Consultation on 'Improving consumer access to mobile services at 3.6 to 3.8 GHz'

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About CONNECT

CONNECT[1] is a national centre for research in networks and communications in Ireland. It is co-funded by Science Foundation Ireland and industry. CONNECT is headquartered in Trinity College Dublin and is spread over 10 different academic institutions in Ireland and has over 200 researchers.

In CONNECT, we recognise the centrality of networks to society and the economy and we take a system-wide, end-to-end perspective and carry out research in all aspects of networks (from the components and systems that make up the networks, to the resources the network uses, to the network infrastructure design, to the software elements that create, manage, control and monitor the networks, to the services that run on the network systems). We work on topics such as Internet of Things (IoT), 5G, and advanced wireless, optical and satellite systems.

The CONNECT vision is to change the way networks are designed, created, owned, and operated so that we can expand the reach, the possibilities and the impact of a connected world of people and things. Our mission is to carry out impactful collaborative research at scale with academic and industry partners, from an end-to-end system-wide perspective of the network.

Summary of the Response

CONNECT welcomes the opportunity to respond to Ofcom's CFI[2] on how could spectrum access for mobile services be expanded in 3.6 – 3.8 GHz band.

[1] http://www.connectcentre.ie
[2] https://www.ofcom.org.uk/consultations-and-statements/category-1/future-use-at-3.6-3.8-ghz

As we pointed out in our response[3] to 3.8-4.2 GHz CFI[4], we firmly believe that this is another initiative that represents the opportunity to take pioneering regulatory steps around building the culture of sharing to cope with the 5G demands by developing a uniquely flexible, adaptable and dynamic sharing framework that is multi-band applicable.

The timing of bands release and considerations presented in this CFI point to the possibility to unlock the potential of sharing, by addressing the sharing challenges prior to 5G deployments so that appropriate studies and analyses can be conducted to accommodate 5G demand.

While we welcome Ofcom's initiative and a new approach to spectrum management strategies, we have the following suggestions to maximize the benefits of such activities and explore the potential of having multi-band sharing framework that would be sufficiently hospitable to a diverse range of users, applications and sharing systems:

1. Caution is needed in defining future mobile use in the context of 4G and 5G, particularly because of the way traditional licensed carriers have been entitled to certain privileges when it comes to spectrum resource ownership.

2. Illustration of spectrum requirements and demand in the context of 5G deployments, presented in a response to questions 7 and 8 sets the argument for why this band should be included in a wider spectrum range sharing initiative.

3. The approach of dissecting the spectrum range by dedicating it for extremely different usage modes should be abandoned, and market-driven approaches should be the drivers of spectrum strategies, but at the same time market should open spectrum bands for more diverse range of players. Emerging types of service providers would want a license to spectrum to provide their services for half an hour or few minutes. Therefore, the spectrum management tool needs to rely on advanced database systems, such as the developing spectrum access system (SAS) that can manage automatically multiple authorisation requests and dynamically assign and reassign users[5]. There is no longer space for concerns of traditional licensed carriers that if sharing they need to return spectrum back to the incumbent and terminate their operations once incumbent needs it back because geo-location database solutions can perform spectrum management in real-time and dynamically assign and reassign users, adapting to radio environment while still enabling continuous operations. Also, virtualisation and particular architectural solutions such as C-RAN coupled with massive distributed MIMO for example, can exploit the full potential of sharing the spectrum on the infrastructure, which is perhaps the fastest and most effective way of sharing.

