Ofcom Spectrum Advisory Board

Annual Report 2013 - 2014

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Contents

Section 1

Message from Ofcom's Chairman

OSAB has, over the past ten years, provided invaluable advice to Ofcom. This has predominantly been as part of its role of "looking beyond the horizon" but OSAB has also acted to broaden the understanding and insight of executive and non-executive members of Ofcom. OSAB's advice has regularly influenced Ofcom's work, from informing policy projects to suggesting topics for longer-term study.

A lot has changed in a decade. Consumers have access to super-fast broadband services, both in their homes and on the move; smartphones and tablets have fundamentally changed the way we communicate; and we stand on the verge of the next communications revolution, which will see millions of devices connected to the Internet of Things. However, while much has changed, we are aware that not everybody is able to benefit from these new services. Issues around cost, coverage and quality of communications services pose significant challenges that Ofcom continues to address, often with expert advice from committees such as OSAB.

Over the past decade, Ofcom has established itself as an effective and efficient regulator, often working with committees such as OSAB to anticipate market and technology developments ahead of time. OSAB's remit has itself changed, from its original focus on spectrum to cover all communications technology, network and services – and the diverse nature of its membership reflects this wide remit.

This year has also been a time of transition for me, as I have replaced Colette Bowe as Chairman. Colette was a strong supporter of OSAB and I, too, value the insight and advice that the highly experienced members of the Committee offer to Ofcom.

I am hugely appreciative of all the time, commitment and, most importantly, the enthusiasm that OSAB members bring to their role and look forward to continue working with them.

Dame Patricia Hodgson

Chairman of Ofcom

Section 2

Foreword by OSAB's Chairman

The Ofcom Spectrum Advisory Board (OSAB) is pleased to present its tenth annual report and my fourth as its Chairman.

In this last year OSAB has offered insight and advice to Ofcom on a number of issues which have predominantly related to the use and management of spectrum. We have explored the future demand for mobile and wireless services and how they will be delivered, debated how the Internet of Things could potentially transform wireless communications and pondered the factors that could affect quality of service and consumer experience in the delivery of mobile and wireless services.

Towards the end of the reporting year Patricia Hodgson took over from Colette Bowe as Chairman of Ofcom and I am delighted to say how very much I look forward to working with her. This year has also been a time of change for OSAB with two members stepping down – William Webb and Simon Saunders – and I wish to use this address to express my thanks for the contribution they made to OSAB during their terms of office.

OSAB meetings are always characterised by the diverse knowledge and the passion for their subject which members bring to its meetings. Its meetings are always attended by senior members of Ofcom who also actively engage in the debates. Chairing OSAB meetings is a genuine privilege as well as a pleasure. I am most grateful to members, and to Ofcom staff (especially the secretary) for making the Chairman's job so easy.

OSAB is embarking on its eleventh year with unabated enthusiasm.

David Meyer

Chairman, Ofcom Spectrum Advisory Board

Section 3

Introduction

Background

4.1 The Ofcom Spectrum Advisory Board (OSAB) was established on 19 May 2004 to provide independent advice to Ofcom on strategic spectrum management issues. OSAB provides Ofcom with:

- A rapid way to test new ideas across a wide range of experts;
- A means of identifying issues that are beyond Ofcom's regulatory "headlights";
- A demonstration of Ofcom's commitment to consult in an open and collaborative manner; and
- A mechanism to help reach an agreed industry view of difficult and contentious issues through the hosting of open fora.

Annual report

4.2 This document reports on OSAB's tenth year. It is intended to summarise selected discussions throughout the year and its content is based on published minutes of OSAB meetings.

Terms of reference

4.3 In 2008 the terms of reference for OSAB were revisited. Ofcom and OSAB agreed that although OSAB's initial role had been to provide advice to Ofcom on spectrum-related matters; it was increasingly difficult to consider spectrum-related matters in isolation in a converging world.

4.4 Hence it was decided that OSAB's remit should be broadened to include all future communication architectures, access methods, physical layer technologies, spectrum issues, services and applications. OSAB would be responsible for high level and longer term vision and not for detailed assessment of different approaches, standard setting or consensus building amongst industry. However, it would not involve itself with content matters.

Membership

4.5 The membership of OSAB is reviewed on an annual basis. This year William Webb and Simon Saunders stepped down from the Committee. Greg Bensberg and Niall Murphy have been newly appointed to the Committee.

4.6 Details of OSAB membership including the length of tenure are at Annex 2.

Work Programme

4.7 OSAB is responsible for agreeing its own work programme. During this year a range of topics was discussed, predominantly related to use and management of spectrum. These topics are broadly indicative of the key themes that OSAB, its members and many in the wider community have been considering over the past 12 months. We have organised the topics into three broad categories:

- The evolution of mobile broadband services;
- The Internet of Things; and
- Quality of service.

4.8 OSAB meets 4-5 times a year and holds an annual workshop where a whole day is devoted to a particular issue. This year the workshop considered demand for pervasive communication services.

The Year Ahead

OSAB sets its agenda from meeting to meeting depending on progress made in particular areas, time available and topics arising. It deliberately does not plan a year ahead to allow for flexibility and responsiveness.

Further Information

4.9 For further information on the work of the Ofcom Spectrum Advisory Board, please contact the OSAB Secretary:

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Section 4

Topics considered during the year

5.1 During this year a range of topics was discussed by OSAB, predominantly related to use and management of spectrum. We have organised the topics into three broad themes:

- **The evolution of mobile broadband services:** exploring demand for mobile and wireless data services and options for their delivery;
- **The Internet of Things:** examining the range of possible applications that make up this emerging and potentially transformative area of wireless communications; and
- **Quality of service:** exploring some of the factors that could affect quality of service and experience in the delivery of mobile and wireless services.

