¶70).

102. In principle, the process of filling out an SAL application form, submitting it to Ofcom, a coexistence analysis being performed, a licence being issued, and payment of the licence fee can all be automated by a SAS-like service with no changes to the licensing regime or existing licences, no changes to equipment either in use or available for use, no changes to how the engineer configures the device to comply with the licence, and no changes to how the operator or Ofcom behaves after the licence is issued.

103. We note that SALs were explicitly designed with a future migration to automated-to-the-device Dynamic Spectrum Allocation in mind [15] §3.184-186. Given the lead-times required for custom device firmware or Network Management Software to be implemented and rolled out to new and existing device ecosystems (¶¶39, 59), and the lack of necessity to do so in slow-heartbeat scenarios, it is our view that an exclusively automated-to-the-device approach is unnecessary and excessive in the SAL bands.

104. We also note that SALs were explicitly designed to benefit from utilising existing mobile device ecosystems [15] §4.86. We strongly support this aim, and we believe an automated-to-the-engineer approach enables the widest possible use of existing devices and Network Management Software.

105. We support Ofcom's aims to enable innovative spectrum use, and recognise that this may take place with devices which are outside of the 4G/5G ecosystem. It is our view that an automated-to-the-device approach is unlikely to be appropriate in the early stages of such innovation, and that it is attractive to offer to innovators a lower bar to entry than is possible with automated-to-the-device. Nevertheless, we recognise that as some innovations mature they may be more suited to an automated-to-the-device approach, particularly if they require highly dynamic or very short-term licences.

106. SALs are broadly equivalent to PALs in CBRS, in that they are paid-for licences in shared spectrum which guarantee spectrum use, provide protection, and permit human-reported parameters (¶85-89). Ofcom should consider phasing in at a later date an additional, lower, GAA-like licence-exempt tier if the ecosystem or new innovations demand it.

107. Unlike licence-exempt TVWS, SALs have no need for devices to have on-board automated geolocation. It is not reasonable to expect that off-the-shelf 4G or 5G equipment will have that capability. It is our view that Ofcom should not mandate automated geolocation in SAL bands, and where automated geolocation is available it should be non-exclusive and supplemented by human-reported parameters (¶¶42, 53, 67).

108. An automated-to-the-engineer SAL framework can later be expanded into a combined framework (¶84) where the automated-to-the-engineer and automated-to-the-device approaches are used in the bands, regions, or use-cases where each is most appropriate (e.g. urban vs rural), with a variable heartbeat (¶83), and support for movable devices. This expansion in complexity (¶70) should take place when the ecosystem evolves to need it, or when particular incumbent users require unscheduled changes to their protection at short notice, or to exploit more efficient spectrum use (e.g. varying protection of a Satellite Earth Station depending on its current direction).

2.3.2 Shared Access Licences in the 3.8-4.2GHz Band

109. We concur with Ofcom that the 3.8-4.2GHz band is a strong candidate for Automated Spectrum Sharing [1] §1.13. We will therefore consider the details of how automating the SAL framework as in §2.3.1 applies to this band in particular.

110. We concur with Ofcom that an important use-case is private 5G networks [1] §4.35. We expect the primary use-cases for 3.8-4.2GHz to be:

a. Private 5G campus, village, factory, or agricultural mobile networks, using band n77 base-stations with smartphone handsets or sensor devices;

b. Private 5G Fixed Wireless Access ("FWA") networks, using band n77 base-stations with FWA Consumer Premise Equipment ("CPE") broadband modems (e.g. installed throughout villages).

111. We note that the existing Shared Access Licences for 3.8-4.2GHz have restrictions around mobile networks [15] §1.6. We support Ofcom's decision to keep this band free from National Mobile Broadband and concur that the 3.6-3.8GHz band is sufficient for this purpose. We are concerned that the requirement for operators to keep accurate records of mobile devices (i.e. handsets) [15] §3.48 does not prevent SALs forming part of national networks, and instead serves only as an administrative burden for smaller providers.

112. The USA C-band (3.7-4.2GHz) auction raised $81bn in December 2020 [16]. The 3.8-4.1GHz parts of the n77 band were auctioned in Japan in 2019 [17]. The EU is investigating the use of 3.8-4.2GHz for local vertical applications [31]. There is good reason to expect a surge in demand, and for major OEMs to invest in a healthy ecosystem of carrier- and consumer-grade devices for use in 3.8-4.2GHz. Many OEMs already offer consumer handsets supporting the n77 band in some fashion [18]. However, we expect some handsets and FWA CPEs to have their firmware locked to a particular carrier, precluding their use in private 5G networks.