4. Reconsider the policy approach and release this band under dynamic sharing mode. This represents a unique opportunity to set it right for the future. Policy tools should be

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[3] CONNECT, CONNECT's Response to Ofcom's Consultation: 3.8 GHz to 4.2 GHz band: Opportunities for Innovation, available at: https://www.ofcom.org.uk/__data/assets/pdf_file/0031/85198/connect_research_centre_for_future_networks_and_communications_trinity.pdf

[4] https://www.ofcom.org.uk/consultations-and-statements/category-2/opportunities-for-spectrum-sharing-innovation

[5] https://apps.fcc.gov/edocs_public/attachmatch/FCC-15-47A1.pdf

adaptable and flexible, with simple and clear rules, that incorporate spectrum sharing, sharing of the infrastructure and new kinds of operators appropriately regulated through the policy enforcement measures. Technology is ready; dynamic spectrum access techniques are not being utilised enough. Research is also progressing. An example of LSA shows a framework regulated for MNOs that is actually not being implemented. With the sharing initiatives in the U.S., Asia and UK that embrace the dynamic sharing modes through their regulatory activities, 5G demand and requirements on spectrum could be adequately met.

5. Licensing scheme particularly tailored to exploit geographic dimension of spectrum space, especially in 3.6-3.8 GHz and 3.8-4.2 GHz bands with their geographic usage distribution shown in consultation documents, would help to get to the right solutions. If the band is to be released under dynamic sharing mode implementing the multi-tiered access to spectrum, the approach to geographic licensing scheme design is necessary. We suggest the concrete steps for such approach and call for consideration of including the database-based sharing and geographical licenses based sharing combined, in order to fully utilise spectrum.

Response to Questions

Question 1: Do you have any comments on the use of the 3.6 to 3.8 GHz band by existing services?

NO

Question 2: Do you agree with our identification of a trend towards the use of mobile in the 3.6 to 3.8 GHz band?

YES. In particular, we agree with trend identification regarding the role of this band in future 5G/mobile networks, but we would like to point to another approach to the interpretation of the identified trends, regarding spectrum policy.

Spectrum Availability Analysis conducted for the C-band[6] has shown great potential for geographic sharing of the portion of 3.6-3.8GHz. In addition, it has demonstrated that coexistence with a large scale macro cell deployment could be very challenging.

This calls for adopting small cell approach to dynamic sharing in this band, and adding this spectrum chunk to the 3.8-4.2GHz proceeding, towards developing comprehensive, flexible, dynamic sharing framework, applicable across many bands. 5G networks must support higher performance for some users and extreme energy efficiency for others. Cloud-based solutions to dynamic control and optimization of wireless networks are needed. Small cells (and massive MIMO) are key enablers to high rates but pose different technical challenges. What spectrum policy approach can provide is the comprehensive spectrum strategy that will result in the development of advanced spectrum sharing techniques and continue to advance the efficient use of spectrum while promoting flexibility, necessary to meet different demand of 5G applications.

Ofcom recalls that RSPG has identified this band as a part of a wider band, targeted primarily for the introduction of 5G. This is aligned with the current trends in Asia (Japan) and in the U.S. for the same band. We think that the US approach to this specific policy point should be replicated, since already now the success of the story of sharing in 3.5GHz is projecting more efficient spectrum usage and readiness for 5G developments. This framework has introduced different types of markets in spectrum sharing (CBSDs market, SAS market, secondary markets, auction license market, ESC market, etc.) enabling all tiers of users and database providers to identify new business models. It also promised to foster the innovation through new, dynamic sharing architectural solutions, automatic interference management, assignment methods (licensed and licensed-by-rule), etc. But most importantly it has addressed both, technology and market barriers through an effort to have harmonized standards towards broad deployments which is the key point Ofcom should consider at this stage.

Potential for harmonization and global roaming, compatibility of 3GPP LTE bands 42 (3.4 - 3.6) GHz and 43 (3.6 - 3.8) GHz, spreading of the trend across Asia and the U.S[7]., emerging

[6] https://www.ofcom.org.uk/__data/assets/pdf_file/0012/51303/c-band-sharing.pdf
[7] In Europe: 3.4 – 3.8 GHz recommended for 5G, 700 MHz for IMT 4G/4.5G/5G before 2020; in Korea 3.4 – 3.8 GHz for 5G trials; in Japan 3.4 – 4.2 GHz and 4.4 – 4.9 GHz; in China 3.4 – 3.6 GHz for 5G trials (these are 5G spectrum developments given for sub 6GHz worldwide – alongside initiatives for 5G spectrum developments in high frequency bands for ultra-high capacity).

equipment ecosystem and the band-wide operability for 5G devices and equipment - when combined with an upper band (3.8 – 4.2) GHz could fully unlock the potential of sharing and actually foster competition, but also innovation.

