Non-confidential version

Award of the 700 MHz and 3.6-3.8 GHz spectrum bands

- Further consultation on modelling and technical matters

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Comments should be addressed to:
BT Group Regulatory Affairs, BT Centre, London, EC1A 7AJ

Executive summary

1. BT[1] welcomes this opportunity to comment on Ofcom's "Single User Throughput" (SUT) technical model that was used for assessing whether competition measures are necessary to address concerns over very asymmetric assignment of spectrum in the 3.4 - 3.8 GHz band, and how this could affect future 5G services.

2. The SUT model considers the somewhat artificial scenario of a single user in a cell and determines whether the data rates that can be provided with a given spectrum bandwidth will support various 5G services. The conclusions to be drawn from the analysis would be rather different in real-world scenarios. Specifically, in the real world multiple users are likely to require data capacity simultaneously, and expect to receive services where others are present and consuming similar services. The user might also be indoors (where signal levels are weaker) and users may be consuming multiple 5G services.

3. Our conclusion from our analysis of the SUT model is that an operator having just 40 MHz of spectrum to provide high data rate 5G services to multiple users simultaneously would be seriously disadvantaged compared to an operator having 100 MHz or more, [✂ *redacted*]. Competition would be promoted if Ofcom improved the opportunity for all MNOs to secure 80 - 100 MHz of spectrum that can immediately be deployed for 5G.

4. Ofcom has underplayed the importance to competition of contiguous spectrum holdings when considering practical implementation issues, device availability and costs. It is critical that Ofcom's interventions maximise the possibility that operators can achieve contiguous spectrum holdings in the 3.4 – 3.8 GHz range.

5. We consider that competition would be promoted to the benefit of consumers if measures are included to address the risk of [✂ *redacted*]. This could be achieved through the application of a cap of 140 MHz on spectrum holdings in the 3.4 – 3.8 GHz band.

[1] Including its subsidiary EE Ltd.

1 Introduction

BT welcomes this opportunity to comment on Ofcom's SUT model which we understand was used by Ofcom in reaching its conclusions as to whether asymmetric shares of 3.4 - 3.8 GHz spectrum raise competition concerns that need to be addressed in the auction design.

We set out our comments on the SUT model, and the way in which Ofcom has applied and interpreted the results from the model, in **Section 2** below. In **Section 3** we comment on the use of other technologies and frequency bands to deliver high data rate 5G services. Finally, in **Section 4** we discuss the conclusions that follow from the modelling in terms of measures that would promote competition.

2 BT's comments on Ofcom's SUT modelling

2.1 Overview of BT's comments

We set out below our concerns about the principles underpinning Ofcom's modelling as well as certain modelling assumptions. We also have some concerns over the way the SUT modelling results are interpreted and the applicability of the modelling output and analysis to real-world networks and expected customer experiences. These considerations, together with the significant impact of the correction of errors in the earlier modelling, suggest that a change to Ofcom's conclusions needs to be considered. With appropriate adjustment for real-world factors, we think that the technical analysis indicates a need to apply competition measures to address the problem of very asymmetric 3.4 - 3.8 GHz spectrum holdings and the risk of strategic bidding by Three.

2.2 Principles of the methodology used by Ofcom (SUT)

One of the key limitations of the SUT model is that it does not address the multi-user environments that we see in the real world with adequate rigour, and it does not model impacts on network capacity at all. In the consultation document (CD) §1.19 Ofcom says:

> *We recognised in the 13 March Statement that the SUT Model is a simplified theoretical model and that in an actual deployment many users would share the resources of a carrier, but considered its results could nonetheless give us some indication of what services carriers of different bandwidths might technically be capable of supporting.*

We question whether an analysis that gives "some indication" is an appropriate standard or is a sufficient basis for decisions on competition assessment/auction structure, given that more sophisticated alternatives, in particular, system level simulations could have been used.

Modelling the throughput delivered to a single user and then applying a "technical judgement" (CD §1.37), to assume an operator would be able to deliver a similar service to multiple users based simply on the SINR, we believe, is far too simplistic and speculative.

Ofcom has considered the data rate that a single user could achieve and then compared that to what certain 5G services may require. It has then concluded that 80 - 100 MHz bandwidth is not necessary to compete effectively with an operator that already has 100 MHz contiguous bandwidth.