5.2 We address each of these topics in turn in the sections below.

5.3 Throughout the year, OSAB also discussed a number of other topics that, for the sake of brevity, are not summarised here. These include a discussion on the principles and practical implications of the emerging Licensed Shared Access (LSA) concept and an exploration of heterogeneous networks. OSAB also was kept informed of progress of activities on which they had provided input in the previous year, such as Ofcom's spectrum management strategy, mobile data strategy and TV white space implementation activity.

5.4 More broadly, OSAB often discusses topics which explore how Ofcom's overall approach to spectrum could best address economic and wider social goals. These are recurring themes, to which OSAB will return in the future.

The evolution of mobile broadband services

5.5 During the year, OSAB discussed a number of topics covering how demand for mobile data services might evolve, along with options for delivering those services. Three such topics are summarised below.

Topic 1: Assessing future spectrum demand

5.6 All wireless and mobile services rely on the availability of radio spectrum. As the uptake of ever more sophisticated services increases, it is important to form a detailed understanding of potential demand, to ensure that spectrum availability is not a barrier to delivering these services in the future.

5.7 OSAB received two presentations on future spectrum demand. The first was on the future demand for mobile broadband spectrum and, in particular, consideration of potential bands that could be made available in the future. The members noted that:

5.7.1 The ITU-R[1] World Radiocommunications Conference in 2015 (WRC-15) will consider a number of candidate frequency bands for mobile broadband use. In particular, agenda item 1.1 will be forward-looking, aiming to address forecast demand for wireless broadband spectrum in the 2020 to 2030 time frame;

5.7.2 Preparations for WRC-15 agenda item 1.1 will: studies to estimate the amount of spectrum likely to be required by mobile and Wi-Fi networks; studies to identify suitable frequency ranges; and studies to assess the scale of any compatibility issues arising from changes in spectrum use.

5.7.3 Groups within the ITU-R have developed estimates for spectrum requirements (which include existing allocations). They are between 1340MHz and 1960MHz by the year 2020 for mobile broadband services and a minimum of 880MHz for wireless services, such as Wi-Fi, by 2018.

5.7.4 These groups have also identified a range of new frequency bands which could be suited for mobile broadband use (including 410 – 430MHz, 470 – 790MHz, 1000 – 1700MHz and 2025 – 2100MHz); and for use by wireless services, such as Wi-Fi (including 5350 – 5470MHz and 5725 – 5850MHz).

5.7.5 The current assumption is that a combination of techniques will need to be used in order to meet anticipated growth, in addition to additional spectrum allocations. They include improvements in the spectrum efficiency of mobile technologies, increasing the number of cell sites and offloading traffic to small cells and Wi-Fi networks;

5.8 OSAB made the following comments on the presentation:

5.8.1 There may be resistance to the idea of allowing access to spectrum from 5340MHz upwards because of potential problems with satellite communications at an international level.

5.8.2 It was likely that the ITU-R would consider the potential of bands at frequencies higher than 5GHz at the next WRC in 2018 when more data was available.

5.8.3 The lower frequencies could be allocated to mobile broadband (OSAB noted that the lower frequencies of spectrum were most valuable but careful consideration was required, given existing uses of the bands).

5.8.4 OSAB noted that the efficient use of spectrum was now a national and international issue and it was to be anticipated that there would be significant opposition from vested interests on changing the use of spectrum.

[1] The International Telecommunications Union – Radiocommunication sector

5.9 OSAB received the second presentation on the subject which outlined the results of a study on the future spectrum demand for terrestrial mobile broadband applications. The members noted that:

5.9.1 The study estimated UK mobile data demand between 2015 and 2030 and was undertaken to identify and justify input parameters used by ITU-R spectrum estimation methodologies. The study estimates UK spectrum requirements needed to achieve particular coverage and capacity levels for a range of demand forecasts.

5.9.2 Modifications to the ITU-R methodology were required to accurately estimate spectrum demand for Wi-Fi traffic. The study also identified key sensitivities in order to determine the impact on spectrum requirements.

5.9.3 In the process of undertaking the study, a number of limitations and deficiencies in the ITU-R methodology were identified. In particular, no network costs were able to be included in the model. The study determined that significant changes to the ITU-R methodology were necessary to account for factors including practical network capabilities and actual network deployments.

5.9.4 Subject to the limitations inherent in the study, the results indicated that, in a high demand scenario, around 1GHz of additional spectrum would need to be made available to meet predicted demand. For a medium demand scenario, around 200-300MHz of spectrum would be required while, for a low demand scenario, existing allocations are sufficient.

5.9.5 A number of key sensitivities were identified when trying to predict demand for licensed spectrum. They include the extent to which networks make greater use of small cells, the percentage of high, versus low, mobility traffic and the extent to which traffic is off-loaded on to Wi-Fi networks.

5.10 The members discussed the presentation, questioning the author to satisfy themselves that the range of assumptions used in the study were comprehensive.

Topic 2: The use of LTE to provide communications for the Emergency Services

5.11 Mobile communications services for the emergency services (ES) are currently provided by the dedicated Airwave network, which is based on TETRA technology. There is an active debate, both in the UK and abroad, about how best to support the next generation of ES communications services. One option is to use technologies that are used for consumer mobile networks, such as LTE.

