#### Thank you for contacting Ofcom.

You submitted the following information:

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Mrs

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Eiman

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Mohyeldin

#### **Representing:**

Organisation

#### **Organisation (if applicable):**

Nokia

#### Email:

#### What additional details do you want to keep confidential?:

No

#### If you want part of your response kept confidential, which parts?:

#### Ofcom may publish a response summary:

Yes

#### I confirm that I have read the declaration:

Yes

#### **Additional comments:**

Nokia welcomes this opportunity to respond to Ofcom's Call for Input regarding Spectrum above 6 GHz for future mobile communications.

Nokia is a leader in the fields of network infrastructure, location-based technologies and advanced technologies. With operations around the world, Nokia invests in the technologies of the future. Nokia has three strong businesses: Nokia Networks, our network infrastructure business; HERE, our location intelligence business; and Nokia Technologies, which is

focused on technology development and intellectual property rights activities. Through these businesses, we have a truly global presence. We are also a major investor in R&D, with investment through the three businesses amounting to several billion dollars annually. Nokia's expertise in mobile broadband is being leveraged to the fullest extent as it researches 5G technologies. Nokia is actively driving and participating in collaborative research on 5G and related industry collaboration. Nokia view is that exploring spectrum above 6GHz deemed important stage for 5G activities in the different research and standardizations fora that are emerging around the world.

Nokia view is that centimetric and millimetric wave bands present an important opportunity to open up large contiguous blocks of spectrum to facilitate the increasing mobile broadband data demands, particularly in urban and sub-urban areas and specific venues and locations where large number of mobile devices are concentrated. 5G services will also need to use spectrum below 6 GHz to support a great QoE (quality of user experience) with ultra-low latency and ultra-high throughput.

## 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?:

In general, carrier aggregation is more complex approach compared to a case if wide contiguous spectrum would be available.

To increase performance and spectral efficiency, several technologies like carrier aggregation have been developed and as well enhanced. However, two fundamental aspects have to be considered: the substantial increase in system complexity along with fundamental limits on hardware implementation and channel conditions, and limitation for future improvement to meet the growing wireless data usage.

Technologies used to increase peak data rate and capacity in lower frequency bands are for example the use of Massive MIMO technologies in base stations and Carrier Aggregation over fragmented frequency bands. For both cases, there are some implementations complexity and limitation. For carrier aggregation there are limitation of the number of aggregated carriers and the implementations complexity, as carrier aggregation could also make the receiver more complex. Thus technologies that potentially could enhance performance/ throughput have some challenges and limitations.

#### 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?:

The elements related to emerging advances in technology (like massive MIMO and beamforming) are still under study. However from the recent advancements in technologies developed, it is expected that effective solutions to overcome the challenges like propagation environments and the higher losses in these higher frequency bands will be enabled using large antenna arrays and beamforming. It is also expected that there will be different antenna and RF solutions for different band ranges at higher frequency bands.

As the carrier frequency increases there is an advantage of inherently smaller antenna sizes,

which can be arranged in relatively small-footprint phased-arrays for high directivity and beamsteering. This feature will provide previously unconsidered benefits that may be needed to account for:

- Higher gain (and perhaps adaptive) antenna systems at the base stations.
- Beam steering arrays on the user terminals.
- Dynamic pointing of the base station beam(s) according to traffic demands.

Polarization is expected also play an important role in higher frequency ranges. For example the base station can employ two arrays per sector where each array has an orthogonal polarization to the other. The user terminal could also have two antennas or two arrays with orthogonal polarizations.

## Question 3: Are there any fundamental/inherent frequency constraints of the 5G technologies currently being investigated with regard to: a) 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?

b) 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?:

5G is envisaged to expand and support diverse applications and use cases. Thus 5G is expected to have varying requirements with respect to peak date rates, latency, bandwidth and frequency. The technical requirements related to different 5G use cases and application including as well frequency bands and possible different technical constraints arising from those different bands (e.g. propagations conditions) are still under study.

5G systems are expected eventually to deliver end user data rates as high as 10 Gbps. In order to facilitate the very high performance expected from future systems, Nokia opinion is that a wide contiguous bandwidth of several hundred MHz up to at least 1GHz is needed per operator, depending on operators required user/service bit rates, use cases and deployment scenarios. It should be noted that discussions related to minimum bandwidth per operator are still ongoing.