113. We concur with Ofcom's aim to utilise existing equipment ecosystems [1] §§4.35, 4.40, 6.20, and it is our view that all the conditions already exist for this ecosystem to arise in this band. In the next few years we anticipate ready availability of affordable equipment stacks suited to Private Mobile and FWA 5G. We anticipate the OpenRAN initiative [19] to play an important role in facilitating the interoperability of various components of a network stack. We likewise anticipate Core-as-a-Service (e.g. Working Group Two [20]) and open-source Core software (e.g. Open5GS [21]) being critical enablers of smaller, innovative business models for Private 5G networks outside of the orthodox large-MNO models.

114. An automated-to-the-engineer SAL framework will allow off-the-shelf n77 and C-Band equipment and Network Management Software to be used immediately in the UK without modification.

115. An automated-to-the-device SAL framework will require devices to include UK-specific firmware, or to be controlled by UK-specific Network Management Software. It is our view that this is a realistic aim, but a substantial lead-time will be required for OEMs to formulate a business case, develop the software/firmware, and acquire any necessary certification before making the devices available to operators.

116. We partly agree with Ofcom's view that "the 3.8-4.2 GHz band could benefit from the ecosystem for the 3550 MHz to 3700 MHz (CBRS) band in the USA". From a hardware perspective, CBRS devices primarily use LTE as the underlying technology, which is not compatible with 3.8-4.2GHz – although some devices may support both, and 5G use in CBRS is emerging. It is likely that some minor customisation will be needed for existing CBRS device firmware and/or centralised Network Management Software ("Domain Proxy") to support a UK automated-to-the-device framework, even if that framework closely mirrors CBRS. Use of CBRS firmware/software where available can mitigate the difficulties described in ¶115, but the likely need for a custom UK version will still cause additional lead-times; it is also likely that there will be devices and/or Network Management Software which are suitable for SAL bands but which have no existing CBRS support to build upon.

117. 5G Standalone ("SA") user equipment can attach directly to 5G New Radio ("NR") cells and a 5G core network. However, the large majority of 5G user equipment (handsets, FWA CPEs etc.) available at the time of writing are 5G Non-Standalone ("NSA") – i.e. they require 'anchor' 4G cells and a 4G core network to also be in place. Use of such equipment by shared-spectrum 5G users in 3.8-4.2GHz will also require 4G spectrum for the uplink, e.g. an SAL in the 1800MHz or 2300MHz bands. As 5G SA equipment becomes more readily available, we anticipate that this use-case will fall away.

118. 5G SA users have up to 400MHz in the 5G band, which is sufficient to allow multiple networks in the same vicinity to coexist in different frequencies while meeting their individual bandwidth requirements. Any 5G NSA users relying on SALs for both the 5G and 4G parts of their network have 400MHz in the 5G band, but either 3MHz FDD in the 1800MHz or 10MHz TDD in the 2300MHz 4G bands. For an individual network this gives sufficient bandwidth for a 4G uplink, but it provides little opportunity for two such networks in the same vicinity to coexist in different frequencies. It is our view that as 5G SA overtakes 5G NSA this problem will fall away, and that in the short term the beneficial commercial security of the first-come-first-served nature of SALs outweighs the difficulty of two or more 5G NSA coexisting in the same vicinity. The first-come-first-served nature of SALs is the most appropriate approach.

2.3.3 Demonstration of SAS technology

119. Part of the 5G New Thinking project's remit is to develop a prototype of an automated SAS in the SAL bands, and to make practical demonstrations of both automated-to-the-engineer and automated-to-the-device sharing, using the same underlying SAS and the same protocols for both. We would be pleased to share this work with Ofcom later in 2021.

2.4 Proposals

120. We propose that Ofcom promptly puts into place an Automated Spectrum Sharing regime in the 1781.7-1785MHz/1876.7-1880MHz, 2390-2400MHz, 3.8-4.2GHz, and 26GHz (indoor) bands, so as to meet a coming surge in demand for SALs.

121. The first phase should be a lightweight "automated-to-the-engineer" extension to the Shared Access Licensing framework whereby an engineer can obtain SALs via a web interface provided by an SAS/WSDB based on automated coexistence calculations. The engineer will then manually configure the devices, directly or via Network Management Software, to transmit in compliance with the licence, and notify the SAS/WSDB that they have done so. The engineer may later be required by Ofcom to reconfigure the device to use a different frequency within a specified period.

