Response to Ofcom's Call for Inputs on:

Fixed Wireless Spectrum Strategy

(Issued by Ofcom on 11 July 2016)

BT plc and EE Ltd
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Introduction

BT/EE welcomes this opportunity to respond to Ofcom's call for inputs on Fixed Wireless Spectrum Strategy. BT/EE makes extensive use of fixed wireless links, both in various fixed links bands managed by Ofcom and using the 32GHz spectrum access licences acquired at auction. BT operates fixed wireless systems in various parts of its network, including extensively to provide backhaul services to other MNOs. Following the BT acquisition of EE the fixed link spectrum licences held by EE Ltd and by MBNL continue to be used to provide important backhaul connectivity to the BT/EE mobile network.

BT operates *c.* 7000 microwave radio links mainly in numerous Ofcom managed bands as well as increasingly using its own 32GHz spectrum. EE also holds fixed links licences directly as well as via its MBNL joint venture with Three.

BT/EE continues to invest in new fixed links within its network and anticipates continuing to do so in those cases where it is cost effective to do so compared to the generally preferred alternative of fibre. We support the development of a spectrum strategy for fixed wireless and support efforts to promote the efficient use of the fixed links spectrum bands, including introduction of new technologies and further exploitation of higher frequency bands.

Our responses to the consultation questions

Question 1:
a) Please indicate which user type given in Table 1 best describes your use of fixed wireless links?
b) If you are a telecom network operator or an organisation providing wireless solutions for different user types, please indicate where possible, a breakdown of the percentage of fixed wireless links used to support the different user types i.e. mobile network operator, emergency services etc.

BT/EE operates fixed and mobile networks that use fixed wireless links within these networks. BT uses fixed wireless links to deliver connectivity solutions to most of the other "User types" Identified in Table 3 of the Call for Input. In EE's case 100% of its fixed links (and those operated also for Three by MBNL) are for mobile backhaul. In BT's case the vast majority of the fixed links it operates are for public mobile network backhaul applications, the other major uses being as part of BT's core and access networks and for emergency service networks.

Question 2:
a) Please indicate the applications provided by your use of fixed wireless links and the benefits these provide to citizens and consumers.
b) For each application, please indicate the frequency band used and the rationale for choosing that band, i.e. the application specific characteristics that affect your specific choice of frequency band.
c) For each link, please provide details of the application supported.

Mobile network backhaul – this underpins the provision of 2G, 3G and 4G voice, data and video services. The fixed wireless solutions for mobile network backhaul provide a cost effective and expedient solution that helps maximise the extent of mobile coverage and enables consumers to benefit from availability of mobile services. The main bands used for this purpose by BT are 18GHz, 32GHz, 38GHz and in the case of EE also the bands 10GHz and 42GHz via MBNL. These bands are compatible with the availability

requirements and typical path lengths and lowest spectrum costs. Our preference is to deploy in self-managed bands due to the propagation characteristics and economic benefits. Where this is not possible the most suitable Ofcom managed band is used. The band is selected against a typical link planning process and is a balance between technical performance and cost of licence, equipment, installation and maintenance.

Broadband networks – in a few niche cases fixed wireless links can provide a more cost effective solution than fibre between the exchange and street cabinet for delivering NGA. The benefits to consumers are in terms of improved availability of NGA as a result of a lower cost alternative to fibre in some very special circumstances. The 18/32GHz bands are used for this purpose.

Question 3:

a) How do you envisage the current and future applications provided by your use of fixed wireless links to change in the next 5-10 years?

We anticipate a continued migration to higher speed circuits with associated migration to wider RF channels and introduction of technology advancements (e.g. higher / adaptive modulation schemes, wider and adaptive channel bandwidths and cross-polar working). As cellular architectures change and convergence of fixed and mobile network solutions occurs we anticipate greater use of higher frequency (mmWave) bands, e.g. for small cell backhaul. The background to these trends is detailed below.

Increasing demand for mobile data services will drive coverage, capacity and performance enhancements to existing mobile networks. To date most mobile networks have focused on deploying wide area coverage with large macro-cell radio sites while managing small coverage areas and/or capacity hot-spots with micro-cell radio sites.

The future cellular landscape will be focused on LTE and its evolution, along with 5G systems. Such an evolution will result in significantly higher peak and average data rates, greater system capacity, lower latency and greater network/service availability. To support such a vision will require an evolution of backhaul, or variants such as fronthaul and x-haul, depending on future radio network architecture. The backhaul network architecture will likely support a different functional split within the RAN however it is anticipated that this will be closer to the current backhaul scheme than existing CPRI fronthaul, this evolution is known as x-haul however the term is often interchanged with backhaul and fronthaul.

