Huawei response to the Ofcom call for inputs: "Spectrum above 6 GHz for future mobile communications"

Introduction

Huawei welcomes the opportunity to provide feedback on this very important call for inputs on spectrum above 6 GHz for future mobile communications. Availability of spectrum above 6 GHz is essential for future 5G IMT technologies and solutions, and we appreciate Ofcom's forward looking approach in initiating the process of discussions with stakeholders to identify suitable bands at an early stage.

We have summarised our views below, and present our responses to Ofcom's specific questions in the remainder of this document.

Summary of Huawei's recommendations

Huawei appreciates that radio spectrum is a major asset to the UK, providing the critical basis for a wide range of services. Securing the optimal use of this scarce asset and ensuring continued availability of spectrum for future use for wireless telegraphy is a key consideration.

We note that spectrum below 6 GHz remains the primary range for mobile services, mainly due to the favourable radio propagation in these bands, and the low cost of electronic components. We also acknowledge that increasingly larger bandwidths will be required to achieve the demanding data rates expected of future 5G mobile communications, and that these bandwidths are chiefly available at frequencies above 6 GHz.

Specifically, we acknowledge that to achieve a maximum link data throughput of 10 Gbit/s or greater would require bandwidths of the order of 1 GHz or more per operator.

We also note that it would be preferable for the spectrum assigned to multiple operators to be contiguous. This is because non-contiguous assignments would increase the cost and complexity of the end user devices, due to the need to isolate and protect the services that may be using the intermediate spectrum blocks. Contiguous assignments would also minimize the tuning range of the end user devices, and mitigate the costs associated with very wideband electronic components and antennas.

We believe that technological advances in a number of areas are increasingly facilitating the utility of spectrum above 6 GHz. These include advances in semiconductor technologies (allowing increasingly linear and efficient RF components) and antenna array designs combined with adaptive spatio-temporal signal processing algorithms (allowing increasing range and spectral efficiency).

We believe that the assignment of dedicated spectrum for the mobile service continues to be the preferred approach for ensuring that a high quality service is delivered to citizens and consumers. However, we acknowledge that in certain circumstances, and in certain geographic areas, sharing of spectrum with existing radio services may be needed. We believe sharing would be least challenging where the existing service has receivers whose area of operation is restricted geographically, or where the receivers are geographically fixed and their numbers are low. We believe technologies including database assisted access (e.g. building upon the concept of Licensed Shared Access) and polite protocols are key enablers in this area.

We note that the need to provide adequate backhaul connectivity for expanding mobile services is a significant technical and administrative challenge. With the massive number of cells required for mmW access, traditional individual licenses for each cell's backhaul link may be an administrative burden. Licensing flexibility to enable an operator to apportion channels between access and backhaul may be helpful to reduce administration and simplify coordination.

We note that technologies which allow the sharing of spectrum (by a mobile operator) between radio access and backhaul are currently under development. We believe that these may allow an "integrated" technology solution to 5G access and backhaul in addition to the more traditional approach of using dedicated solutions. Also of importance is the requirement that the ongoing assignment of bands for radio backhaul within the 6-100 GHz range continues to account for the need to maintain and expand the capacity to serve the rollout of LTE-A and its evolution and in the longer term to serve future 5G systems. The allocation of spectrum above 6 GHz to both Fixed and Mobile services provides the flexibility to address the future requirements for access and backhaul capacity.

In the context of expanding the scope to frequencies above 100 GHz, we believe that frequencies below 100 GHz are of higher priority, due to both more favourable propagation conditions and lower cost of equipment. For this reason, it is important that any search for frequencies above 100 GHz does not compromise the availability of bands below 100 GHz for future mobile services.

Finally, we emphasise the importance of global harmonisation of the targeted mmW bands in order to benefit from the global manufacturing economies-of-scale for low cost equipment that will be attractive to industry and consumers who already benefit, to a large extent, from such harmonisation in the lower frequency bands (< 6 GHz).

We therefore strongly encourage Ofcom to support a WRC-19 Agenda Item to study the possibility of mobile services, including IMT designation, for bands in the 6 to 100 GHz frequency range, with the objective of ensuring harmonization at a global level.