Related to part b), recently considerable research has been carried out by various organizations on a global scale on feasibility of 5G systems in frequency ranges above 6 GHz. Channel models under different propagation environments are still under study in different research fora. Nokia believes it is not desirable to rule out any frequency band options in this early phase of 5G studies.

#### 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 elements related to 5G system deployments are still under study. As per their nature, higher bands above 6GHz inherently would lead to smaller coverage areas, however, there are some studies ongoing how to enhance the mobility and coverage of 5G in the bands above

6GHz.

It is still under study how 5G would be deployed geographically but most likely it will be quite flexible and suitable for different kind of deployments scenarios (e.g. nationwide or local).

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

c) What technical characteristics and mitigation techniques of 5G technologies could facilitate sharing and compatibility with existing services?d) Could spectrum channels be technically shared between operators?:

Nokia opinion is that exclusive licensed/dedicated spectrum assignment methods will remain important for ensuring QoS and stability for long term investments into networks and the underlying spectrum. However, the interest in improving spectrum utilization further could drive more innovative regulatory tools that provide new spectrum sharing opportunities for 5G systems. Elements related to sharing (either geographical and/or time basis) and aspects related to compatibility are still under study.

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? 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?

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The elements related to 5G backhauling are still under study. However, most likely there will be flexible solutions available where the spectrum can be shared between 5G mobile access and wireless backhaul. This would further enhance the efficient use of spectrum.

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

In Nokia's opinion, currently it is not necessary to expand the scope above 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?:

In Nokia's opinion, it is not desirable to rule out any frequency band options in this early phase of 5G studies. In the end of the day, 5G as a mobile system needs to have mobile allocation (either new or existing allocation) and identification for IMT.

Several methods and criteria to evaluate the suitability of the bands above 6 GHz for 5G need to be considered. There are good opportunities for bands already allocated to the mobile service in the ranges from 6-100 GHz that need to be considered. However, the key goal is to find a contiguous band(s) that are (or can be) harmonized at global level. Nokia's opinion is that frequency ranges that contain bands with no primary allocation to mobile service should also be examined and considered for 5G.

### 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?:

Spectrum aspects of 5G need to be studied in detail in the next ITU-R study period (assuming that there will be an Agenda item for WRC-19 for 5G spectrum). Also, in CEPT ECC, there is a new strategic plan in place for next 5 years (as agreed in ECC at Montreux, Nov 2014) where 5G and bands above 6GHz is one key topic:

"CEPT ECC should consider strategic initiatives to support the development of advanced technologies related to broadband needs in higher frequency ranges and to obtain contiguous spectrum in substantial blocks. "

In Nokia's opinion, it would be very useful to have a CEPT/regulator led process to find a most suitable spectrum solution for 5G, covering all services above 6GHz.

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

In Nokia's opinion, the whole spectrum between 6 -100 GHz needs to be investigated in detail in order to find a most suitable spectrum solution for 5G.

In the initial mobile industry exercises (e.g. METIS) to find suitable bands it has become clear that there is not enough public information about the current usage and, especially, the future plan for the current incumbents, e.g. ITU-R Radio Regulations only has information about the allocations but the actual usage is not there. Therefore analysis within a research study that is based on particular assumptions and the current regulatory situation assuming that:

- the usage is in line with the current allocations in the ITU Radio Regulations;

- this existing usage does not change in the foreseeable future

will not provide fully comprehensive and complete picture of the suitability of bands above 6GHz.

Therefore it would be very useful to have a CEPT/regulator led process to find a most suitable spectrum solution for 5G, covering all services above 6GHz, like e.g. mentioned in CEPT ECC Strategic Plan for next 5 years (see our answer to Question 9).

# 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.:

Please see our answer to Question 10.

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

Please see our answer to Question 10.

## 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?:

Please see our answer to Question 10.

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

In addition to methods and criteria mentioned in answers to Question 8 & 10, Nokia would like to note that for the 5G to provide a range of different services and applications with different characteristics and requirements (e.g. from ultra low latency and high reliable applications to extreme high data rates applications) different types of spectrum should be considered from different parts of the frequency range between 6 GHz and 100 GHz.

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