

## Consultation response form

Ofcom 5G 26 GHz spectrum Call For Inputs (CFI) September 2017

Samsung Electronics UK Submission

21<sup>st</sup> September 2017

### 1. About Samsung UK and Ireland

- 1.1 Samsung has been in active in the UK since 1982 when we established the UK as one of our key sales subsidiaries. Over the years our presence and activity in the UK has grown as we utilise the significant growth and investment opportunities the UK offers. Both our European Headquarters and design and innovation centre are based in the UK.
- 1.2 The UK is an important European hub for Samsung. There are now 8 out of 9 Samsung Electronic functions based throughout the UK with a growing number of employees working in sales, R&D, design and quality assurance.

### 2. The Growth of Connectivity: Fuelling Future Technologies

- 2.1 In global terms, Samsung now views the UK as a pace setter in welcoming and embracing innovation. It has moved from a cautious, late adopters stance, to a society where our relationship with technology is now increasingly confident, and importantly increasingly demanding.
- 2.2 A decade ago nations like Finland were seen as tech pioneers, but the UK has caught-up and whether it is our capital's transport, our children's classrooms or even just our weekly shopping, it is increasingly technology led and above all smart technology led.
- 2.3 Consumers want to create and consume content "Anytime, Anywhere" –creating a digital social environment. The variety and type of content we consume has exploded. We have new digital formats such as multiplatform gaming, interactive content, and user generated content.
- 2.4 Digitalisation has also allowed the consumer to gain more control of when and where content is consumed: time shifting of video content, for example, is revolutionising the video markets.
- 2.5 All of these services are supported by competing and cooperating broadband technologies, consumed on different technology and service platforms, which themselves interconnect and change based on where you are and how you want to consume them.
- 2.6 Connectivity is changing not just our everyday lives but also the way we do business, opening up new commercial and strategic opportunities for all kinds of companies. UK-based companies are making better use of digital platforms, whether through online interaction with customers or in-house digital processes, to boost sales and productivity.
- 2.7 The evolution of connectivity and specifically machine to machine communications is an important future development. Many businesses are well placed to harness this opportunity, and it's imperative that the UK's digital infrastructure is able to support and enable the opportunities to be realised.

- 2.8 Wireless broadband technology is the major element of a nation's critical digital broadband infrastructure and it essential that the regulations and spectrum are in place to support the continuing growth of 4G and the adoption of the new 5G technology. There is the opportunity for the UK to be amongst the global leaders in the adoption, commercialisation and proliferation of 5G. The UK has a once in a generation opportunity to be one of the global leaders in the commercialisation of 5G.
- 2.9 5G is being designed to enable a different range and combination of frequency bands to address different requirements, such as data rates, capacity, coverage and population densities. In simplified spectrum terms you could think of this as low, mid and high bands. Given that the characteristics of these three frequency bands are very different and the cell range and therefore number of base stations required (and therefore investments needed) to cover a given area vary greatly it may be that different regulatory and authorisation approaches are needed between the bands. These three bands will become available over the next few years and therefore there exists an opportunity to design the award and regulatory framework in all three bands. There is the opportunity to have an holistic top down approach and for the UK to have full nationwide coverage with huge capacity, data speeds and latency – one of the world's top 5G nations – starting in cities in 2019 finishing with full nationwide coverage by 2025. The same way in which all have access to water and electricity we believe that the goal should be for all to have access to 5G by 2025.
- a) Low Bands. Spectrum in bands less than 1GHz is great for providing wide area coverage networks and can be combined with several sub-networks - sometimes referred to as layer, to achieve coverage, capacity and performance. For example, a Mobile Network Operator (MNO) may have an LTE 800 MHz layer to provide very wide area coverage. 700MHz is likely to be made available for 5G which will enable wide area coverage. The coverage in the UK needs to improve and this spectrum offers an ideal opportunity to help realise the 5G vision of high speed low latency communications to all, regardless of whether you live in a city, town or village. Given the relatively small amount of spectrum available and the need to have wide spectrum channel widths to provide 5G careful consideration will be needed to be given to coverage obligations, use it or share it requirements, spectrum and infrastructure sharing while still retaining service layer competition and network competition in dense areas etc.
  - b) Mid Bands. Spectrum in bands between 1 to 6GHz can provide suburban and urban area coverage and complement low bands. LTE wide area coverage bands can be augmented with an LTE 1800 layer to provide capacity in suburban areas and completed with a layer of LTE 2600 for dense urban areas. Each of these layers fulfills a role to enable deployment of a network delivering capacity where it is required and affordable coverage everywhere. Specific bands may also have their own characteristics in terms of latency, support for multiple antennas or support for high mobility and indoor coverage. MNOs combine networks deployed across several bands to reap the benefits of all these. Spectrum in the 3.5 GHz (3400-3800MHz) bands are being made available for 5G and are suitable for suburban mobile and fixed wireless access deployments. The availability of the full 400 MHz of this spectrum has been challenging for Ofcom to make available, for a variety of reasons and often beyond the control of Ofcom, but Ofcom and Her Majesties Government are urged to redouble their efforts to make all of this spectrum available as soon as possible.
  - c) High Bands. Spectrum in bands above 6GHz, such as 26GHz (24.25-27.50 GHz) which is the focus for this consultation, provide capacity for very high data rates in hot spots to support