Consultation questions and our responses

Question 1: Are there practical ways of achieving the very high performance that use of wide channels above 6 GHz could offer, for example using carrier aggregation of lower frequency bands?

The very high performance requirements for future 5G radio systems correspond to a maximum delivered link data throughput of 10 Gbit/s or greater, coupled with a low latency of 1 ms or less. In the bands above 6 GHz, these requirements can be most practically achieved with channel bandwidths of the order of 1 GHz or more.

In the bands below 6 GHz, the available channel bandwidths are often of the order of 20 MHz. We note that aggregation of up to 5 component carriers is foreseen by the existing standards. The future evolution of the standards will consider larger channels as well as the possibility to aggregate a larger number of carriers. Nevertheless, while aggregation of these channels is possible, most practically when they are adjacent, the available aggregated bandwidths will still be of the order of 100 MHz and insufficient to achieve the 10 Gbit/s target.

While wider bandwidths may be created from the aggregation of channels in different bands, such aggregation can be technically challenging, especially for the end user devices. One of the major practical issues is the filtering required to isolate and protect the services that may be using the intermediate spectrum blocks. Multiple power amplifiers (PA) and antennas/filters would be needed on the transmit side and multiple antennas/filters on the receive side to suppress the intervening signals. If the intervening signals are strong, they may completely overpower the reception of signals in desired channels, and so block the use of the aggregated spectrum.

Furthermore, the bandwidth of an antenna has in practice an upper limit of about 10% of the centre frequency of the antenna’s operational range in the end user devices. This makes aggregation across widely separated channels difficult, as multiple antennas may be required. It is particularly difficult to provide multiple wideband antennas within the form factor of mobile devices to accommodate multiple bands of widely differing frequencies. The ability of mobile users to roam or transfer among operators with separated bands may be impacted if multiple antennas are required.

Being able to utilise significant bandwidths of contiguous spectrum to reach the 10 Gbit/s goal is the principal reason for migrating the 5G systems to operate in the mmW bands.

Question 2: What recent or emerging advances in technology may provide effective solutions to the challenges in higher frequency bands? For example can increased propagation losses be mitigated by using the high gains available with massive MIMO?

There are three areas of advances in technology that provide practical solutions to utilizing the higher frequency bands. These include improved semiconductors, multi-antenna arrays and adaptive spatio-temporal signal processing techniques.

New semiconductor developments are now delivering electronic components (e.g. low-noise amplifiers, power amplifiers and mixers) using processes and material that achieve the necessary linearity, efficiency and power levels to meet the needs of link budgets in the mmW bands.

Recent developments have also shown the practicality of antenna arrays to achieve additional gain to both serve the link and to provide directionality to minimise effects on adjacent users. Techniques for integration of LNA/PA within the arrays to minimise losses have also been developed. These techniques provide gains that help to address the propagation losses for the mmW radio signals.

Adaptive signal processing techniques are also being developed that enable the radio link coding, modulation, and antenna beam patterns to be adapted and coordinated among cells to address the local RF transmission and interference conditions. This includes joint rate adaptation and dynamic beam-steering/tracking. The use of MIMO techniques also enables the new radio systems to adapt to multipath propagation and exploit this to provide parallel channels to improve throughput.

The development of suitable integrated circuits (SiGe, CMOS and SoC) has already started for equipment intended for the 60 GHz bands in some systems. This development work will also carry over to other bands above 6 GHz and speed up the development and deployment of practical equipment.

It may be noted that only the part of the mmW transceiver (e.g. the LNA/PA/Osc/mixer) that operates at mmW RF frequencies requires very high frequency chip (e.g. SiGe) performance. Once amplified, the mmW signals are converted to baseband where "conventional" (e.g. Silicon and CMOS) chip designs may be used.

Question 3(a): Are there any fundamental/inherent frequency constraints of the 5G technologies currently being investigated with regard to minimum contiguous bandwidth per operator? Will the spectrum for multiple operators need to be contiguous (i.e. a single band) or could multiple operators be supported through multiple bands?

With regards to a minimum contiguous bandwidth per operator for frequencies above 6 GHz, it is preferred if this bandwidth is 1 GHz or more to enable the high throughput "Gbit/s user experience" discussed in the Ofcom CFI and elsewhere in this document. This is of course the principal reason for moving to the mmW bands for 5G technologies.