Question 3**:** Do you agree with our high level proposal to make 116 MHz within the 3.6 to 3.8 GHz band available for mobile and 5G services, bearing in mind our statutory duties and the high level trends we have identified?

In principle, we agree that the high-level proposal makes sense, but we would caution how it is phrased and expressed. There are those who read 5G as a continuation of 4G. Making 116 MHz available within the 3.6 to 3.8 GHz band for *mobile and 5G services* might create a sense of entitlement to these bands on the part of those who read the terminology in that way. While the document does stress the band will be made available on a *non-exclusive basis* this does not necessarily change that level of expectation. We would use the Licensed Shared Access (LSA) framework as an example. Though LSA can in principle support any kind of licensee, most examples that are in existence showcase versions of traditional mobile network operators sharing with incumbents.

While there is much to be decided still in defining 5G, one thing that is sure, is that 5G is about the digitalization of different sectors (e.g. transport, health, agriculture, etc.). It is likely that very different types of network operator may emerge in these circumstances. While the consultation document does not preclude any of this, it is none-the-less very much written from a perspective of how we understand 4G rather how we might understand 5G in the future.

Question 6: Do you have a view on any of the two options we identified?

We are happy that the incumbents remain – see answers to question 7 & 8 for further details.

Question 7: Do you have any quantitative evidence on the costs and benefits associated with the options? This includes costs for existing users and/or consumers of existing services associated with potential changes, and benefits to UK consumers in gaining access to mobile services in this band. Question 8: Do you have any other suggestions that would allow widespread 5G availability, using the 3.6 to 3.8 GHz band, across the UK while allowing certainty for at least some existing users to continue to provide the benefits currently provided by use of the 3.6 to 3.8 GHz band.

We answer both of these questions collectively. To answer these questions we draw on a recent 2016 study, commissioned by the EU and titled, ‘Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe’ [1]. A chapter was devoted to the the study of spectrum requirements needed to deliver future 5G services. The study examined different use cases for the year 2025 to get an understanding of the expected spectrum demand.

Of the use cases studied, the most relevant for this paper is termed ‘the motorway use case’ because of the focus on demand for mobile services. The use case details were based on the services envisaged in various EU 5G research projects rather than on speculation by the authors of the report with added input from open workshops. A high-level approach to determining spectrum requirements was taken. The expected total number of devices per km^2, the operating data rate/usage rate of the devices, and the spectral efficiency were taken into account. Smart hubs, augmented reality glasses, tablets, and on board video systems were among the types of devices considered for the motorway use case. The devices were densely deployed geographically and proportionally assigned to three frequency sub-ranges (Sub-1 GHz, 1 – 6 GHz and above 6 GHz). The spectrum estimates within each sub-range were calculated by multiplying the number of devices by their respective occupancy of the spectrum in bps according to the scenario and divided by the assumed spectral efficiency of the technology used for each device type. The spectrum demand was added across all device types to yield a total spectrum estimate for the use case.

Most importantly for this paper, the spectrum requirements were estimated based on different network operator scenarios. These scenarios assumed 4 operators[8], and five different sharing arrangements spanning from the case in which the four operators operate independently, to the case in which there is 100% spectrum sharing between operators. The socio-economic study does not specify how the sharing scenarios might be implemented, though the study lists different potential sharing approaches. The scenarios which involve 20%, 50% or 75% sharing are ones in which different densities of incumbents exist in the bands, therefore limiting the potential for full sharing to different degrees.