stationary and mobile use, fixed wireless access deployments and complement low band and mid band deployments. These bands provide the main opportunity for the UK to realise the full 5G vision and to match the timescales of other leading 5G countries around the world.

- 2.9 Samsung applauds this initiative by Ofcom, in co-operation with HMG, coupled with high level political support, and would urge that Ofcom licenses 26.50-27.50 GHz in 2018 with a view to making it available for commercial use in 2019.
- 2.10 5G Commercial deployments should be in place for the European Football Championships Semi Finals and to be held in London in 2020.

### 3. Consultation Questions

**Q2.1: What are your planned timelines for commercial availability of network equipment and devices for the 26GHz band? When will equipment for testing and trials be available? Please specify the specific mmWave tuning ranges supported and their timing.**

- 3.1 Canada, Korea, Japan and the US are releasing spectrum within the 28GHz band and China is consulting on releasing spectrum within the 26GHz band. These two bands will be defined in the standards organization, called the Third Generation Partnership Project (3GPP), for 5G in the 24.25-29.5GHz frequency range: 24.25-27.50 GHz (26 GHz band) and 26.50-29.50 GHz (28 GHz band) with the target for completion by December 2017 and the latest by June 2018 during Release 15. These two bands share 26.50-27.50 GHz in common and there is therefore an opportunity to globally harmonise this 1GHz of spectrum within this range. This global spectrum enables the UK and the rest of Europe to leverage and benefit from early deployments and early commercially available equipment from these other countries outside of Europe which are planning launches within the 2018-2020 timeframe. This all helps to generate global economies of scale which are essential in the initial phase of establishing a new technology along with a competitive infrastructure and terminals market for 5G equipment. As the networks scale and more spectrum is made available then the previously established equipment market can then continue to grow, expand into new spectrum that could potentially be made available in a second phase, and other markets can be addressed all benefiting from this global scale. This is why it's important that licensing of the 26 GHz spectrum in the UK and the rest of Europe includes at least the global 1GHz (26.50 – 27.50 GHz) in a first initial phase to take advantage of 5G equipment that has been developed for other countries in other regions.
- 3.2 Samsung already has trial equipment that can operate within the 26.50-29.50GHz GHz band and this equipment is being used in the Arqiva Samsung 5G London trial as well as other trials around the world. A subset of this spectrum is being used for the trial. This includes a full suite of Chipsets, Consumer Premises Equipment, Infrastructure Access Units, Virtualised Core Network, 5G planning tools. Commercial Chipset, Consumer Premises Equipment (CPE) and Access Units (AU) will be available in 2019 that support 26.50-27.50 GHz. This meets Ofcoms indicative timeline of licensing and commercial deployment in the 2018-2020 timeframe. Further, more commercially sensitive, details can be discussed in further bilateral discussions. The Global Suppliers Association (GSA) which represents the major 5G equipment suppliers has published a 5G 26 GHz licensing report which also includes information on equipment availability.
- 3.3 In summary Samsung supports Ofcom making 26.50-27.50GHz in a first step to leverage global developments and scale. The UK and key countries within the rest of Europe would need to

commit with specific spectrum award and availability timelines for the full 24.25-26.50 GHz band in order to generate scale and provide confidence to the industry to pre-commit to developing equipment, particularly chipsets, for the full lower 26 GHz band. The UK is not a large enough market on its own to support a competitive devices and infrastructure eco-system in the 24.25 – 26.50 GHz spectrum therefore other countries are needed in addition to increase the size of the addressable market. UK leadership and pan European market making activities are essential to generate economies of scale. Samsung applauds and supports Ofcom efforts within Europe to make 24.25-26.50 GHz available and persuading other countries to also licence this spectrum. As soon as other countries such as Finland, France, Germany, Sweden etc commit to making this spectrum available with a clear confident timetable then Samsung will deliver products. If China moves early on this band then this would also have a significant impact on equipment availability that operates across the entirety of the lower part of the 26 GHz band.