It is also preferred if the spectrum assignments to multiple operators are contiguous to facilitate multi-operator roaming of the end user devices. Therefore, assuming four operators with national coverage, this implies the availability of 4 GHz or more of contiguous spectrum.

For the implementation of practical antennas in the end user devices, the total bandwidth across all the operators' bands should be kept below around 10% of the centre frequency of the spectrum assignment. A similar bandwidth limit is also required for practical RF filters in order to avoid excessive insertion loss.

Without band contiguity, the end user devices may require multiple antennas and RF circuitry to address separate operator assignments, and the issue is further exacerbated where multi-antenna technologies such as MIMO are used. This will either increase the size and complexity (and cost) of the end user devices or preclude their interoperability across operators if only a single band is accommodated in an end user device.

Question 3(b): Are there any fundamental/inherent frequency constraints of the 5G technologies currently being investigated with regard to frequency range over which the technologies are expected to be able to operate, for example due to propagation, availability of electronic components, antenna designs and costs of deployment? For example, is 10-30 GHz better or worse than 30-50 GHz and why?

Many factors are important in the choice of suitable mmW frequency bands for future mobile services. These include required bandwidth, RF propagation, availability of electronic components, antenna designs and the costs of deployment and spectrum sharing between the mobile services and incumbent services.

As noted elsewhere in this document, given that very high throughput services of 10 Gbit/s or greater are to be supported by the end user device, then wide bandwidths of 1 GHz or greater are necessary. For this reason, mmW bands of greatest interest are those where bandwidths in excess of 1 GHz can be assigned per operator.

To the extent that all the bands in the range 10-100 GHz experience radio propagation that is largely limited to line-of-sight or shorter range non-line-of-sight communications, the listed bands are more-or-less equivalent. The lower frequencies may be slightly preferred due to reduced propagation and building penetration losses, but the upper bands may also benefit from increased specular reflections that may be exploited to increase throughput or reduce interference.

While the lower bands may benefit initially from slightly lower costs of electronic components and reduced RF losses, these benefits will decrease over time as new designs and devices are developed.

Bands which may be adjacent to passive services (e.g. EESS or RAS) are less desirable as these may require significant guard bands and/or significant geographic protected areas to prevent harmful interference to the sensitive scientific instruments.

Of overriding importance for the selection of mmW bands, however, is the need for at least regional and preferably global harmonisation for usage of the spectrum for mobile services. Whatever band the local mmW service may be using, the end user devices need the ability to roam among operators and bands nationwide and globally. It is only through globally harmonised frequency bands and technical regulations that end user devices can be provided with the global manufacturing economies-of-scale that will be attractive to users accustomed to lower frequency devices that already benefit from such harmonisation. Without regional/global harmonisation of UK spectrum assignments and technical regulations, the UK-specific mmW mobile services will not achieve the low equipment costs expected by consumers.

Also of importance is the requirement that the ongoing assignment of bands for radio backhaul within the 6-100 GHz range continues to account for the need to maintain and expand the capacity to serve the rollout of LTE-A and its evolution and in the longer term to serve future 5G systems.

Going forward, we envisage an approach whereby the relevant mmW spectrum bands are allocated to both the Mobile and Fixed services, thereby allowing sharing of spectrum between access and backhaul. This might be via an integrated technology solution or dedicated solutions. The market will then exploit this flexibility appropriately based on advances in technology.

Question 4: Will 5G systems in higher frequency bands be deployed, and hence need access to spectrum, on a nationwide basis or will they be limited to smaller coverage areas? And if so, what sort of geographic areas will be targeted?

The very high-throughput mobile services using the mmW frequencies will typically be deployed where there is a high density of users (i.e. indoors or in dense urban settings).

Such traffic concentrations happen on a nationwide basis, although typically in small clusters within and surrounding cities and towns. Individual cell-sizes will be of the order of 100 m or less due to radio propagation constraints and cell groupings will likely be deployed locally and including indoors.