Figure 1 is reproduced from the socio-economic study and summarizes the spectrum needs for the motorway use case across all network operator arrangements. In an exclusive licensing environment in which the operators function completely independently, the spectrum needed is equal to the total use case driven demand estimate multiplied by the number of operators in the environment. This is, of course, an extreme scenario as in reality operators tend to serve a percentage of the market rather than every operator having an expectation that they should be capable of supporting 100% of the market. In a fully shared environment, the spectrum needed is equal to the total use case driven demand estimate and for different levels of sharing the demand lies in the range between the two extremes. The main message from Figure 1 is that the spectrum demand for 2025 is extremely large, even when sharing is taken into account.

[8] Four is the number typically considered as offering competition in EU states.

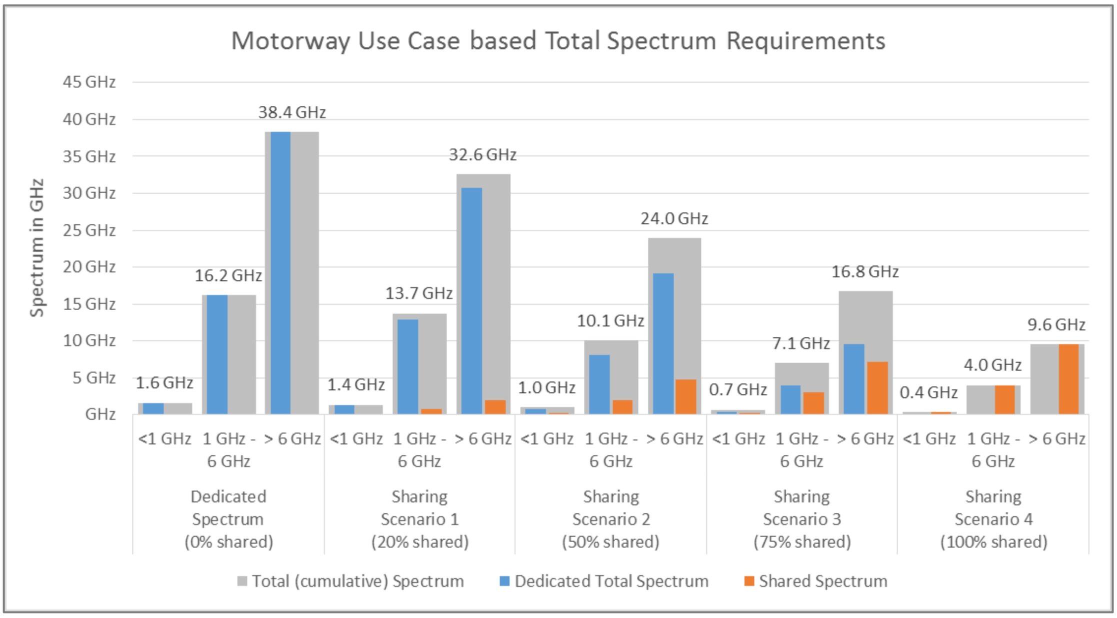

Figure 1: This is reproduced from [1] and shows the spectrum demand for the 2025 motorway use case, for different sharing conditions.

The results become more startling when placed side by side with Figure 2, which summarises the *maximum amount of spectrum* available within in the three spectrum sub-ranges, and was generated by Real Wireless[9].