3.4 It is also important to note that spectrum within 27.50 – 29.50 GHz is owned by a number of commercial entities in the UK such as Arqiva and the mobile network operators. We see no reason therefore why these entities should not be able to reuse this spectrum for Fixed Wireless Access on a national basis thereby enabling the UK to benefit from early global supply of equipment and increased capacity.

**Q2.2: 3GPP studies into NR-based operations in licence-exempt spectrum, when (if ever), do you expect to support licence exempt operation and/or coordinated sharing in the 26 GHz band in your products?**

3.5 There is relatively little focus in 3GPP at the present time on licence-exempt operation for 5G New Radio (NR). If the operation of 4G LTE in licence-exempt bands, supported by industry initiatives such as MulteFire, prove to be successful then it is anticipated that 5G operation in licence-exempt bands will receive more attention. The market for licence-exempt 5G is not yet here which doesn't mean it won't be in the future however at the present time the industry is fully occupied to making 5G in licenced spectrum work. Once the hump of this work is completed then attention may turn to other aspects including the potential use of 5G in a licence-exempt mode. We therefore do not support spectrum within the range 26.50 – 27.50 being made available for licence exempt operation. It is suggested that this issue of licence-exempt operation and regulations to support this should be put on hold and coincide with the second phase of the release of the remaining 5G mmWave spectrum at 26 GHz (24.25 – 26.50 GHz).

3.5 It is important to note that the industry is at the early stage of 5G developments and getting the market and technology successfully launched. Mobile operators are essential to enable this and we therefore support the 26.50 – 27.50 GHz spectrum being licenced on a national exclusive basis. Verticals can be addressed initially through network slicing and use it or share it mechanisms. This approach would provide a balance between getting the technology successfully launched and addressing the verticals.

3.6 Co-ordinated use is a slightly different topic and can be addressed through a variety of technical and regulatory tools. The CBRS spectrum approach in the US may be an example. If local area geographic licenses are to be the way forward in the UK then some way, which is as simple and real world realistic as possible, for the owners of the infrastructure equipment to co-ordinate is required to minimise interference and preserve quality of service. The use of Databases, pre-defined licence areas etc all need to be considered. It should be noted that while the use of pre-defined local areas may sound simple but it should be noted that transport corridors provide a useful test case such as railway lines and motorways. For example how could the East Coast London Edinburgh railway line



be served by 5G under a local area licensing regime. This is an area that would benefit from a joint Ofcom/DCMS/industry activity and then a wider European discussion so that we don't end up with different solutions and potentially different regulatory implementation requirements in different countries across Europe.

**Q 2.3: When do you expect to support standalone New Radio in the 26GHz band in your products.**

3.7 Commercial Chipset, Consumer Premises Equipment (CPE) and Access Units (AU) will be available in 2019 that supports 26.50-27.50 GHz to coincide with potential licensing in 2018 and commercial deployments in 2019. The UK is not a large enough market on its own to support a competitive devices and infrastructure eco-system in the 24.25 – 26.50 GHz spectrum therefore other countries are needed in addition to increase the size of the addressable market. UK leadership and pan European market making activities are essential to generate economies of scale. Samsung applauds and supports Ofcom efforts within Europe to make 24.25-26.50 GHz available and persuading other countries to also licence this spectrum. As soon as other countries such as Finland, France, Germany, Sweden etc commit to making this spectrum available with a clear confident timetable then Samsung will deliver products. If China moves early on this band then this would also have a significant impact on equipment availability that operates across the entirety of this lower band.