It is expected that there will be nationwide availability of spectrum bands, with nationwide assignments and common technical specifications for networks to facilitate user convenience and national roaming. In many deployments, the mmW access cells may be operated in a manner that is complementary to the ubiquitous lower-frequency access network cell coverage.

Question 5(a): To what extent will 5G systems in higher frequency bands need dedicated spectrum on a geographical and/or time basis or can they share?

Traditionally mobile services have been assigned dedicated spectrum over a wide geographic area. This is because of the wide geographic distribution of the mobile devices’ operation. The assignment of dedicated spectrum for the mobile service continues to be the preferred approach for ensuring that a high quality service is delivered to citizens and consumers.

However, we acknowledge that in certain circumstances, and in certain geographic areas, sharing of spectrum with other radio services may be needed. Such sharing will be contingent upon availability of knowledge of the technical parameters of both the mobile service and the existing services to permit their effective technical coordination.

To the extent that other services, such as the Fixed service, may be confined to limited geographic areas (i.e. between two link endpoints), spectrum sharing may be possible if the areas of mobile operation do not overlap with those of the fixed service links. For the mmW bands, where the individual mobile service links are confined to short-ranges (e.g. within small cell areas), there may be sharing with the fixed services in areas outside of the “footprint” of the fixed service radio link beams.

Question 5(b) If they can share, what other types of services are they likely to be most compatible with?

The sharing of spectrum between the mobile service and another radio service is less challenging where the other service’s use of the spectrum is restricted geographically and/or in the frequency domain and/or in time.

Furthermore, sharing is least challenging where the geographic locations of the other service’s receivers are fixed and well known, and the number of receivers is low.

Question 5(c) What technical characteristics and mitigation techniques of 5G technologies could facilitate sharing and compatibility with existing services?

Sharing between the mobile service and existing services could be facilitated via two categories of technologies:

1) The first category consists of the use of “polite protocols” implemented in the physical layer and medium access control layers of the mobile service. These include technologies such as “listen-before-talk” and dynamic frequency selection. Such polite protocols, for example, may permit the mobile service system to listen and detect existing usage of a channel and thereby either defer transmission or reselect another unused channel. Such techniques are being considered, for example, for the use of 5 GHz license exempt spectrum by LTE technologies; the so-called licence-assisted access (LAA) approach.

2) The second category consists of database-assisted spectrum access (building on the existing concept of LSA). Here, a database of the geographic and time usage of spectrum by the existing services may be used by the mobile service to restrict mobile operation where harmful interference might be caused to the existing service.

In some future implementations, these two categories may be combined.

Question 5(d) Could spectrum channels be technically shared between operators?

Traditionally, the preferred approach for the use of spectrum by mobile network operators has been on an exclusive basis. That is, a mobile operator would be the only user of the spectrum in the channels that they have been assigned. We believe that this model will be the dominant approach for some time. Going forward, with the mmW deployments for mobile services in which the cell sizes are small and the geographic coverage may be non-contiguous, further arrangements may be considered.

In recent years, alternative models and arrangements have emerged. This has involved mobile network deployments where, for example, the radio access network is provided by a single entity. This entity’s access network would accept mobile traffic from multiple “service providers”. The entity would route the traffic from the access network to the appropriate service provider’s network. This effectively implies the sharing of a single block of spectrum among multiple virtual network operators. In another future variation to this theme a group of licensees may pool their resources and infrastructure to a joint entity that provides improved coverage and capacity to all of their customers.

One can also envisage further alternative models emerging in the future to ensure efficient use of the spectrum:

1) One approach might be through tight coordination at the medium access control (MAC) and radio resource management (RRM) layers, whereby multiple operators cooperate and route their traffic over the totality of their pooled spectrum assignments, thereby using the spectrum with increased efficiency.

2) Another approach might be through the use of polite protocols implemented in the physical and medium access control layers of the mobile service. This approach will further facilitate co-existence between cooperating collocated mobile network operators.

Again, such techniques are currently being considered for the use of 5 GHz licence exempt spectrum by LAA-LTE technologies.

Question 6(a): Given the capacity and latency targets currently being discussed for 5G how do you anticipate backhaul will be provided to radio base stations? Are flexible solutions available where the spectrum can be shared between mobile access and wireless backhaul?