Future requirements for fixed links will include; higher capacity, greater geographical reach and greater network availability. Greater availability may not result in greater per link availability, which depends on architecture evolutions such as meshing (multi-point to multi-point radio systems and/or overlay multi-path connectivity at an Ethernet/IP layer over point to point connections). Additionally the backhaul network will require greater flexibility and programmability through the adoption of SDN technologies and the implementation of SON capabilities. Large cell sites in urban and sub-urban areas will increasingly be connected with fibre based backhaul circuits while microwave will continue to support many rural deployments. Within urban and sub-urban areas a large number of small cells will be deployed, these are likely to use wireless backhaul however not necessarily as we know it today. Backhaul and radio access spectrum could be used in a more cooperative manner with the concept of self-backhauling being adopted in certain scenarios.

From a network perspective the growth in data traffic is asymmetrical, meaning there's greater volume of traffic flowing in the downlink (from network to user equipment) than uplink (from user equipment to network). This is quite different when compared to the mainly symmetrical voice traffic which was

considered when microwave radio spectrum strategies were developed previously. Given this change in application and the dynamic nature of data communications it is recommended that this review considers spectrum strategy, including band-plans and duplex modes, which offer most flexibility and overall spectrum efficiency.

b) What market trends and drivers will affect the use of fixed wireless links to deliver the relevant applications in the future?

The increasing densification of mobile networks and general increase in capacity/speeds may lead to further fixed wireless requirements, perhaps using higher frequency bands than those commonly used in mobile backhaul of macrocells today.

The evolution of video is a key contributor to traffic growth on mobile networks, greater consumption of ever higher-data rate content driven by an evolution from SD and HD to UHD 4K and 8K content. The introduction of augmented reality (AR) and virtual reality (VR) technologies will drive significant demand whilst new verticals such as automotive, education, health care and security will further drive demand for capacity and geographical coverage.

c) What bands will be relevant to support the future changes?

Existing microwave and millimetre wave bands along with new, higher frequency millimetre wave bands such as W-band and D-band. In certain use cases spectrum which has traditionally been associated with mobile radio access could be used for backhaul connectivity.

d) Could your use of fixed wireless links be provided by alternative solutions? If so please give details of alternatives.

Yes, in general fibre based solutions will be preferred and used where more cost effective than wireless. A techno/economic analysis for the particular scenario would be required.

Multi-point wireless connectivity could be an alternative to fixed point to point links however this is still an evolving solution.

Question 4:

a) How will Fixed Service equipment continue to evolve to meet the increasing capacity requirements?

The clear trend is to migrate to wider channel bandwidths and utilisation of higher frequency bands. Radios operating on 56MHz channels to deliver Gigabit Ethernet connectivity in bands around 20-40GHz are available today. Higher speeds with 112MHz channels, and eventually 224MHz, are envisaged. Cross-polar working further improves spectral efficiency. The use of adaptive modulation and coding and adaptive channel bandwidths provide technology innovation to allow higher frequency bands to be exploited and highest speeds to be delivered with acceptable availability over a range of propagation conditions. These innovations are anticipated to be widely available in the next few years. Another longer term efficiency gain may come from full duplex systems. These solutions increase capacity however they all introduce new challenges relating to technical and commercial implementation. IP header and/or payload compression is an option however these may introduce latency in certain use cases.

b) What is the timescale for implementation in equipment?

Modulation schemes up to 512QAM are commonly available today whilst many vendors have 1024QAM available now or on roadmaps for late 2016/2017. Even higher order modulation schemes will be available beyond 2017 however these impact system gain significantly. RF channels of up to 56MHz are common today with many vendors including channels of 112MHz on roadmaps for 2017/2018. Co-channel cross polarisation is available with XPIC today. IP header compression is available today, payload optimisation is available from some vendors and further enhancements are being researched.

It should be stressed that continuing to increase the modulation scheme above 512QAM will increase link throughput however this is likely to have limited practical application due to the negative impact on radio link system gain. The increasingly densely packed constellation requires an ever higher receive threshold to minimise error-vector magnitude interference between symbols.

Question 5:

a) What capacity enhancing techniques are you deploying or intend to deploy?

BT/EE intends to make greater use of cross-polar working and increased use of the widest channels (e.g. typically 56MHz/512QAM in bands below c. 40GHz) and Co-channel cross polarisation with XPIC along with certain vendor specific traffic optimisations (many of which are default within packet microwave radios).

Potential replacement of a large number of microwave radio links in traditional bands with E-band is possible where very high capacity is required (>800Mbps).

b) How does this affect your future demand for spectrum?