**Q3.1: Are there any aspects related to the existing use of 26 GHz not covered in the CFI that you believe need to be considered.**

3.8 None identified.

**Q3.2: What options for the existing services in the 26 GHz band do you believe need to be considered to allow for the introduction of new 5G services? Please give as detailed a response as possible along with all relevant information and explain how you would see any potential option your provide working in practice.**

3.9 Begin the planning process to move the fixed links out of the 26GHz band. It is suggested that the five year notice should be given to existing users such as Fixed Links that the band should be vacated so that 5G can be deployed by 2022 at the latest in the 24.25 – 26.50 GHz spectrum in a second phase of licensing. If a sharing solution can be found in the meantime between 5G (FWA & Mobile) and Fixed Links and the spectrum made available for 5G in some areas beforehand then great, but giving a vacation notice it is considered prudent and if a realistic sharing approach cannot be achieved in the next few years then 5G will not have been unnecessarily delayed. Recent Ofcom studies indicate that it is very challenging for 5G and Fixed Links to be able to share in many locations.

**Q3.3: Should a moratorium be placed on issuing new licences in the 26GHz for existing services? E.g. to ensure that the 26GHz is not unnecessarily encumbered prior to the development of a new authorisation / licensing approach for 5G services.**

3.10 Yes.

**Q4.1: What service would be delivered and to which consumer and/or organisations.**

3.11 As with all new mobile technologies at this stage in the development cycle there is always debate as to the 'killer application' and 'business case' etc etc. For previous mobile generations (2G, 3G and 4G) it has been easy with the benefit of hindsight to say what the business case and use

cases were and then say that these were well understood prior to licensing and deployment. This is not really the case in practice and there is certain degree of innovation and entrepreneurship required by all parties, including Ofcom and HMG. Samsung believes that there are numerous market opportunities to be addressed by 5G. Fixed Wireless Access is an early specific opportunity and this is what is being explored by Arqiva and Samsung in the London 5G trial and also with operators such as Verizon in the US. Enhanced mobile broadband is another and a number of operators in the US, Japan and Korea are looking at this opportunity such as busy streets, stadiums, offices, hotels etc. Smart cities and the internet of things such as advanced cameras, smart traffic devices, smart manufacturing and buildings, provides another opportunity. Transport corridors and providing high speed low latency connectivity to trains, buses, lorries and cars is another opportunity both within cities but also along roads and railway lines between cities.

**Q4.2: Where in the UK would the 26GHz spectrum be used to deliver services? For example, will deployments be focussed on:**

3.12

**a) Areas of existing high mobile broadband demand?**

Yes.

**b) Rural areas?**

5G FWA may provide an opportunity to provide fixed wireless broadband to underserved areas.

**c) Rail and road corridors**

Yes. There are a number of 5G transport trials planned with discussions taking place around the world. 5G at 26 & 28 GHz could enable high speed backhaul between an access unit on the trackside and an access unit on the carriage. Distribution within the carriages via wifi &/or small cells then enables users to receive fast broadband. There are a number of regulatory and industry ecosystem challenges around providing ultra-high speed capacity broadband to railways. Government leadership is needed to bring the ecosystem together in a workable and scalable solution. For example Treasury, Department of Transport, DCMS, Ofcom and the multitude of entities involved in the trackside and carriages would need to be brought together and aligned in a workable, scalable and ultimately commercially viable approach. Providing 5G communications from the trackside to a base station on the train is being investigated which would then enable ultrafast wifi be distributed within the carriages. Having reliable ultrafast wireless broadband would provide significant productivity enhancements and adds value to a nations railway investments and network. Similar approaches could be envisaged for road corridors serving buses and lorries and later cars.

**d) Specific types of enterprise or industrial sites?**

Enterprises, factories, industrial sites etc are often cited as an opportunity for low latency 5G. There is considerable discussion within the wider industry if this should be served by traditional mobile network operators or whether the enterprise should own the spectrum licence and have their own site specific network deployed in their own spectrum. There are pros and cons to both approaches. Network slicing offers the opportunity for mobile network operators to provide bespoke connectivity to enterprises while the option for enterprises to own their own spectrum may provide longer term confidence to the enterprise to invest in 5G. It should be pointed out that we are at the start of the development of a new technology, in this case 5G, and as such commercial actors are required which have technical experience, money, scale and spectrum to help gain market traction and lift off for this new technology. Samsung believes that only the MNO's meet this criteria at this stage in the development of 5G. After 5G has been successfully deployed then smaller more bespoke players could benefit from this technology. If Ofcom is minded to make spectrum available for enterprises then the amount of spectrum should be limited in the initial phase to test demand when compared to that available for mobile network operators who are absolutely needed in order to help 5G to become established. As



discussed previously Samsungs preference is for all of the 26.50 – 27.50 GHz band to be licenced on a national exclusive basis in order to help establish the 5G market. Network slicing and use it or share it requirements can help serve the vertical market during this first stage. Once the remainder of the spectrum 24.25 – 26.50 GHz is made available in a second stage then Ofcom & DCMS could evaluate whether dedicated local area licensing is needed for verticals.