122. This first phase requires no significant changes to the licensing regime, no changes to SALs which have already been issued, no change to the level of protection provided to incumbent primary users, and no changes to the hardware, software, or firmware of equipment either in use or available for use. The SAL framework will continue to permit human-reported location and height, will continue to offer low-power and high-power variants, and will continue to provide licences on a first-come-first-served basis.

123. We envisage that Private 5G networks, with or without a supporting 4G network, will be the primary use-case supported by this framework.

124. Further frequency bands can be added into this framework as appropriate.

125. A subsequent phase can be added to divide the SAL tier into sub-tiers where licensees pay greater or lesser fees to receive a greater or lesser degree of protection from other SAL users.

126. A subsequent phase can introduce a lower, free, licence-exempt tier similar to GAA in CBRS, using a fully “automated-to-the-device” approach similar to CBRS & TVWS, and enabling manual geolocation using either an operator licence similar to a MCWSD licence, or a certified installer programme similar to that of CBRS. This should take place when there is sufficient market demand, when the ecosystem evolves to need it, or when particular users require unscheduled changes to their protection at short notice.

127. We strongly recommend that Ofcom enables specialist third-party providers to build and operate the SAS/WSDB services for SALs, as has proved successful for TVWS and for CBRS. This is true both for automated-to-the-engineer and automated-to-the-device, and any future additions to the sharing framework will be greatly expedited by having this SAS/WSDB ecosystem already in place.

3 Consultation Answers

3.1 Question 1

Do you have comments on the overall approach to the review?

128. We have no specific comments on the overall approach to the review.

3.2 Question 2

Have we captured the major trends that are likely to impact spectrum management over the next ten years?

129. We agree with Ofcom's list of major trends [1] §3.31, most especially the "increasing numbers of niche entrants and sub-national providers".

3.3 Question 3

Could any of the future technologies we have identified in Annex 6, or any others, have disruptive implications for how spectrum is managed in the future? When might those implications emerge?

130. We strongly agree that automated spectrum management tools are relevant to how Ofcom can and should manage spectrum [1] §A6.14-19. We agree that using a centralised service to "schedule resources between different users" has the potential to increase the efficiency of spectrum use, and note that a CBRS SAS can perform a nightly optimisation process to distribute frequencies between licence-exempt users in a fair and efficient way. In the short term the focus on Automated Sharing should be on a centralised service capable of issuing licences and enabling licence-exempt use with assurances of ongoing spectrum availability. In the future, the role of the centralised service can be expanded to facilitate coexistence between users in the frequency and/or time domains, should the demand for the shared spectrum necessitate it.

131. We do not believe that blockchain is or will be an appropriate solution for automated spectrum management databases [1] §A6.20. Generally 'database' is used in this area to denote a 'spectrum access service' which performs complex coexistence calculations using large volumes of privileged data (e.g. incumbent users) and public data (e.g. terrain). Automated Coexistence is practicable only when performed by a centralised service, or a small number of such services. It is possible that a role can be found for blockchain in authenticating devices or for digitally signing requests and licences. Given the power implications for battery-powered devices, and the commercial and environmental cost of centralised services consuming power to perform blockchain calculations at large scale, we would recommend that any consideration of blockchain must demonstrate a tangible benefit when compared to classical methods such as Public Key Infrastructure, certificates, and digital signing.

3.4 Question 4

Do you agree that there is likely to be greater demand for local access to spectrum in the future? Do you agree with our proposal to consider further options for localised spectrum access when authorising new access to spectrum?

132. We strongly agree that the demand for local access to spectrum will increase significantly in the future. The growing success of CBRS in the USA [23] is proof that Private Mobile Networks enable real use-cases which are not supported by the orthodox MNO model, and that a well-targeted automated sharing framework can make a significant impact.

133. We support Ofcom's introduction of Shared Access Licences and Local Access Licences [15] and we strongly believe that these licensing products form the basis of a growing trend of Private Mobile Networks in the UK. We strongly encourage Ofcom to consider further localised licensing options, particularly in the area of Automated Spectrum Sharing; we discuss this in detail in §2.

3.5 Question 5

Do you agree with the actual and perceived barriers identified for innovation in new wireless technologies, and our proposed ways of tackling those?