But to reach robust conclusions on competition measures using SUT outputs, Ofcom needs to apply real-world and more customer-centric scenarios rather than relying on a highly stylised and hypothetical single user scenario. We see the following implications when the SUT modelling results are viewed through a different lens:

- For two MNOs with similar networks and similarly large number of customers and multiple simultaneous customers consuming high data rate 5G services, the users of the MNO with 40MHz would experience both typical throughput and available peak data rates that are *c.*40% of that of an MNO with 100 MHz available. If the MNO with 100 MHz has fewer customers, the difference would be even greater.
- If there are multiple simultaneous users (rather than a hypothetical single user) requiring 5G services that need the highest peak data rates in a cell, then compared to having 100 MHz, the MNO with 40 MHz would only be able support 40% as many simultaneous users for a given type of high data rate service.
- The signal quality varies considerably across the coverage area of the cell. Users at the edge of the cell and deep indoor locations would demand significantly more capacity to deliver the same service. The penetration loss of walls can be as high as 20 – 30 dB with the latest building types[2]. In parallel, it is widely considered that *c.*80% of the mobile data is consumed indoors[3]. This results in significantly higher radio resources required for those users. It is not reasonable to assume that this can be resolved by operators for all indoor customers through the deployment of indoor solutions. Consequently, the operator *will* require more capacity in terms of wider bandwidths to serve the same service to customers irrespective of their environment. As noted (CD §1.29), the SUT methodology does not consider the distribution of users across the coverage footprint and therefore does not show the real world network performance for a given 5G service and spectrum holding.
- User behaviour in a mobile network is highly unpredictable. Hotspots can be created ad-hoc and it is infeasible for an operator to deploy small cells or other supplementary network connectivity to all such locations as they arise. An example would be a traffic congestion scenario. An operator with lower spectrum will require more base stations to deliver the same service in light of these dynamic changes. In most cases acquiring suitable sites would not be easy, and in some scenarios could be impossible. Cell densification affects the interference environment which will in turn affect the SINR. This further highlights the importance of considering real-world network deployment scenarios (which Ofcom has not). Please see section for 2.3 for implications on small cell deployments with < 80 MHz in a single band.

Clearly operators can densify their networks using small cells to boost capacity. Reflecting this, Ofcom's modelling should have taken into account the limits to small cells densification as well as the implications of combinations of 5G services and multiple simultaneous users which affect the technical feasibility of delivering 5G services. We do not think that the modelling provides helpful input to a position on competition measures without taking these factors into account.

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[2] Aegis system ltd: "Building materials and propagation report to Ofcom", 14/09/14 https://www.ofcom.org.uk/__data/assets/pdf_file/0016/84022/building_materials_and_propagation.pdf

[3] For example https://www.real-wireless.com/capitalizing-on-the-indoor-coverage-opportunity-oliver-bosshard-managing-consultant/

2.3 Future 5G Services used in the modelling

Ofcom identified possible future 5G services described in 3GPP document Technical Report (TR) 22.891. That document is a technical study and was part of Release 14 which does not specify 5G standards.

The scope of the study was "market segments and verticals whose needs 3GPP should focus on meeting, and to identify groups of related use cases and requirements that the 3GPP eco-system would need to support in the future… that cannot be met with EPS"

The TR 22.891 study contributed to, but did not define, the requirements against which the 5G system was standardised. The 5G Service requirements for the 5G system are detailed in Technical specification (TS) 22.261. TS 22.261 includes "Performance requirements for high data rate and traffic density scenarios" and "Performance requirements for low-latency and high-reliability scenarios". These scenarios include user experienced data rates of up to 1 Gbps.

Ofcom states (CD §A1.22) that "For the scenarios requiring Gbps throughput we consider that operators would likely need to deploy mmWave spectrum and/or small cells to deliver these kinds of download throughput to multiple users, and therefore we have not included them in our analysis."

It is clear from CD Figure 1 that only 80 MHz and 100 MHz spectrum allocations are capable of delivering 1 Gbps. Excluding services that require 1 Gbps from analysis leads to the incorrect conclusion that "none of the services is strictly infeasible technically in any of the scenarios." (CD §1.35). Whereas a 1 Gpbs service *is* infeasible with less than 80 MHz of Spectrum, even for a single user let alone in the real-world scenario where customers would reasonably expect that they could use such services even when others are also doing so in the same location.