**e) Indoors or outdoors?**

Both. Providing deep indoor coverage will require the access unit to be located indoors in many deployments.

**f) Specific nations or regions of the UK?**

Cities and significant suburban areas as a major driver along with transport corridors and industrial and research areas. As spectrum below 1GHz is made available then wide area full nationwide 5G coverage should be the objective by 2025.

**Q4.3: Where 5G cells are deployed, are they expected to be individual cells or as clusters of cells required to give wider areas of contiguous coverage? What would be the area of a typical contiguous coverage cell cluster?**

3.13 It depends. For 5G FWA deployments it is anticipated that access units (mini base stations on buildings, lampposts etc) would be typically 200-300metres apart from each other. The ongoing 5G FWA trial with Arqiva in London will give further information on the balance and real world relationship between coverage, data rates, capacity, power, etc. For smart cities applications such as video monitoring then 5G hot spots are envisaged initially in areas with high concentrations of people and vehicles. For hotspots supporting mobile use and taking London as an example the following provide useful potential examples of typical target areas; Oxford Street, Trafalgar Square, St Pancras Station, Heathrow, Wembley Stadium, Silicon Roundabout, Imperial College Campus, Waterloo Bridge, British Museum, St Ormond Street Hospital, O2 Arena Canary Wharf, all of the major rail routes, the M25, London Buses, etc etc. The size of cluster therefore varies from Wembley Stadium, Oxford Street, Fixed Wireless Access connectivity for the start-ups in Tech City around Silicon Roundabout, through to the M25 and the London to Edinburgh East Coast Railway Mainline.

**Q4.4: What capacity and bandwidth (i.e. Channel Bandwidth in MHz) would be required at each cell to meet initial capacity requirements? How will this change over time?**

3.14 It depends. There are always trade-offs between the amount of available spectrum and the number of networks that are envisaged for competition purposes. It is our view that between 500 MHz and 1000 MHz per network is required to support the range of applications envisaged and realise the full 5G vision while balancing the regulatory competition requirements for more than one network. While it is hard to say with any precise view given the early nascent stage of the market this is our view in order to provide high speed, high capacity low latency services. Obviously if there is a total of 1000 MHz to be made available in a first phase (26.50 – 27.50 GHz), and 500 MHz is the minimum amount of spectrum per network, then this restricts the UK to two networks. Obviously given that there are four mobile network operators in the UK, and potential new entrants should not be ruled out, then this poses some challenges and it is our view that the option for network and spectrum sharing should be allowed along with the option for neutral host arrangements enabled given that the cells are small in size and the amount of investment required significant. As the rest of the 26GHz spectrum (24.25 – 26.50 MHz) becomes available then this can be revisited. Ideally each network should have 1 GHz of contiguous spectrum once the full 26 GHz band has been made available so some flexibility will be needed to support band rearrangements in a second award of spectrum.

**Q4.5: What quality of service is required? How sensitive is the service being offered to variations in radio interference from other operators 5G cells and other spectrum users?**

3.15 It depends on what services are to be provided. For example, studies show that to support real time UHD video streaming/gaming, the maximum peak data rate requirement can be as high as 20 Gbps, whilst the required user data rate of web browsing is less than 0.05 Mbps. To support VR and real time gaming, the typical required latency needs to be smaller than 5 ms, whereas in some latency sensitive applications, e.g., Robotic control, the required latency needs to be 1 ms. The sensitivity of quality of service also depends on the interference level, the density of the network, etc. It is generally believed that quality of service is expected to be more sensitive to interference (even the weather) at mm-wave band. However, such interference issues can be mitigated by using advanced technologies such as beam scheduling. The FWA trial in London shows the robustness of providing consistent performance at 26 GHz, even in occasions such as bad weather, despite the general belief of severe detrimental effect of bad weather on LOS performance at the mm-wave band. In summary it is difficult to give quantitative measurements of the sensitivity of the performance. However, numerous studies and simulations have at least validated the feasibility of providing some services at such bands in an interference scenario.