As the traffic and density of usage grows, the backhaul from the base stations to the core network becomes a significant practical and technical challenge. Each base station of the mmW system will require communication of the traffic and control signalling to and from the core network and other base stations.

Traditionally this backhaul has been provided by separate services including cable, fibre optic transmission and fixed radio link services. It is to be expected that some of the mmW installations will continue to make use of such backhaul facilities. It is also expected that the large number of small-cell coverage base-stations of the mmW access systems may also make use of radio backhaul that is integrated with the mobile access system and spectrum (i.e. self-backhaul).

In other words, the mmW mobile network operator may share its spectrum (with itself) between radio access and radio backhaul functions. The selection of the radio channels and areas of coverage for each function will be based on the operator's need to address the offered access traffic and to conduct it back to the network. Such flexibility and close internal coordination may permit additional efficiency in spectrum usage. Research on such integrated sharing systems is ongoing.

Integrated sharing of spectrum between access and backhaul might be practical if the relevant mmW spectrum bands are allocated to both the Mobile and Fixed services and with perhaps an IMT designation. With the bands identified for both services licensed to a mobile network operator, the operator can then self-coordinate the sharing of spectrum between radio access and radio backhaul functions within their network. Access and backhaul might be implemented via an integrated technology solution or dedicated solutions.

Question 6(b) What, if any, spectrum will be required? What channel sizes will be needed? Will the bands used be similar to those currently used for wireless backhaul?

Simple arithmetic suggests that the amount of spectrum required for the backhaul may be about equivalent to that used for mobile access traffic (minus the portion of backhaul traffic that is handled via terrestrial cables or fibre).

If the backhaul links can be engineered as point-to-point links with high gain antennas, then they may be more efficient than the access links and so further reduce the backhaul spectrum requirement.

None-the-less, the backhaul requirement is a significant technical and administrative challenge. With the massive number of cells required for mmW access, traditional individual licenses for each cell's backhaul link may be an administrative burden. Licensing flexibility to enable the operators to apportion channels between access and backhaul may be helpful to reduce administration and simplify coordination. As noted elsewhere, integrated access/backhaul systems for mmW are already under development and may make use of the same bands for backhaul and access.

Question 7: Should we expand the scope of bands being reviewed beyond the 6-100 GHz range?

We note that spectrum below 6 GHz remains the preferred range for mobile service radio access. This is primarily due to the favourable radio propagation conditions in these bands. As such, the search for suitable mmW bands for future 5G mobile services must not in any way prejudice the ongoing assessment and the allocation of mobile bands below 6 GHz.

We also note that frequencies above 100 GHz are currently of lower priority than those below 100 GHz for purposes of mobile access. This is both due to increased radio propagation loss and the challenges in transceiver design. For this reason, it is important that any search for frequencies above 100 GHz does not compromise the assignment of bands below 100 GHz suitable for mobile services.

Having said this, we note that the new technologies that are enabling the use of mmW bands (e.g. at 60-80 GHz) for mobile and fixed services will evolve to also be applicable for frequencies above 100 GHz. It is expected that as the working experience at frequencies near 100 GHz develops, the channels above 100 GHz will become more attractive (and practical) for future mobile access and backhaul systems. Such frequencies may, for example, be very helpful to provide the integrated access and backhaul (fixed point-to-point or point-to-multi-point) needed to distribute the user data-traffic in the access network. Such an integrated service should be permitted by the regulations (both above and below 100 MHz).

To the extent that new regulations may need to be developed to enable widespread mobile and backhaul services (including their integration) above 100 GHz, it would seem prudent to begin that process now. However, such consideration should not dilute the activities for enabling access to spectrum for mobile services below 100 GHz.

Question 8: Do you agree that it is likely to be necessary for bands to have an existing allocation to the mobile service? Does this need to be a primary allocation?