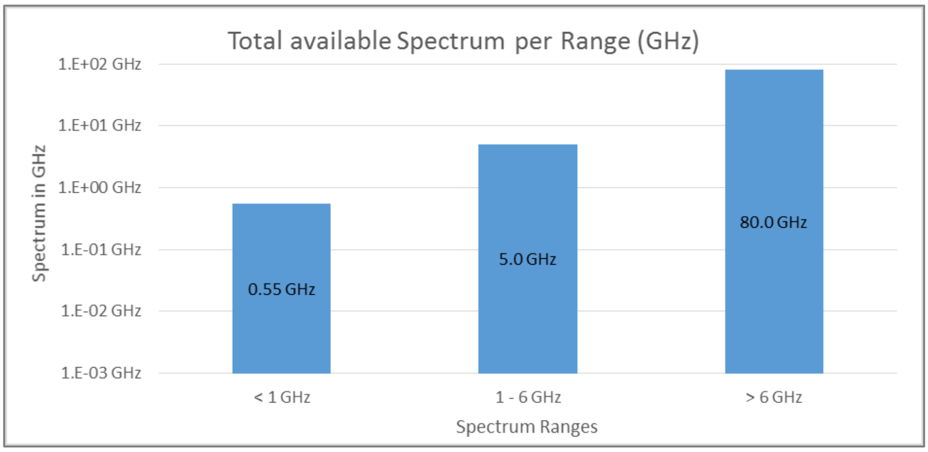

Figure 2: The maximum amount of spectrum (total spectrum) available in each sub-range. Source: Real Wireless

In the range above 6 GHz, there is enough spectrum. It remains to be seen how much of this will be set aside for international mobile telecommunications (IMT), which is the collective term for 3G, 4G and 5G. Currently, there is no spectrum in this range allocated to IMT though a number of bands are under consideration. But it is the lower ranges that are of importance for this report. For the sub 1 GHz range and the 1 - 6GHz range (the range within which the 3.6 to 3.8 GHz lies), not enough spectrum physically exists to respond to the demand unless full sharing is possible, and even then, it means that mobile communications will completely

[9] http://www.realwireless.biz/

dominate spectrum usage in these ranges. The annexes of the report do include sensitivity analyses and justification for the methodology.

While the report did not specify how sharing would be achieved, the ultimate aim has to be to move towards a new way of doing business based on much more extreme sharing scenarios than currently exist of are contemplated. It could be possible to pool all spectrum and dynamically allow different networks to access the pool of spectrum on an as-needed basis rather than assign spectrum to any one network (or future network operator). The key challenge here, and in any other sharing solutions, is the management of interference. It may be possible to draw on advanced interference management techniques, cognitive radio-based solutions, and use sophisticated database or spectrum access systems to keep track of spectrum usage to manage the coexistence between different services and technologies [2],[3],[4]. Whatever the solution, it will involve a complex web of technologies and may require significant clearing of spectrum bands in which different incumbents currently exist. It involves an enormous change in how business is done in less than a decade.

This leads us to conclude that a much more systematised approach to sharing must begin now. It is important to begin the process of the mindset-change that is needed and the transition to extreme sharing scenarios.

With this in mind, we feel that dynamic sharing approaches that can cope with change and develop over time should be considered. The Citizens Broadband Radio Service (CBRS) is a new class of service established by the FCC to promote innovative sharing in the 3.5 GHz band. This class of service came about in response to the President's Council of Advisors on Science and Technology (PCAST) Report of 2012 [5] which sought to maximize the use of spectrum occupied by different federal incumbents. For the 3.5 GHz band, the primary holders of the spectrum are federal users (military high-powered radars on ship platforms across the coastline) and grandfathered fixed satellite services. These are classed as Incumbent Access (IA) users, and have the highest priority to access the spectrum. These users will receive protection from harmful interference that commercial users sharing the bands generate; moreover, they are not required to mitigate interference they might cause to those users. The users that share with the incumbents fall into two classes. The first class is termed Priority Access (PA). These users can expect a level of protection from interference. The second class is the General Authorized Access (GAA) user, which has no expectation of protection from interference.

The existing 3.6 to 3.8 GHz users can be the incumbents. While larger exclusion zones may be required now, the CBRS system operates on the basis of a dynamic spectrum access system (SAS) which unlike a static database (such as in the TV white space case) can much more effectively and dynamically calculate interference. The incumbents could be systematically or strategically taken out of the bands and the SAS would simply update to take account of the changes. This would allow time to be taken with existing users while at the same time putting in place a system which is future proof.