**Q4.7: What are the characteristics of 5G at 26 GHz which make this band particularly suited to the service you plan to deploy? What other spectrum bands could be used as an alternative, or in preference to, the 26 GHz band? To what extent could carrier aggregation and other techniques reduce your reliance on 26 GHz?**

3.16 The available wide bandwidth at 26 GHz will be able to support high data rate transmission, one of the most attractive use cases in 5G (eMBB). Higher bands (e.g., 40, 60 GHz etc) may also support the same high data rate, however, the higher the frequency is, the more significant the path loss is. In addition, doppler effect is another factor to consider at higher band, as it becomes increasingly difficult to support mobility at higher band. Administrations and the industry are well progressed along the 28 GHz road towards commercialisation with components and designs available and the UK and wider Europe are committed to 26 GHz. Equipment that has already been developed for 28 GHz will benefit equipment for 26GHz.

3.17 The current state of the art supports carrier aggregation of six bands (Samsung Galaxy S9, <https://www.engadget.com/2017/07/31/samsung-six-carrier-aggregation-modem-fiber-speeds/>), achieving 1.2 Gbps peak data rate. However, such carrier aggregation significantly increases the RF complexity, and also relies on high order modulation (256 QAM) to achieve such high data rates. Carrier aggregation can to some extent reduce some of the reliance on using 26 GHz in the short term, however will be difficult to meet the requirements as service requirements, in particular on data rates, evolve.

**Q5.1: Should Ofcom consider licensing options other than the 3 examples set out above (licence exempt, shared coordinated and area defined) for the 26GHz band? If so, what other options do you consider should be included?**

3.18 It is Samsungs view that the 26.50 – 27.50 GHz should be licenced on a national and exclusive basis with 500 MHz per network. When combined with network slicing and use it or lease it requirements this can serve the vertical markets while the 5G market is established in the shorter term. It is suggested that Ofcom and DCMS can then review the market and the licensing approach in advance of a second phase of licensing in 24.25 – 26.50 GHz and determine whether local area licensing and dedicated spectrum is needed at that stage. Samsung believes that this represents the



most appropriate balance between rapidly establishing the market in the UK and providing future flexibility.

**Q5.2: What methodologies could be used to pre-define 'high demand areas' for area defined licences?**

3.19 As discussed in the previous section Samsung proposes national exclusive licences for 26.50 – 27.50 GHz with network slicing and use it or lease it conditions. A subsequent review could be undertaken prior to 24.25 – 26.50 GHz being licenced in a second stage.

**Q5.3: What mechanism could be used for determining cell deployments by different operators in shared spectrum?**

3.20 no comment at this stage

**Q5.4: What methodologies could be used for determining the proportion of spectrum to allocate using area defined licences and coordinated deployment?**

3.21 There are multiple factors that affect the estimation of the proportion of spectrum to licence for a network. For example, the user density, the service to be supported, the modulation and coding order used, the path loss in the given frequency, etc. Capacity and coverage analysis can be carried out to estimate the required spectrum, given some assumptions on, for example, the frequency, the profile of the user activities, the channel model, and the modulation and coding schemes. Our recent studies, on capacity demand at 28 GHz of a 5G hotspot area, comprising a 2km stretch of Oxford Street with a 300 m width (0.6 km<sup>2</sup>), show that to support typical services (web browsing, social media, content sharing, UHD video and VR applications), an average AP capacity of 3.1 Gbps needs to be achieved. Having 500 MHz means to support a peak capacity of 7.2 Gbps, which is able to support 94 % data rate requirements of the highest data consuming applications (UHD video). Samsung would be happy to share this detailed analysis with Ofcom if this would be of interest.

**Q5.5: Do you agree that the 26GHz band should be released progressively? What risks do you envisage with such an approach and how can these be best mitigated?**

3.22 Yes. On balance it is better for the UK to release the 1GHz early rather than wait for all of the spectrum to become available. This poses challenges in the potential second award. Ideally the networks should end up with contiguous spectrum and go from 500 MHz of contiguous spectrum in the first award (lets say, from within 26.50 – 27.50 GHz) to 1GHz of contiguous spectrum following the second award (lets say, from within 24.25 – 26.50 GHz). This means that flexibility will need to be built in to both processes to enable band rearrangements to take place so that efficiencies from wider channel widths and reduced co-ordination requirements can be realised.