5.12 OSAB received a presentation on the options for the provision of future ES communications services. The members noted that:

5.12.1 LTE promised a richer, more reliable mobile data experience than previously available in the mobile environment

5.12.2 A study, commissioned by Ofcom, on explored the possible use of LTE to deliver a range of services that previously required dedicated networks or spectrum, including ES communications services and mobile broadcast services.

5.12.3 High-level emergency services requirements included security, resilience and 'functional' capabilities, such as group calling and direct mobile-to-mobile calling (i.e. in the absence of a basestation).

5.12.4 The study explored the pros and cons of using LTE for ES communications services at a range of frequencies. LTE at 450MHz had the benefit of requiring potentially reusing existing cell sites. However, the study identified difficulties with making this spectrum band available for mobile use. LTE at 700MHz had the advantage that ES may be able to share network infrastructure with any future mobile operator with an allocation in this band. However, this might have the effect of reducing the value of the band at any future spectrum auction. Finally, LTE at 800MHz also had the advantage of the potential for sharing with a commercial network operator. However, as this band has already been awarded the study noted that it may be difficult for the ES to negotiate access to a commercial network.

5.13 The members and guests discussed the presentation and offered the following comments:

5.13.1 There need not be a dedicated network for ES but their traffic could not compete for access with commercial traffic. A system of priority usage would be needed.

5.13.2 The problem with the existing TETRA system was that there was no driving pressure for users to innovate and make the most efficient use of the resource. A competitive network would drive costs down.

5.13.3 For LTE at 700MHz, the impact on the release value was thought to be relatively minimal. An assessment of the opportunity cost of the lost traffic could be made and set off from the auction price.

5.13.4 OSAB noted the experience of the USA. In the late 1990s 24MHz had been dedicated for public safety but it turned out to be a waste of resource. A better approach would have been to impose a licence obligation at the 700MHz band. OSAB noted that, in the more litigious USA, issues might arise where a private citizen's enjoyment of spectrum was interrupted by the emergency services.

5.13.5 Any change in provision of ES services would need to demonstrate savings compared with the existing approach.

5.13.6 There could also be issues of interoperability and compatibility for all emergency services.

5.13.7 Whilst this was an Ofcom study, the responsibility for emergency services access rested with the Home Office. Ofcom could be of assistance in

identifying technical options and suggestions on how to achieve efficiency in the use of the resource.

5.13.8 Ofcom should assess how spectrum was used for emergency services within Europe and develop strong arguments to support its position.

Topic 3: Perspectives on 5G mobile communications

5.14 As the rollout of 4G networks continues to gather momentum, there is already growing interest in starting to think about the next generation of mobile technology. During one session, a number of OSAB members offered their own views of what 5G might look like. The members noted that:

5.14.1 The key issues facing the mobile industry now are capacity and profitability. The focus for 5G, therefore, should be about profitability rather than user experience. There was consensus that a large capacity increase was needed but there were mixed views about where it will come from (e.g. from spectrum or through improvements in technology). 5G networks must be able to be deployed and operated more cheaply than previous generations.

5.14.2 5G service requirements would include: support for large display sizes and high resolution devices; video conferences and calls; access to cloud-based services; support for new types of devices, such as cameras, watches and cars; wireless control services such as haptic control and remote medical monitoring.

5.14.3 Technical requirements included: a peak data rate of around 10 Gbps; a ubiquitous data rate of around 1 Gbps; high capacity and efficiency; low latency; low cost; low network/terminal power consumption; high security/privacy; reduced complexity.

5.14.4 The term 5G has a number of connotations, including: end-to-end MIMO and distributed/massive MIMO and co-ordinated multi-point communications; various flavours of carrier aggregation; better self-organising/self-optimising technologies; more stream-lined interfacing with Wi-Fi; an embracing of higher frequencies; increased use of geolocation databases; virtualisation taken to the next level – but confined mainly to some virtualised version of the current business model.

5.14.5 Future online experiences will need fast connections (400 Mbps +) and mobility and include: interactive learning, guided training, communications/work hub; ultimate gaming; audio visual relocation.

5.14.6 Questions yet to be addressed include: whether the number of mobile users in the UK has plateaued; whether immersive experiences fit inside a mobile case; whether it is capacity of speed that is required; whether there is a distinction between outdoor and indoor; whether the battery life of devices cope with a multitude of bands and transmission methods; whether/when operators will invest for network upgrades and whether/will such upgrades be delayed because of the prohibitive costs of rebranding.

5.14.7 There are a number of challenges for Ofcom, including: huge market uncertainties due to nature of demand; pace of technology change and investor enthusiasm. There is also an international dimension, in which there are multiple bodies and objectives, and the need for UK to keep ahead of the curve. Finally, there is a spectrum dimension, including the potential need for spectrum release, which may involve conflicting interests (e.g. incumbents vs. new entrants, TV vs. mobile operators); and the potential to re-engineer the approach to spectrum release in order to make better use of market mechanisms.

5.15 The members and guests discussed the presentations and offered the following comments:

5.15.1 That 5G presented a massive investment challenge for MNOs and that this would impact profit margins. It was not clear whether it would be appropriate for public money to be invested in 5G.

5.15.2 Mobile operators need to explore changes billing methods – particularly in respect of voice.

5.15.3 Ofcom would need to ensure that market mechanisms were in place to make the most efficient use of spectrum for 5G.

5.15.4 There was a role for the Government to define the 'public interest' in 5G with a UK spectrum strategy to be put in place.

5.15.5 5G was an issue that should be taken to WRC-15 and that it was important for the UK to retain a degree of freedom on the development of 5G.