The other types of users, i.e. the PA users and GAA users can be balanced in a ratio that best lends itself to innovation. This might in fact exceptionally well suit 5G. As mentioned earlier in the document 5G is still evolving. New types of operators or service providers working in wider sectors may choose to start life as GAA users, and once business models are proven invest in spectrum further through PA licenses. Alternatively and perhaps desirably, given the situation described in Figure 1, PA users may learn to understand that GAA actually provides adequate access to spectrum.

There are challenges with the CBRS system that would need to be addressed. The licensing scheme for PA licenses as defined by the FCC would require improvements. The exact mechanisms for management of PA licenses would also need to be explored. There are many possible auction mechanisms that can be used and Ofcom has much experience on this front. The current vision for PA license duration in the USA is for a number of years which is in line with thinking of the kind of certainties needed by current mobile operators. It might be possible to rethink this in the context of newer 5G services. It might be possible to explore payment mechanisms in terms on new forms of currencies such as data. The UK would have the opportunity to observe progress in the USA, change, adapt, improve and adopt.

Question 9: Do you have any comments in relation to these proposals?

We would call for consideration of the third policy option for the band, which encompasses elements of Option A and Option B identified by Ofcom in terms of more comprehensive analysis of incumbent protection but puts policy activities in a broader context - important in order to: (1) set the sharing frameworks dynamic, adaptable and flexible from the beginning and, (2) enable sharing through the database-driven approach to spectrum management and, (3) introduce sharing across entire range of 3.6-4.2 GHz spectrum (potentially extending this range to 3.4 – 4.2 GHz). It would be an exercise of a new approach to spectrum management, contrasting to the legacy type of approach of dissecting the spectrum bands, by dedicating them for particular usage without considering the neighbouring band usage and dealing with problems that arise in spectrum ecosystem at a later stage.

As Ofcom states, the band in question has a duplexed nature, and the effect of policies on this band are coupled with the effects of policies in the upper band 3.8-4.2 GHz, which has recently been opened for innovative sharing approach. Use of this band by fixed links is paired with spectrum in the upper band. These issues that may arise from the *conflicting policies introduced in two adjacent bands* with duplexed nature of use by certain incumbents could be easily avoided if the entire range 3.6 – 4.2 GHz would be considered for sharing, and the band 3.6-3.8 GHz becomes included in the current policy work around 3.8-4.2 GHz band.

Opening this band for dedicated exclusive mobile use *does not promote competition nor does it encourage efficient use* of radio frequencies. Traditional licensed carriers feel entitled to large license areas, which are (too often) nationwide licenses or licenses for entire cities. They are also long-term licenses. This is accompanied by the typical award procedure, auction or beauty contest, procedures usually not designed with spectrum sharing considerations embedded in the model through the identification of incentives to share. The nationwide auctions leave spectrum unused over the area, frequency and time. And this closes the door for any other kind of a new market player to enter the competition. It also negatively affects any activity towards harmonized standards, creating a risk of losing industry support and involvement, necessary for successful implementations of sharing frameworks.

Policy Option C: Lessons should be learned from the FCC 3.5GHz sharing framework approach because some aspects of the extensive work done were very successful and some have not been that effective. To name a few, particular aspects of FCC 3.5GHz framework that we think were successful and should be replicated are: (1) band plan (and the identification of substantial amount of spectrum for new services), (2) creation of new classes of service and introduction of a citizens framework (providing spectrum to both, licensed and unlicensed use while protecting incumbents), (3) stakeholders involvement (the interest in the band has led to the creation and wider adoption of standards), (4) CBSDs and the equipment ecosystem, (5) types of markets created (most of the flexibility of this framework is in enabling market to determine highest valued use), (6) dynamic assignment, authorisation, interference management, coordination and potentially enforcement (SAS based on cloud-computing principles, cyber security protections considered from the start), (7) introducing small cell use, matching with propagation characteristics of the band (small cells are the solution to increasing cellular system capacity and power efficiency, requiring self-optimisation in the cloud but also key enabler (alongside massive MIMO) to high rates) etc.