Higher order modulation schemes will push some links to a lower band for a given antenna/atmospheric availability configuration. Wider RF channels will result in a lower link density per area/band. Both of these considerations would drive a need for more spectrum, assuming that the area link density is to remain the same or increase, but the anticipated growth could be supported in existing available spectrum along with greater use of higher frequency spectrum, and any migration towards more use of fibre would reduce the spectrum demand.

c) Do you see any barriers in the current authorisation approaches preventing use of such technology? If so, please indicate the changes you consider would be required to facilitate this?

The spectrum fees for individual links licensed by Ofcom are high compared to the market value of fixed link spectrum as revealed in the 2008 auction and for wide bandwidths these per link annual fees can become very significant. Whilst it is important to promote efficient use of spectrum, there is a risk that if fees are too high the spectrum will not be used at all, which will be less efficient. We note that Ofcom is currently reviewing fixed link annual fees and consider that increases in fees would be detrimental to introduction of higher speed wireless technologies.

Whilst equipment support features such as XPIC, gaining access to the second polarisation is not guaranteed, particularly in the 7.5GHz and 13GHz bands.

Incentive use of XPIC in E-band for very high capacity links would be enhanced by low-cost licensing of the co-channel on the opposite polarisation but taking account of the additional impact of such use on adjacent channels.

Question 6:

a) How do you expect future mobile backhaul network architecture to evolve as part of the 5G ecosystem?

The backhaul network architecture will likely support a different functional split within the RAN however it is anticipated that this will be closer to the current backhaul scheme than existing CPRI fronthaul, this evolution is often known as x-haul however the term is interchanged with backhaul and fronthaul. Backhaul/x-haul will need to scale to meet the demands of the new radio interface, in the bands below 6GHz this is likely to be some Gigabit per second, while bands above 6GHz could support some 10s of Gigabits per second.

x-haul is a generic term which describes backhaul, fronthaul, or something in between. Today's distributed RAN has the radio units and baseband capability co-located at the cell site, usually separated by a few metres or tens of metres of optical fibre cables. A centralised RAN, also known as a cloud-RAN, moves the baseband unit to a central location and extends the fibre links between the radio units and baseband unit to some kilometres. This allows multiple radio units across multiple sites to coordinate their radio interface scheduling to achieve enhanced radio performance and reduce overall energy consumption on a per cell site basis. The requirements for conventional C-RAN fibre links running the CPRI or OBSAI protocols are extremely challenging in terms of capacity and latency specifications. Additionally, the current fronthaul interface scales in a linear manner with additional spectrum and additional antennas, making it unrealistic for wider radio channels and massive MIMO deployment, both of which are likely components of an evolved LTE and/or 5G network.

Alternative functional splits between the radio unit and baseband unit are being discussed in industry fora and standards bodies. This results in a next generation fronthaul interface which can be satisfied with an evolved Carrier Ethernet backhaul and is therefore more commercially viable and practical to implement in real networks. Figure 1 illustrates this concept.

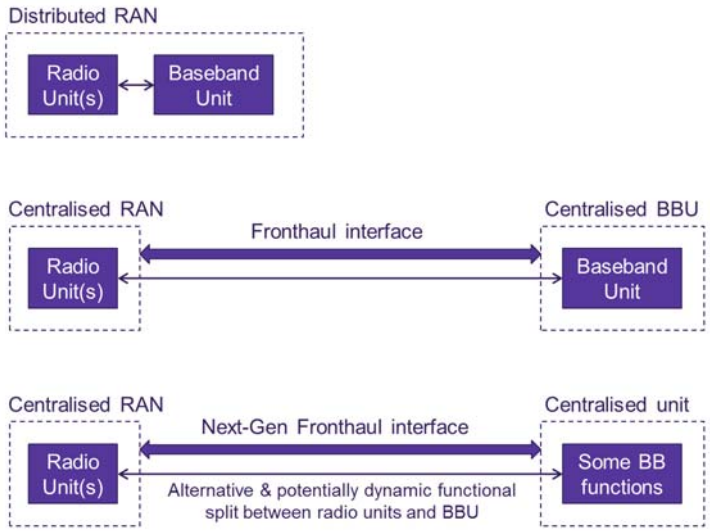

Figure 1: RAN functional split

Network topology will contribute to overall backhaul/x-haul demand as several sites could be aggregated together at a hub site and therefore the sum of demand will have to be supported. 5G concepts such as ultra-dense, ultra-reliable and ultra-low latency networks will all impact on the mobile backhaul architecture evolution. We have on-going network architecture evolution studies however as 5G isn't

standardised as of yet, it's not possible to state the exact implications on mobile backhaul network architecture.

b) How would this impact on future demand for fixed wireless links as a backhaul solution in the next 5-10 years and beyond? Please explain in terms of specific frequency bands i.e. which bands will be important for macro and small cell backhaul and why.