134. We agree that international-level coexistence and equipment standards serve as a barrier to innovation, and that more flexible non-specific regulation can mitigate this [1]§4.45-4.52.

3.6 Question 6

Do you agree with Ofcom's proposals to improve our outreach and reporting activities, and spectrum information tools? a) Are there additional ways that Ofcom could better engage with existing and future users and providers of wireless communications? b) Please explain any specific areas where you believe more or better provision of information could provide value to stakeholders

135. We support Ofcom's aim to provide information tools which are tailored towards "less spectrum aware users" [1] §5.40-5.43. This will make an important contribution to supporting emerging business models with smaller providers using localised licenses.

136. Potential applicants for Local Access Licences have no direct means of exploring whether a particular frequency range is currently in use in a given location; Ofcom have acknowledged this [15] §4.78-79. We recognise the commercial and security sensitivities inherent in the locations and details of MNOs' transmitters. We recognise the distinction between data detailing current usage, and detailing any planned usage which may reasonably preclude the issue of an LAL [15] §4.101. We note the distinction between

publishing transmitter details and publishing coverage maps, and note that it is the latter which is of interest to LAL applicants. We note that all four MNOs publish maps showing their coverage; as this is generally not disaggregated by band or by technology it is of limited use. We suggest that Ofcom explores further means of making data and maps available to describe current MNO coverage in a band-disaggregated fashion.

3.7 Question 7

Do you agree that it is important to make more spectrum available for innovation before its long-term use is certain? Do you have any comments about our proposed approach to doing this?

137. We agree with Ofcom's aim to make spectrum available for innovation before its long-term use is certain [1] §6.39-41. We agree that licence exemption, light-licensing, and automated spectrum management are appropriate tools for Ofcom to use.

3.8 Question 8

Do you agree that it is important to encourage spectrum users to be 'good neighbours' to ensure more efficient use of the spectrum? Do you agree with our proposals to: a) increase realism in coexistence analysis at a national and international level? b) encourage spectrum users to be more resilient to interference? c) ensure an efficient balance between the level of interference protection given to one service and the flexibility for others to transmit? Do you have any comments on which of these will be the most important?

138. We agree with Ofcom's proposals to ensure more efficient spectrum use. It is our view that more realistic coexistence analysis is the most important of these.

139. We concur that automated spectrum management tools allow Ofcom to make quick refinements to technical conditions as new evidence arises [1] §7.76. We note that the provisions for doing so in TVWS amount to changing a few simple parameters. If evidence arises about a coexistence under- or over-protection issue which cannot be solved by tweaking one of these parameters, and is instead rooted in one of many details of the coexistence process [2], then the framework is unable to adapt. Ofcom should predefine a process for making agile changes to any part of an automated coexistence process, as a natural extension of their existing ability to make changes to various parameters.

3.9 Question 9

Are there any other issues or potential future challenges that should be considered as part of this strategy?

140. We have nothing further to add for this particular question.

3.10 Question 10

> *Q10: Do you agree that continued use of our existing spectrum management tools (as set out in sections 4-7) will be relevant and important for promoting our objectives in the future, in light of future trends?*

See § 2 above.

3.11 Question 11

> *Is there anything else we should be considering doing, or doing differently, to promote our objectives?*

141. It is our view that socio-economic problems arise in rural areas as a direct consequence of poor connectivity, the provision of which is often commercially unviable. We note the Shared Rural Network is an attempt to resolve this market failure by obligating the large MNOs to increase their coverage [25].

142. We support Ofcom's aim "to support the growing diversity of wireless services and providers" [1] §1, and we concur that local licensing in shared spectrum is a key enabler of business models for such smaller operators.

143. Regardless of their size, wireless network operators must commit capital expenditure in a number of areas, including transmitter sites & towers, power, radio equipment, spectrum licensing for end-user service, spectrum licensing for backhaul, and fibre backhaul. For a business model to be viable, enough end-users must be charged an affordable fee to enable a return on investment in a reasonable time. Rural areas by definition have a smaller target end-user market, so reducing capital expenditure is particularly important.

144. It is our view that Ofcom can and should do more to reduce the costs of smaller operators deploying rural networks, by taking a joined-up and sector-specific approach across all aspects of an operator's expenditure which lie within the scope of Ofcom's role as a Regulator.

145. A smaller operator targeting rural end users may choose to deploy a network independently, but this is a difficult model to make viable. If possible they may instead enter into some form of agreement with one or more MNOs, either on a cost-sharing basis or as a Neutral Host. These options do not fundamentally alter the nature of the necessary expenditure, the physical topology of the network, or the equipment needed.