In the consultation (CD §1.48) Ofcom notes that a small cell deployment could deliver some of the 5G services. This is correct and it is also the case that a small cell network could provide a 1 Gbps service, provided the operator has 80-100 MHz spectrum. However, it is important to understand that small cells are primarily single band devices, there are no multi-band 5G small cell devices and we do not believe there will be any in the future. It is, therefore, technically infeasible for an operator to provide a 1 Gbps service with less than 80 MHz of spectrum.

There are two reasons why there will be no 5G multiband small cells.

- Firstly, small cells must necessarily be small and the 3.4 GHz band at 80 -100 MHz is the optimal band/bandwidth for small cell design and could incorporate M-MIMO most likely 16 x 16 or 32 x 32. A small cell incorporating multiple bands and aggregating up to 80 MHz of spectrum is necessarily more complex and expensive. [✂ *redacted*]. Additionally, the multiband antenna cannot deliver M-MIMO in both bands without significantly increasing the size and weight. Such a "small cell" will be challenging to deploy in the macro environment.
- Secondly, these multi-band small cells products will not be available in the market because demand is likely to be very low. This is because they are impractical to deploy and the vast majority of operators deploying 5G around the world have large contiguous bandwidths in the < 6 GHz frequency range and will therefore deploy a single band small cell instead.

2.3.1 Support for more than one 5G service

The single user throughput model analyses the technical feasibility of delivering a single service to a single user. This is entirely unrealistic: the 5G system is designed to deliver a range of services which are not mutually exclusive. In reality, an operator will need to deliver multiple services to a single user to complete the user experience demanded.

As a few examples:

- ***Connected and Autonomous car:*** Although Ofcom considered Cloud computer games for connected vehicles with 4K 3D graphics (CD §1.40), it may be only one of the streams demanded by a user in a connected car. In parallel, there might be streams of video uploaded from dash cams for security and dispute resolution while the vehicle itself may demand data in terms of maps and telemetry. Our internal analysis has shown the demands could be up to 70 Mbps downstream per cell from connected cars alone.

- ***Connected Ambulance***: BT has already made significant progress on a 'connected ambulance' service on 5G with a trial showcased in November 2019 [ref https://newsroom.bt.com/uhb-and-bt-demonstrate-uks-first-remote-diagnostic-procedure-using-a-5g-connected-ambulance/]. It included 5G VR/AR together with robotic technology on healthcare, all working in parallel.

- ***Media and Broadcast***: BT demonstrated the first live 5G broadcast with BT Sport [ref: https://newsroom.ee.co.uk/ee-continues-5g-leadership-with-first-live-5g-broadcast-in-partnership-with-bt-sport/] where the content was limited to 2 cameras and advanced compression techniques used due to limitation on the 5G uplink. Contrary to assumptions made by Ofcom in (CD §A1.33) the demands on the uplink in a 5G network could be far higher than the use cases modelled, rising to at least 200 Mbps per 8K camera in a live media broadcast. Although Ofcom cites small cells as an alternative solution available to operators in several paragraphs to supplement capacity, they are simply not feasible to support some scenarios, such as live news broadcasts. They would need to be connected to the wide area macro network. These trials show that without sufficient spectrum these services cannot be commercialised in real world deployments including Macro and small cell. [ref: https://newsroom.bt.com/bt-trials-the-uks-first-live-tv-production-with-5g/]

2.4 Consideration of the need for contiguous spectrum

Ofcom does not give adequate consideration to the device and radio equipment maturity in the arguments made.

- **Carrier Aggregation:** Ofcom states (CD §1.12) that carrier aggregation is an alternative option for an operator with <40 MHz to deliver services similar to another with >80 MHz. The terminals that are currently available do not support mid band - mid band carrier aggregation. This would place the operator with a lower bandwidth at a disadvantage for at least a period of time.
- **Radio performance**: There is no radio equipment available or on a roadmap that will support the full frequency range between 3.4-3.8 GHz. Therefore, it may be impossible to aggregate carriers across the band, e.g. an operator with <40 MHz in the new 3.6 GHz band will have limited opportunity to aggregate carriers in the existing 3.4 GHz band to get equal performance of a 80 MHz channel.