The Internet of Things

5.16 Machine-to-machine (M2M) communications and, more broadly, the Internet of Things (IoT), are topics of significant interest at present[2]. Estimates of the likely size and shape of the IoT market vary, but all appear to suggest the potential for both significant growth and benefits to citizens and consumers from a range of industry sectors.

5.17 During the year, OSAB received two presentations on the IoT; one introductory presentation, which covered definitional aspects and the potential future market in broad terms; and another which looked in detail at the range of potential future IoT applications in order to understand implications for spectrum management.

[2] M2M tends to refer to the connection of devices that would not ordinarily require connectivity, such as temperature or water depth sensors. IoT is a broader term that refers to the interconnection of many M2M devices of different types, permitting the capture and exchange of data across multiple industry sectors. The terms M2M and IoT are often used interchangeably.

Topic 1: Introduction to M2M communications

5.18 OSAB received a presentation on the findings of a recent study on machine to machine communications. The members noted that:

5.18.1 M2M describes a very broad category of communications services and there was still no agreed definition of the term "M2M". The list of potential applications was long, varied and was continuing to evolve. Each application may have different requirements for the underlying delivery networks.

5.18.2 Approaches for delivery would depend on architecture options (e.g. from long range radio to very short range devices) and the authorization options for the spectrum.

5.18.3 The value chain is fragmented, immature and potentially stifling growth. The largest deployments were driven by government intervention, such as smart metering.

5.18.4 Mobile networks meet many, but not all, application requirements. Alternative delivery approaches are available, but currently lack scale, and fixed broadband providers may have a role to play.

5.18.5 Volumes of data were expected to be manageable (based on the study's definition of M2M).

5.19 OSAB made the following comments on the presentation:

5.19.1 That there should be a greater awareness of the benefits of M2M and that resource should be directed to areas where benefits were realisable.

5.19.2 That a common set of data and network requirements were needed.

5.19.3 That M2M crossed divides between home and office and raised security issues.

5.19.4 Whilst M2M was a fast growing area and that there were vested interests to overcome in order to make usage wide scale. Costs would be driven down as scale increased.

5.19.5 Usage would be wide in scope and M2M should not be restricted to lower frequencies

5.19.6 Work was required to assess the different characteristics of different services. Ofcom colleagues noted that it was planned to undertake such a study, the results of which would be brought back to OSAB in due course.

Topic 2: Categorisation of M2M and IoT applications

5.20 This second topic was in part stimulated by the above discussion at OSAB, in which members highlighted the need to undertake a study to understand the different

characteristics of IoT applications. Members received a briefing on the preliminary findings of the study and the following points were noted:

5.20.1 182 IoT applications across 58 application groups in 12 sectors had been identified. Certain applications where an end-user was involved were excluded to avoid potential double counting of data capacity requirements.

5.20.2 The study concluded that by 2022 there would be 369 million IoT connections in the UK. Intelligent buildings would dominate and account for around 50% of connections. Utilities (mostly smart meters) would be the second most common application, followed by automotive.

5.20.3 Application characteristics were used in the grouping analysis – with 21 primary and 11 secondary criteria.

5.20.4 Four market development scenarios were planned with two sets of variables – supply side 'capacity' and demand side 'need'. Demand side examples (including whether demand could be driven higher or lower) could include: strong public push on certain applications (higher); increasing demand from enterprises for machine data based on additional perceived benefit for business processes (higher); or push back from consumers over privacy fears (lower).

5.20.5 Supply side examples (including whether demand could be driven higher or lower) could include: deployment of multiple national low power wide area (LPWA) networks (higher); long term retention of 2G (higher); near-universal deployment of LTE (higher); aggressive 2G refarming (lower); or delayed LTE deployments (lower).

5.20.6 The objective was to group applications by preferred approach to spectrum use, for example mobile/cellular network, private or closed-user-group network, short-range licence exempt, shared licensed or satellite.

5.20.7 The approach to grouping identifies characteristics most likely to influence type of spectrum use and scores each application against each of these characteristics. An application scores higher where a characteristic favours the use of a particular approach to spectrum use. A check is made against the actual approach currently used and any other relevant application-specific factors are also considered.

5.20.8 There are a number of characteristics which may affect spectrum use. For example, applications that are sensitive to security, criticality or delay may favour a public or closed user group solution rather than a private public network or licence exempt spectrum. Outdoor, wide area coverage or the need for mobility may favour access to licensed spectrum, while indoor or local use may favour licence exempt access to spectrum. Device cost will also have an impact on spectrum requirements, implying that simple communications protocols would be preferred.

5.20.9 A number of preliminary findings were discussed. Many applications rate highly for security and criticality, indicating a potential preference for a

private/closed user group solution. A significant bias towards uplink for many applications was noted, and the bit rate and amount of data exchanged by devices tended to be low for most applications, as did the transmit duty cycle. Many applications are characterised as short range or concentrated around specific locations, but a significant number were wide area and highly distributed. Short range (mostly licence exempt) and cellular connections very much dominate, reflecting their widespread availability today – but this could change as IoT-oriented technologies evolve.

5.20.10 In terms of spectrum demand, IoT traffic is expect to be a small proportion of total cellular traffic – but could have bigger impact if 2G is continued to be used, given its relatively high signalling overheads. Private/closed user group networks may require special consideration if users demand this approach, for example to assess whether shared spectrum or a multi-network solution is an option. Many apps show strong bias towards licence exempt access, implying a need to consider implications of demand growth on existing bands (e.g. 868 MHz) and whether they need more spectrum.