146. Providing 4G services as a smaller operator was previously impossible due to the relevant spectrum being provided only as national licences, or being available as unlicensed spectrum for too short a duration (e.g. [13]). We welcome the addition of Local Access Licences to enable such services in MNOs' unused licensed spectrum, and of Shared Access Licences to enable such services with limited bandwidth in the 1800MHz and 2300MHz bands. We strongly support Ofcom's decision to open the 3.8-4.2GHz band for shared 5G use.

147. Ofcom has priced both the SAL and LAL licences on a cost-recovery basis. As such, they represent one of the lesser parts of an operator's expenditure.

148. It is our view that operators of SALs or LALs will inevitably need to purchase other licences in order to deploy their network. For 4G a 5GHz backhaul link may be sufficient, and these are inexpensive [30]. For 5G a higher-bandwidth link is needed between 'leaf' nodes and 'hub' nodes, and potentially multiple bonded links from 'hub' nodes to reach a backbone. 13GHz and 18GHz licences fulfil this need, but are significantly more expensive [27]; wireless backhaul will likely constitute the large majority of a rural 5G network's licensing costs.

149. Ofcom suspended the most recent fee review due to "uncertainty about how [some bands] might be made available for mobile use [including 5G]" [28], and a supporting external report recommended that "fees in low demand areas should be set at cost-recovery levels" [29].

150. It is our view that now is an appropriate time for Ofcom to revisit those Fixed Wireless Access licence fees which appertain to backhaul links for rural 5G. We do not propose that Ofcom reopens that consultation in full, but we instead propose targeted, sector-specific alterations to fees in support of the wider aims of this strategy consultation. For example, making 13GHz & 18GHz licences available on a cost-recovery basis specifically for SAL and LAL licensees deploying networks in rural areas to serve end-users.

151. Regardless of the number of wireless links, a smaller operator of a 4G/5G network in a rural area will ultimately need to connect the network to a core network. With few exceptions this is highly likely to be an Openreach fibre connection, and is likely to incur significant cost. In an earlier statement on 5G, Ofcom stated "We would expect [fibre backhaul] competition to lead to a diverse range of services in the market … where competition does not provide the necessary services, we will need to consider regulation to ensure such services are available" [26]. Noting the distinction between "available" and "affordable", we recommend that Ofcom considers how it may make targeted, sector-specific alterations to its regulation to reduce the fibre backhaul costs for smaller providers of rural wireless networks, in support of the wider aims of this strategy consultation.

152. Even when a business model can be found which is viable in the first instance, it must be sustainable over a sufficient period to ensure a return on investment. Operators may need to raise funding, e.g. from Venture Capital, and may need to demonstrate profitability over e.g. a 7-year period. Each element of its capital expenditure must be sustainable or replaceable over the same period. This is particularly applicable to spectrum licences in cases where more than one licence product is needed, and where those products have different durations.

153. Shared Access Licences currently have an indefinite duration with no specific end-date, subject to yearly payment, ongoing usage, and to Ofcom's discretion to make future spectrum management decisions [15] §3.205-206. We support Ofcom's intention to revoke licences which are not being used. We recognise Ofcom's wish to retain flexibility for spectrum management purposes, but we are concerned that this gives insufficient security of tenure to make investment attractive. We note that having an indefinite end-date is not mutually incompatible with having a guaranteed minimum duration. We

suggest that Ofcom includes a minimum duration in Shared Access Licences of at least 5 years.

154. We support Ofcom's aims to keep the 3.8-4.2GHz band clear of "national mobile broadband" so as not to "deny opportunities for local users" [15] §1.6. We ask that Ofcom makes an explicit exclusion to enable such "local users" – e.g. rural 5G providers – to use this band to act as a Neutral Host for national mobile broadband to contribute to a viable business model of also providing other services which are not otherwise commercially viable but which provide socio-economic benefits.

155. Local Access Licences currently have a default duration of 3 years [15] §4.59-61. Given that this duration can be extended by agreement with the relevant MNO licensee, it is our view that Ofcom has found an appropriate balance between the needs of the LAL user and those of the MNO licensee.

156. We recommend that Ofcom brings the 700MHz and 3.6-3.8GHz bands into the LAL scheme as soon as is practicable. The 700MHz band may be particularly useful in rural areas for 4G 'anchors' for 5G Non-Standalone networks.

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