- **M-MIMO:** M-MIMO products are only currently available for 3 GHz in a macro configuration due to its larger size and weight. The products available in 1.8GHz, 2.1 GHz and 2.6GHz bands are immature and use FDD M-MIMO which have significantly poorer performance. A large portion of costs in deploying M-MIMO are fixed regardless of channel bandwidth used, such as physical installation and site upgrades. Therefore, an operator deploying M-MIMO on a larger channel bandwidth is able to drive more efficiencies and economies of scale.

- **MIMO**: when radiating two carriers through an 8x8 MIMO antenna, each carrier can only use 4x4 instead of all 8 layers, reducing performance when compared to contiguous spectrum. It is unclear whether Ofcom considered this in its estimate of reduced efficiency of non-contiguous spectrum.
- **Cost of non-contiguous carrier operation:** In the case where an operator cannot aggregate carriers within a single radio unit, it will be necessary to use two radios. Hence, in order to deploy both two non-contiguous carriers, the operators' costs will be significantly higher.

3 Other solution to support high data rate 5G services

3.1 Feasibility of alternative solutions to deliver high data rate services

Ofcom states (CD §1.12) that high bandwidth services can be achieved through alternative means and refers to mmWave and WiFi offload among them. Use of mmWave is then referred to in many parts of the document as an alternate means to provide services similar to another operator with a bandwidth >40 MHz. In reality, the timelines for deploying mmWave solutions in UK are still very uncertain and are potentially many years away. Ofcom is yet to announce if, when, and how it will release the primary mmWave band at 26 GHz for 5G services, by auction or otherwise and the radio ecosystem is still immature. In any case, mmWave solutions are not ideal for services that demand macro connectivity. We therefore argue that mmWave should not be cited as a reason not to require 80-100 MHz of 3.4 – 3.8 GHz spectrum to compete effectively in 5G services.

We disagree that wifi, or even more broadly use of licence-exempt spectrum is an adequate substitute as a means of delivering high data rate 5G services to customers of an MNO. Unlicensed spectrum is subject to unwanted interference that cannot be managed by the MNO and therefore it cannot assure the 5G service it offers. Further it is not ubiquitously available and does not have the guaranteed quality of service that would be available with 5G and licensed spectrum.

3.2 Dynamic Spectrum Sharing

Ofcom discussed Dynamic Spectrum Sharing (DSS) as an option (CD §1.50-1.53). Ofcom states (CD §1.51) that DSS would introduce 7-10% inefficiency on the LTE capacity vs using the channel as a dedicated LTE carrier. While this may be true, we estimate the inefficiency rises to 10-20% on NR capacity vs using the channel as a dedicated NR carrier. Therefore, operators would need to maximise the efficiency of bandwidths where the ecosystem has developed for 5G. DSS also increases the hardware costs for operators as they would need to deploy multiple baseband equipment in the cell.

Enabling DSS does not provide additional resources to a 5G service; the net effect is actually a reduction if an operator has implemented ENDC (4G/5G Dual connectivity). This is due to inefficiency, as Ofcom correctly notes (CD §1.50-1.53). Existing 4G spectrum is heavily used and required to serve customers without 5G capability and we do not see DSS as a valid mitigation to the fact that 80 – 100 MHz of 3.4 – 3.8 GHz is important to promote competition in 5G services.

4 Conclusion

When considered in the more realistic context of multiple simultaneous users and simultaneous high data rate 5G services, including 1 Gbps, very different conclusions are likely to be reached from the SUT modelling undertaken by Ofcom.

With appropriate adjustment to reflect real-world factors, the SUT model indicates that operators who fail to secure 80 - 100 MHz of spectrum are placed at a serious disadvantage in their ability to compete in the provision of 5G services requiring highest data rates. This is especially so where spectrum is not contiguous as it is more costly to deploy and much less efficient to use. This is certainly the case in the short to medium term before other bands can be re-farmed to 5G.

In light of this, we see an obvious risk [✂ *redacted*]

We consider that it is proportionate and would promote competition if measures are taken to address the obvious asymmetry in 3.4 - 3.8 GHz spectrum holdings [✂ *redacted*]. This would be achieved by applying a cap of 140 MHz on 3.4 – 3.8 GHz band holdings.