It's likely there will be less microwave radio links in traditional bands in urban areas while an increased use of V and E-band is very likely (for different use cases). Microwave links in sub-urban areas will increase in capacity through the implementation of the techniques discussed above, and millimetre wave radio is also likely in certain use cases in sub-urban areas, but potentially increased use of fibre would reduce spectrum demand. An increased use of high capacity microwave along with line of sight relays and space diversity will be needed in rural areas, and this will require access to wider RF channels in lower frequency bands, typically between 6GHz and 18GHz.

c) What is the most appropriate authorisation regime to facilitate this?

Incentivise the use of efficient ETSI Class 4 antennas in all bands.

Question 7:
For each Fixed Service band currently identified for study for 5G under WRC-15 Agenda Item 1.13 and 3.6–3.8 GHz band, please explain the impact on your backhaul use should the bands be identified and be repurposed for 5G given that the viability of in-band sharing between mobile access and backhaul is currently being studied.

For the 3.6-3.8GHz band there is no foreseen impact on BT/EE as we no longer use this band for fixed links.

For the bands above 24GHz being examined under WRC-19 Agenda Item 1.13, we are currently evaluating the potential to share between fixed and mobile uses. Where an existing fixed link band is identified and re-purposed for 5G mobile the sharing is likely to be very complicated when multiple users and extensive existing networks are involved. Where an existing owner of spectrum decides to repurpose some of its spectrum over time to meet its own diverse uses then it may be easier to achieve this. In the case of Ofcom managed fixed links bands it will be necessary to have a time plan and alternative bands to migrate existing fixed links if it is determined that those bands should be available for 5G.

Question 8
a) What is the current use in the block assigned bands at 10 GHz, 28 GHz, 32 GHz and 42 GHz bands and how do you expect usage in these bands to evolve given that the 32 GHz and 42 GHz bands are also being considered for study for 5G globally?

b) For each band, please provide details including geographic location of each fixed wireless link deployed and the application it supports. Where these bands are used for fixed wireless links, please give details in terms of the capacity supported and total numbers of links deployed.

BT and EE currently use the 32GHz spectrum access licence for fixed point-to-point radio links, mostly for mobile networks backhaul. If the 32GHz band were to be identified globally for 5G mobile applications as a result of Ofcom's success in international negotiations, we would evaluate whether to dedicate some of the spectrum for this purpose, including possible geographic based sharing subject to coexistence studies. It is too early to speculate whether and when we would prefer to use the spectrum access licence for terrestrial applications, acquired in the past auction, for mobile applications in addition to the current fixed links application. The 32GHz spectrum licences of BT/EE are used to deliver fixed links in channels ranging in widths from 7MHz to 56MHz, and about 800 bi-directional links are currently deployed with the use growing. We can provide more detail to Ofcom on a confidential basis as required.

We therefore support Ofcom giving further consideration to dual operation of bands for both radio access and fixed link backhaul including in 32GHz and 42GHz bands. In relation to mobile backhaul in particular, it's likely that any deployment of these bands for outdoor 5G radio interface will be limited to dense urban areas or specific use cases and special events, and examples include Wembley stadium and Glastonbury festival. There will be significant geography over which these bands are not used even in the future timescales for which mobile radio access is relevant and could therefore possibly continue to be used for point to point links. In certain scenarios co-existence may be possible in the same geographical area however this requires careful study.

Question 9:
What impact does the change in the provision of national emergency service network have on both the future demand and supply of spectrum to support the backhaul requirement for the emergency service network? Please explain in terms of frequency bands, particularly but not limited to the 1.4 GHz, 26 GHz, 38 GHz bands?

EE is deploying additional backhaul radio links to enhance the overall network availability and in some cases existing links are being provided with equipment protection and will therefore operate in hot-standby mode.

EE is aware of the sharing conditions surrounding the award of 10GHz as a fixed link band, however this should be used as a use case when considering further spectrum sharing. Naval and air based interference is resulting in significant and increasing issues with the use of this band and mitigation in many cases is to re-plan links in adjacent bands.

Question 10:
a) How do you expect future public safety use of fixed wireless links to change in the next 5-10 years?
b) Please indicate the market and technology drivers affecting your future use of fixed wireless links, and whether your use could be provided by alternative solutions. If relevant, please explain in terms of frequency bands, particularly but not limited to 1.4 GHz, 26 GHz and 38 GHz?