5.21 The members discussed the presentation and offered the following comments:

5.21.1 That the study needed to distinguish between shared and private access to networks and that the long term issue was one of reliability and that certain services would need to be given priority in a public network.

5.21.2 That the concept of ‘ownership’ of the network needed to be thought through as it is too homogeneous.

5.21.3 That, as a consequence of the growth of the IoT there will be an increase in the growth of 2G devices and applications. The impact on the 2G network also needed to be assessed – as messages would need to be sent using 2G to a multitude of devices.

5.21.4 There was a need for harmonisation across regional and national networks to drive costs down.

5.21.5 That Ofcom would need to assess the implications of the IoT for “UK plc” and it would helpful to identify preferred technical and economic solutions and the trade-offs between the two that might be necessary.

5.21.6 That the IoT would be an important part of the future and thought was needed on how transmission of data would occur across the whole network, in particular within the context of 5G communications.

5.21.7 That Ofcom has a leading role to play in assessing the spectrum requirements of the Internet of Things and needed to establish the public policy requirements of future as well as existing usage.

Quality of service

5.22 The delivery of communications services at a given level of quality is becoming increasingly important for citizens, consumers and businesses. With fixed line services, the focus has previously been on delivering connections with maximum data rates. On this subject, OSAB received a presentation of a report by Communications Chambers for the Broadband Stakeholder Group, which modelled bandwidth requirements for UK households and provided a basis for discussion of how policy decisions should be informed by target broadband speeds. More recently, attention has been given to other metrics, such as packet delays. Meanwhile, there is significant interest in coverage and capacity issues around the delivery of wireless and mobile networks.

5.23 During the year, OSAB received three presentations on the subject of service quality. The first outlined the results of a technical study into improving in-building coverage of mobile services. The second covered another technical study, which looked in detail at the range of factors that could affect the delivery of services over the Internet. The final presentation summarised

Topic 1: In-building coverage

5.24 OSAB received a presentation on the findings of a study on the options for improving in-building mobile coverage. The members noted that:

5.24.1 Ofcom's not-spots programme and the related Mobile Infrastructure Project have primarily targeted outdoor coverage problems. However, indoor coverage is also important and is regularly cited as the primary network-related cause of churn. One operator with 99.7% of population coverage indicated that 19% of their users regularly encounter coverage problems at home. All operators have launched or announced in-building solutions in an attempt to solve localised issues and reduce churn.

5.24.2 Currently the level of in-building coverage is typically around 70% but is predicted to increase to 90% in the next few years. The coverage obligation as part of the 800MHz spectrum award is targeting indoor coverage at 98%.

5.24.3 Factors with the potential to improve in-building service include the increased use of lower frequencies, improved macrocell technologies and an increase in the number of macrocells. There are also specific technical solutions for enhancing in-building services, such as femtocells and distributed antenna systems.

5.24.4 Factors with the potential to degrade in-building service include building regulations, which require materials with better thermal insulation properties which also increase propagation losses. It has also been widely established that the RF sensitivity of smartphones tends to be worse than less complex feature phones. In addition, users' expectations of minimum data rate increases with time and greater usage causes greater contention in a given cell.

5.24.5 Requirements for in-building coverage vary significantly between home users, small offices, large multi-storey offices and public buildings and campuses. Current solutions for improving coverage include Wi-Fi (both self-provided and enterprise/carrier-grade), consumer repeaters, intelligent repeaters, femtocells, picocells, distributed antenna systems and distributed basestations.

5.24.6 Outside-in (i.e. macrocell) solutions provide an important 'hassle free' baseline for in-building coverage for consumers but will not reliably work everywhere even when the outdoor cell is near to the building.

5.24.7 Operators have an increasing range of technical options available but remain unconvinced of cost-effectiveness beyond selected consumer and building-specific segments.

5.24.8 Consumers and building owners need to understand the range of dedicated in-building technical options available and the scenarios where they best fit.

5.24.9 A number of common concerns are emerging in relation to in-building technical options. For example, some small cell solutions are not fully integrated into existing operators' networks and multi-operator support is difficult, especially in low-cost consumer products. Best practice implementation of security standards in consumer small cells need to be ensured. Finally, many in-building solutions are still reasonably immature and subject to limited availability.

5.25 OSAB noted that the study had the following implications for Ofcom:

5.25.1 Consumers need assistance to navigate the choice of in-building solutions.

5.25.2 Spectrum is not a fundamental barrier to the deployment to in-building technologies and could help accelerate the adoption of some solutions.

5.25.3 The report made a number of recommendations, including: Ofcom should consider providing updates on in-building coverage levels in their market reports; Ofcom should monitor the openness of solutions to ensure that consumers have a choice of suppliers for their preferred in-building solution; Ofcom should assist in forming best practice implementation guidelines in in-building solutions and raise consumer awareness of this; and, finally, Ofcom should analyse the FCC position on repeaters and consider why it does not fit the UK market.

5.26 OSAB offered the following comments on the presentation:

5.26.1 That consumers needed to change their expectations of the services that a network could deliver in order to appreciate the problem.

5.26.2 That work on this subject should include information on the availability of 4G services.

5.26.3 That access to a range of services would be controlled by tariffs

5.26.4 That consumers wanted access to voice as well as data and would be unlikely to regard access to voice through Wi-Fi as a satisfactory alternative.

5.26.5 That ownership of the physical infrastructure of the network would determine the range of services.

5.26.6 That Ofcom should be encouraged to go into premises and improve the standard of services.

5.26.7 That people would increasingly demand access to the full range of services regardless of whether they were at home or at the office

5.26.8 That operators should be encouraged to fix network problems (e.g. coverage) before it became a matter for the regulator to address

5.26.9 That greater access to services would open the market up to competition and encourage new entrants even into relatively small markets

5.26.10 That competition could only be effective where consumers were able to easily switch providers. The level of switching was still very low.