Aspects of the framework that we think were not successful: (1) licensing scheme based on census tract area units will act as authorization barrier [6], (2) auction rules currently at place may act as a market barrier[10] (no PAL issued if no mutual exclusivity identified, with an exception in rural areas), (3) inter-SAS coordination, SAS information requests, storage and ownership may act as technology barrier[11], (4) licensed carriers concerns that are common when it comes to sharing (network deployment information reveal, mistrust in dynamic reassignments, need for reserve channels and guard bands and tendency to not report their protection contour truthfully) are not adequately addressed in the framework and may negatively impact their willingness to share etc.

The new regulatory framework has to be flexible because technology is advancing much faster than regulatory decisions are set. *Technology and service neutral framework* is one of the key things that will actually enable more efficient spectrum use of the bands, which is why we encourage Ofcom to work towards defining minimum necessary technical thresholds so that incumbents are protected and take a different approach to interference management criteria[12]. Great innovation is not just in the technology itself, but in the wider historical context and it requires a new way of thinking in spectrum policy.

Licensing scheme particularly tailored to exploit geographic dimension of spectrum space, especially in 3.6-3.8 GHz and 3.8-4.2 GHz bands with their geographic usage distribution shown in consultation documents, would help to get to the right solutions. Mobile broadband could enter the band through sharing arrangements, with attractive licenses exploiting geographic component of the spectrum space so that spectrum is not being wasted over the area. Geographic distribution of the current usage provides an ideal basis for a flexible, optimal licensing design scheme. These licenses would be auctioned in an auction model that would encompass incentives. Incentives would be taken into account in the auction design and the license design altogether, because it is necessary that we come up with the optimal license

[10]Auction procedure is still under development, Auction PN to be launched soon. Initial considerations are focused on incentive auction model modifications (TV broadcast auction in 700MHz)

[11] SAS-approval process is work in progress

[12] Pixel-based approach to interference mitigation grounded in TVWS work is computationally extensive for dynamic sharing in the band where diverse applications and systems are, but it could be modified and adapted by including: population information (number of people with access to spectrum as real consumers of network capacity) and more accurate information on spectrum usage in a given radio environment, relying on appropriate metrics that would push towards the optimal license size and the shape. Census tracts in the US are too small to serve as license areas, but Ofcom has an opportunity to design the optimal license size, which reflects awareness of radio environment, number of people served, percentage of spectrum waste over the area and puts a number on competition in order to design the auction model to fit the flexible sharing framework rules (while promoting sharing and innovation for more efficient use of spectrum).

size, and stop the trend of monopolistic spectrum usage among few operators that have been enjoying the privilege to be licensed nationwide. The licensing design has to be done to encompass accurate radio environment information, appropriate transmission power thresholds, the right choice of propagation model and exploiting the existing census areas information in the UK.

The final point we would like to raise is that when thinking about spectrum management, interference mitigation, and spectrum assignment methods for the users in dynamic sharing arrangements, *geographic licensing should be coupled with geolocation database approach* and not considered as two separate approaches which deal with different spectrum issues. Geographic licensing if done right, can lead to a more efficient use of spectrum, because it can reduce the spectrum waste over the area, the main problem in geographic sharing environment with the type of incumbents we are talking about for these two bands. But, it cannot be done without the sophisticated database system, which relies on technologies that support dynamic and real-time modes of operation (cloud-computing) and can automatically manage spectrum requests and authorisations, partially taking over the regulatory role. The accuracy of database-provided *spectrum availability information* as well as *co-channel and adjacent channel interference estimation,* reflected in protection areas and exclusion zones could be significantly improved with the *census data* and *geographic licensing information* incorporated into the geolocation database systems that will drive this sharing. Dynamic sharing has its challenges, but it is the identified current trend in spectrum policy across the globe which will lead to wider adoption of a global sharing model, capable of dealing with the 5G requirements.

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