No comments.

Question 11:
Please indicate whether you consider that the guard band and centre gap of the 6 GHz band would be a suitable substitute for current and future 1.4 GHz applications, particularly in terms of costs to provide for like for like links and if not, the costs of alternative solutions. Please provide detailed evidence to support your answer.
BT/EE has not closely assessed this proposal but is concerned that that no premature decision, without further consultation, is made as to 6GHz's suitability as a destination band for possible replacement of the fixed link 1492-1518MHz spectrum identified for mobile broadband at WRC-15. All options for any future 1492-1518MHz clearance would need be fully explored, and consulted on, and any possible eventual decision should reflect internationally harmonised economies of scale for fixed link equipment and the possible future identification of spectrum required for mobile services.

Question 12:
a) How do you expect the utility sector's future use of fixed wireless links to change in the next 5-10 years?
b) Please indicate the market and technology drivers affecting your future use of fixed wireless links, and whether your use could be provided by alternative solutions. For example, which part of the smart grid network will require fixed wireless links? If relevant, please explain in terms of frequency bands, particularly but not limited to the 1.4 GHz, 26 GHz and 38 GHz bands.

No comments

Question 13:
a) How do you expect the future requirements for fixed wireless links that support HFT applications to change over the next 5-10 years?
b) Please indicate the market and technology drivers affecting your future use of fixed wireless links. If relevant, please explain in terms of frequency bands, particularly the 70/80 GHz band.
No comments

Question 14:
a) What is the future demand for HAPS in the UK both in terms of being a network provider and service provider? Please provide details including specific applications and envisaged deployment scenarios for HAPS.
b) How could sharing with existing fixed wireless links be facilitated? What would this mean in terms of the most appropriate authorisation regime to facilitate deployment of HAPS?

Depending on technology developments HAPS might in future serve some important niche applications and as such we are supportive of efforts to study the spectrum requirements and options. One application could be provision of mobile coverage/capacity on a temporary basis. At this stage we have no specific information to share with Ofcom or specific requests in relation to regulatory actions.

Question 15:
a) How could the 8 GHz band and narrowband channels within the guard bands and centre gaps of the existing channel plans for the 6 GHz band meet future demand for fixed wireless links if additional spectrum could be made available?

b) What types of applications do you consider would be of interest for these bands?
c) What is the status of fixed wireless links equipment availability in these bands?
No comments.

Question 16:
a) What is the demand for a combined Lower and Upper 6 GHz channel plan that could provide wider channels at 112 MHz bandwidth?
b) What are the practical implications for existing equipment that operates under the existing band plans who wish to migrate to the new band plan?
c) What is the status of Fixed Service equipment availability for the wider 112 MHz channels in the combined Lower 6 GHz and Upper 6 GHz band?
No comments.

Question 17:
a) What are the applications envisaged in the W and D bands?
W-band use case could be similar to E-band for point to point radio systems.

D-band use case in support of ultra-dense small cell/heterogeneous networks for LTE evolution and/or 5G applications.

b) What is the timescale of equipment availability for these bands?
Expectation is around 2020.

c) What would you consider to be the appropriate authorisation regime to facilitate access to spectrum in the W and D bands?
We have no firm views at this stage. Given the short re-use distances and the fact that P-MP as well as P-P connections might be of interest it could be that some kind of spectrum block licences (national or in geographic areas) could be of interest. Whatever the licence type, the question of whether or not they would need to be frequency coordinated will depend on the density of use and typical re-use distances, which we have not yet studied.

Question 18:
a) Do you have a view on potential frequency bands between 275–450 GHz that could be suited for Fixed Service and for what applications?
b) What are the anticipated timescales for the development of equipment and applications for these bands?
We are not currently considering potential use of this spectrum range.

Question 19:
a) What is the future demand for bands listed in Table 4 for Fixed Service applications?
With the exception of 65GHz, which has been identified as a band possibly suitable for urban small cell backhaul applications, these bands are not currently used by BT and we currently have no future plan to use them, but we will keep them under review.

b) What is the status of fixed wireless links equipment availability in these bands?

BT/EE is aware of several vendors who have extended their existing 60GHz products to cover the 65GHz band as well

Question 20:
Are there other aspects of the review on which you have evidence that would help inform our consideration of future developments in the Fixed Service sector? If so, please provide as much evidence possible.

It would be helpful if Ofcom would consider providing online access to its fixed links coordination tools for the bands that it manages so that applications from accredited operators could be submitted online for instant coordination and provisional assignment approvals.

END