Topic 2: Internet quality of experience

5.27 OSAB received a presentation from an Ofcom colleague, which outlined a pilot project aimed at measuring quality of experience (QoE) of Internet-based services. The members noted that the project was at an early stage and welcomed the chance to input, noting that:

5.27.1 Ofcom's overall requirements for the project were to better understand the 'State of the Net' and to understand whether the UK's Internet infrastructure is fit for purpose (i.e. could it support a variety of business and consumer applications?). The project also sought to understand the evolution of the UK's broadband infrastructure over time, to better understand the effects of traffic management and the major sources of impediments on a consumer's broadband connection.

5.27.2 The measurement of QoE would include the entire end-to-end chain (from consumer all the way to the server) and the Perceived Quality (PQ) score (equivalent to the mean opinion score in telephony).

5.27.3 The variety of applications being measured would include social media (e.g. Facebook), internet telephony, multimedia streaming)e.g. BBC iPlayer), web browsing, video conferencing and gaming.

5.27.4 The testbed would be 500 sample points across the UK and involve different technologies (ADSL/VDSL/cable) and different line speeds. In the longer term, the project team may explore the possibility of extending the project to include wireless and mobile technologies.

5.28 The members noted some of the project's preliminary results and offered the following comments:

5.28.1 That a focus needed to be placed on the speed capabilities of the network to verify the claims of the operators.

5.28.2 That problems in the speed of data delivery may be experienced due to core network infrastructure (rather than the access network) and identifying the areas where slow speeds occur may be difficult.

5.28.3 Some operators had invested heavily in improving their network whilst others had not and that the exercise should also include mobile broadband so that all problem areas could be identified.

5.28.4 Whilst the preliminary results indicated sources of impairment across each internet service provider, this data needed to include price information to make the results more measurable.

5.28.5 That the study needed to arm Ofcom with data to speak on behalf of operators to major network providers where problems (eg packet loss) are experienced.

Annex 1

Ofcom Spectrum Advisory Board – Terms of Reference

A1.1 The Ofcom Spectrum Advisory Board is to provide independent, strategic advice to Ofcom, and where appropriate to Ministers, on matters that directly or indirectly have a bearing on policy issues to do with future communications architectures, access methods, physical layer technologies, spectrum, services and applications.

A1.2 In formulating its advice, OSAB is to consider the future communications landscape from technological, economic and societal perspectives, consonant with Ofcom's statutory duty to further the interests of citizens in relation to communications matters.

A1.3 In particular, OSAB is to advise on:

- Ofcom's spectrum strategy, major UK national allocation decisions, spectrum management, and the application of spectrum pricing/trading.
- Issues that are currently "beyond Ofcom's headlights" to which Ofcom should start to give attention.
- New communication technologies.
- New means of managing the radio spectrum and their implications for Ofcom.
- Whether Ofcom's current and developing policy stance is appropriate and where new policy might be needed.

A1.4 For example, topics that might be considered by the OSAB include:

- The extent to which future wireless and fixed communications infrastructure and services may be complementary or compete with one another.
- Novel technologies such as cognitive radio
- Ongoing initiatives such as digital TV switchover.
- Emerging uses of spectrum in areas such as transport and healthcare.
- Ways to measure and assess the effectiveness of spectrum management policies.
- The development of market-led initiatives such as SURs.
- The balance between licensed and licence-exempt spectrum.
- The stimulation of innovation through spectrum policy.

- Trends in international relations.

- Ways that spectrum policy could be used to further the interests of the citizen and consumer.

A1.5 To avoid any conflict of interest, members of OSAB will not have access to confidential information pertaining to Ofcom decisions affecting specific companies. This does not however preclude the discussion of potential Ofcom policies.

A1.6 With the support of Ofcom staff, reporting shall include an Annual Report, publication of key findings on the Ofcom or OSAB website and hosting occasional Open Forums.

A1.7 Members of OSAB should be drawn from a mix of commercial, academic and consulting backgrounds, in order to assess topics in a multidisciplinary manner, and to advise Ofcom on matters of strategic significance. Membership will include ex-officio representation by the Department of Culture, Media and Sport (DCMS) who will participate fully in discussions but reserve the right to abstain from agreement on substantive matters. Members will not receive remuneration other than reimbursement of expenses.

Annex 2

Membership of OSAB[3]

David Meyer (Chairman) [May 2015]

David Meyer served in the British Army's Royal Corps of Signals from 1979-2010, leaving as Brigadier and Deputy CIO. During his career he held positions delivering operational information systems and services; leading units responsible for policy, procurement, operations, signals intelligence and computer network defence; and serving overseas in Croatia, Bosnia, Kosovo, the Democratic Republic of Congo, Iraq and Afghanistan. David joined the Foreign and Commonwealth Office as Chief Information Officer in December 2010. He holds a Master's degree in International Studies and is a Fellow of the British Computer Society and a Chartered IT Professional.

Professor Linda Doyle [May 2015]

Linda Doyle is a Professor in Trinity College, University of Dublin, Ireland in the School of Engineering. Professor Doyle is the Director of CTVR. CTVR is a national research centre focusing on industry-informed research in the telecommunications field. CTVR is headquartered in Trinity College and based in six other Irish academic institutions with over 80 active researchers. Prof Doyle's own area of research is in wireless communications with a particular focus on cognitive radio, reconfigurable networks, spectrum management and art & technology. Her group has built an international reputation in experimental cognitive radio work. Prof. Doyle has published over 170 peer-reviewed papers in the field and has raised over 30 million in research funding in the last decade. Prof. Doyle is a Fellow of Trinity College Dublin. She is a Director of Xcelerit, a recent CTVR spin-out.