It is most advantageous for the mmW bands to have a primary mobile service allocation in the international and national frequency allocation tables (preferably in all three regions of the Radio Regulations). An IMT designation may also be advantageous. A mobile allocation across the ITU tables improves the probability of global harmonisation of the band for mobile services. Such a designation also typically indicates an improved possibility of sharing with the other allocated services in the band or in adjacent bands. A band that does not have a primary mobile allocation may be of lesser consideration as it may not be suitable for the global harmonisation necessary for low cost equipment and roaming. Consumers are conditioned to a low price point for their mobile devices. For example, low cost end user devices supporting common services (e.g. GSM, 3G) are ubiquitous in the market today. For the mmW systems to be successful in the long term, similar price and global ubiquity must be reached. A common global spectrum allocation with common technical standards is thus necessary to achieve the low-cost points.

Question 9: Do you agree with the criteria we have used for our initial filter of bands, and are there other criteria that could also be used?

Yes, we agree with the filter criteria. An existing global primary allocation to the mobile service is essential as it improves the potential for successful global economies of scale for services and equipment.

A contiguous bandwidth in excess of 1 GHz per operator is also necessary to offer a Gbit/s experience to the user. Further filtering of the band choices can be based on the existing usage of the bands and compatibility for sharing as well as the usage in adjacent bands (e.g. passive scientific services) which may require protection through significant guard bands or low signal levels.

We note that for the lower mmW bands, where the 10% bandwidth limit of antennas may limit performance for the end user devices required to operate across multiple operator assignments, a narrower assigned bandwidth (e.g. 500 MHz) may be practically appropriate.

Question 10: Of the spectrum bands/ranges mentioned in this section, are there any that should be prioritised for further investigation?

We note that of the bands listed in Annex 5 of the Ofcom CFI, those in the 28 GHz range (27.5 - 28.35 / 29.1 - 29.25 GHz), the 37 GHz range (37.0 - 38.6 GHz), and the +60 GHz range (64 - 71 GHz, 71 - 76 GHz, 81 - 86 GHz) are receiving attention in the US. Priority consideration of these ranges may assist with the goal of international harmonisation of mmW band usage.

Question 11: Are there any bands/ranges not mentioned in this section that should be prioritised for further investigation? If so, please provide details, including why they are of particular interest.

Annex 5 of the Ofcom CFI describes a comprehensive range of spectrum opportunities in the UK. The bands between 31.8 - 33.4 GHz, currently allocated for the Fixed service, are not used extensively today and may be further considered for 5G access and backhaul.

Question 12: Are there any particular bands/ranges that would not be suitable for use by future mobile services? If so, please provide details.

No comment.

Question 13: What additional information, beyond that given in Annex 5 would be useful to allow stakeholders to develop their own thinking around spectrum options?

It is noted that most of the bands listed in the Annex 5 may involve sharing of the new mobile service deployments with other existing or planned services. Assessing these sharing opportunities by Ofcom and stakeholders is one of the key next steps in developing spectrum options for future mobile systems. Such further consideration will require some detailed analysis of the geographic distribution of existing users, their operating channels, as well as the technical parameters of their systems and deployments. Analysis of systems requiring protection in adjacent bands may also be required.

Furthermore, a review of the detailed practical usage of the bands across other nations, particularly those in Europe, will also be necessary in further filtering of the band choices. The most advantageous bands to study further are those for which there is a common global compatible incumbent usage. The tables in Annex 5 would be of additional use if they were augmented to show the usage/occupancy of the bands across Europe.

Finally, we note that it is difficult for stakeholders to assess the viability of co-existence with existing services where details of the existing use are not readily available. Importantly, efficient spectrum sharing can only be achieved if adequate information on the existing use can be incorporated in the co-existence modelling, otherwise the restrictions on the new service become unnecessarily over-cautious. For the above reasons, it is important that, where possible, the existing users are encouraged to share appropriate details of their spectrum usage to stakeholders.

Question 14: What are the most important criteria for prioritising bands going forward?

We believe there are a number of criteria that are key for prioritising bands above 6 GHz for future use by mobile services. These are:

1) global harmonisation of the bands for the mobile service;
2) availability of sufficient bandwidth to support the user’s “Gbit/s experience” (i.e. > 1GHz per operator);
3) compatibility with existing services in the band; and
4) compatibility with existing services in adjacent bands.

Furthermore, it would help to have regulatory flexibility to support both mobile access and backhaul operations within spectrum that is allocated to both Fixed and Mobile services, possibly through joint licensing for access and backhaul.

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