Robin Foster [May 2016]

Robin Foster has occupied several board-level strategy and policy positions in the UK media and telecommunications sectors and is currently an independent adviser on regulatory, policy and strategic issues. He is a founding member of Communications Chambers, a media and communications consultancy.

Robin was part of the first senior team at the then newly-established regulator, Ofcom, as Partner, Strategy and Market Developments, where he led the first Ofcom review of public service broadcasting. His previous senior positions include director of strategy and regulation at the Independent Television Commission, director of strategy at the BBC, and director of economic consultants NERA, where he was responsible for a range of projects on privatisation, regulation and spectrum management.

[3] After each member is given the date that their appointments to OSAB expire.

Since leaving Ofcom, Robin has advised government in two roles: as a member of the UK Digital Britain Steering Board, which developed proposals for UK broadband communications sector policy and regulation and as one of the independent advisers to the UK Convergence Think Tank. He also ran the Global Communications Consortium research programme at London Business School until March 2008, and was Research Fellow at Bournemouth Media School from 2000 to 2002 where he led a programme of research into the future of media regulation in the UK ("Future Reflections").

David Harrison [ex-officio]

David is Director of Technology Strategy in Ofcom. He is responsible for leading Ofcom's technical research programme and supporting Ofcom policy development across a wide range of areas including: white space and cognitive radio, unlicensed Wi-Fi spectrum, radio switchover, network neutrality and next generation broadband access. David led the UHF Strategy project, which sought to identify the how to best balance the competing demands for UHF spectrum by different services including terrestrial broadcasting and mobile broadband. More recently he has been leading working on new approaches to spectrum sharing to increase the future supply of spectrum for mobile broadband and machine to machine applications.

Before joining Ofcom, David worked for the Independent Television Commission where he held the position of Deputy Director of Technology, and before that led the high frequency research and development activities in Thomson Multimedia based in Rennes.

David has published numerous technical papers on RF and high frequency engineering and holds 12 patents. David has a first class honours degree and PhD in Electrical and Electronic engineering. He can be contacted at david.mark.harrison@ofcom.org.uk.

David Hendon [ex-officio]

David Hendon is a senior advisor at Ofcom, working on spectrum, international strategy and network resilience issues. He is a member of the Smart Meters Strategic Programme Board at the Department of Energy & Climate Change and a non-executive director of Multiple Access Communications Ltd and ContinuumBridge Ltd. He is independent Chairman of the 4G/TV Co-existence Oversight Board established by DCMS. He is a Visiting Professor at Surrey University, deputy-chairman of the Radio Communications Foundation and a member of the IET's Communications Sector Panel.

From 2002 to 2011, David was a Director in the Department for Business, Innovation & Skills where he was responsible for BIS's business-facing activities and policy in communications networks, internet, software and computer services, information and cyber security, electronics, digital content, media, publishing and postal sectors and, from 2010, the Office for Life Sciences.He was previously Chief Executive of the Radiocommunications Agency,

which managed UK radio spectrum prior to the establishment of Ofcom. His earlier career included appointments in the Ministry of Defence, the Home Office, Cabinet Office and the Department of Trade & Industry, all involving electronic communications. He was Chairman of the Board of the European Telecommunications Standards Institute from 1996 to 1999 and a council member of the Engineering and Physical Sciences Research Council from 2006 to 2009. He is a Fellow of the Royal Academy of Engineering.

Phillipa Marks [May 2016]

Phillipa Marks is a Director of Plum Consulting. She is an international expert in economic, regulatory and policy analysis of spectrum management issues and has advised operators, regulators and governments in Europe, Asia-Pacific, Middle East and North America on a wide range of spectrum management issues. She also advises on public policy and regulatory issues in the media and telecommunications industries. She was educated in New Zealand and at Oxford University. After a period as a research officer with the New Zealand Institute of Economic Research, she moved to the UK working for the Institute of Transport Studies. She then joined the National Economic Research Associates (NERA) where she became a director, leading assignments in media, telecommunications and utility sectors. In 2000, she was appointed by the Home Office as a member of the Gambling Review Body. She is a member of the Irish Electronic Communications Expert Advisory Panel.

Philip Marnick [May 2015]

Philip is currently CTO of UK Broadband. Philip has spent over twenty years at the forefront of the wireless communications industry. Prior to joining UK Broadband, he held senior operational and strategic executive positions at O2, BT, Orange, J-Phone, Japan (now Softbank mobile), Extreme Mobile and SpinVox.

He has been involved with mobile networks from analogue through to the launch of the world's first GSM 1800 and 900 networks and on to Europe's first 3G network and the development of international roaming. Philip was instrumental in driving the development of mobile data services including the launch of the world’s first camera phone and has been actively involved in the development of the mobile regulatory regime both in the UK and Europe. He was previously vice-chairman of the NICC and chairman of the PNO-IG.

Robert Pepper [May 2014]

Robert Pepper leads Cisco’s Global Technology Policy team in areas such as broadband, IP enabled services, wireless, security, privacy and ICT development. He joined Cisco in 2005 from the FCC where he served as Chief of the Office of Plans and Policy and Chief of Policy Development beginning in 1989 where he focused on telecommunications regulation, spectrum policy, and policies promoting the development of the Internet. Before joining government, he held faculty appointments at the Universities of Pennsylvania, Iowa and Indiana, and was a research affiliate at Harvard University. He serves on the board of

directors of the U.S. Telecommunications Training Institute (USTTI), advisory boards for Columbia University and Michigan State University, and is a Communications Program Fellow at the Aspen Institute. He is a member of the U.S. Department of Commerce's Spectrum Management Advisory Committee and the U.S. Department of State's Advisory Committee on International Communications and Information Policy. Pepper received his BA. and Ph.D. from the University of Wisconsin-Madison.

Jean-Jacques Sahel [May 2016]

Jean-Jacques is currently Director of Policy, EMEA, at Microsoft. Jean-Jacques joined Skype from the British Government where he served UK interests in many telecoms and IT negotiations and forums. He was a Vice Chair of the OECD anti-spam task force and Chairman of the OECD working party on the information economy. Jean-Jacques was the UK signatory of the 2006 UN ITU Convention and Constitution and has chaired the UK Chapter of the International Institute of Communications since 2009. He is also a Vice-Chair of the OECD Business and Industry Advisory Committee (BIAC) for ICT issues. He joined Microsoft's EMEA Policy team following Skype's acquisition in 2011.

Professor Simon Saunders [May 2014]

Professor Simon Saunders is an independent specialist in wireless communications, with a technical and commercial background in both industry and academia. He is founder of the Real Wireless consultancy and founding chairman of the Small Cell Forum (formerly Femto Forum). He has more than 25 years' experience to CTO and CEO level in industry and as an academic for seven years. Simon has invented several novel wireless technologies and is the author of over 150 articles and books, including authoritative books on antennas, propagation and on femtocells, and is a regular speaker at industry conferences. He is a Visiting Professor to the University of Surrey.

Simon Towler [ex-officio]

Simon Towler is Head of Telecommunications Policy in the Department of Culture Media and Sport, with responsibility for telecoms regulation, spectrum and broadband policy. Simon joined the Department of Trade and Industry in 1992. He has held policy posts in civil aerospace, international trade policy, nuclear issues, telecommunications policy and better regulation as well as a secondment to the British Embassy in Washington DC. Simon joined the DCMS in January 2011 together with other colleagues responsible for telecommunications policy and relations with the sector. He was appointed to his current post in June 2011.

Mike Walker [May 2016]

Mike is Head of School for Natural and Mathematical Sciences at King's College London. Until his retirement in September 2009, he was the Group Research and Development

Director for the Vodafone Group of companies, with the responsibility for the Group's research activities, intellectual property and technology standards worldwide. He is a Vodafone Fellow and an Executive Technical Advisor to Vodafone. He is a member of the Board of the European Telecommunications Standards Institute, having been chairman for the 2008-2011 Board period. Mike is a non-executive director of Avanti and is a director of the Alacrity Foundation. He holds the Vodafone Chair in Telecommunications at Royal Holloway, University of London. He is a Fellow of the Wireless World Research Forum. Mike is a Fellow of the Royal Academy of Engineering, and until June 2011 served as a member of Council of the Academy. He was the President of the Institute of Mathematics and its Applications for the Presidential term 2010-2011. He was awarded an Honorary Doctorate of Technology from the University of Plymouth in 2011. He was appointed an OBE in June 2009 for his services to the telecommunications industry.

Professor William Webb [May 2014]

William is one of the founding directors of Neul, a company developing machine-to-machine technologies and networks, which was formed at the start of 2011. He is also CEO of the Weightless Standards body.

Prior to this William was a Director at Ofcom where he managed a team providing technical advice and performing research across all areas of Ofcom's regulatory remit. He also led some of the major reviews conducted by Ofcom including the Spectrum Framework Review, the development of Spectrum Usage Rights and most recently cognitive or white space policy. Previously, William worked for a range of communications consultancies in the UK in the fields of hardware design, computer simulation, propagation modelling, spectrum management and strategy development. William also spent three years providing strategic management across Motorola's entire communications portfolio, based in Chicago.

William has published 12 books, over 100 papers, and 18 patents. He is a Visiting Professor at Surrey University and a Fellow of the Royal Academy of Engineering, the IEEE and the IET where he is a Deputy President. His biography is included in multiple "Who's Who" publications around the world. William has a first class honours degree in electronics, a PhD and an MBA. He can be contacted at william.webb@neul.com.

Gavin Young [May 2015]

Gavin's current role is as Head of Strategy & Planning within Cable & Wireless Worldwide. He leads a team of architects responsible for the architecture and strategy for C&W Worldwide's technology platforms (Data, Internet, Voice, Mobile, Cloud/Hosting, Optical Transport, Access, Call Centre Solutions etc.).

Following a range of Access technology leadership roles within BT, Gavin joined AdEvia in 2000 where as CTO he led the design of pan-European broadband networks. He then moved to Bulldog Communications (later acquired by C&W Worldwide) where he held a variety of responsibilities from product development through to network operations and CTO. As C&W's Chief Architect for Access, Gavin was focused on the design and architecture of

the national broadband network and the associated network products. He has also been heavily involved in regulatory aspects of broadband access and spectrum.

Gavin was a founding director of the Broadband Forum (formerly DSL Forum) was overall Technical Chairman for twelve years. In addition he has been co-chair of the UK21CN consultation's Broadband Group, chair of the UK NICC's DSL Task Group and also vice-chair of the NICC Ethernet Access Task Group. Gavin also serves on the Ofcom Spectrum Advisory Board (OSAB) which provides strategic advice to Ofcom and ministers.