Annex 3 - the importance of data speeds to consumers

1. Other sections of this Response show that the data speeds an MNO can offer on its network are, in significant part, a function of the spectrum available to the MNO. An MNO with much less spectrum than a competitor cannot replicate the speeds achievable by the competitor, either at all or at a cost that would allow it to be competitive.

2. This Annex explores why it matters if an MNO is at a speed disadvantage. The points covered are as follows:

    - Experience shows that customers want higher speeds and change their behaviour in response to differences in speed.
        - Customers use more data and engage in more and different online activities when they benefit from higher speeds.
        - Customers are willing to pay extra for higher speeds.
        - Customers are more likely to leave if speeds reduce.

    - Speeds are important and differentiate operators because they significantly affect the real world consumer experience.
        - Speeds are important to consumers because they provide benefits for the applications that consumers use their data services to access. These applications require high data speeds now, and will require even higher speeds in the future.
        - Unlike voice services, data coverage is not binary. Improvements in service quality can be measured on a sliding scale whereby the user experience on a mobile network is always better when incrementally higher data speeds are available. Service quality continues to improve as speeds increase – there is no upper limit beyond which benefits cease to accrue.

    - Average speeds on a network can be mis-leading because they do not guarantee a consistent user experience. The variance of speeds that will actually be received by consumers over mobile networks is inherently high. This has implications for how high average speeds need to be in order for an MNO to provide an acceptable level of service.

        - Even for average speed levels that sound quite high, a significant proportion of consumers will receive a speed that is below an acceptable level for even “standard” applications today – never mind the more demanding applications of the future.

- Considering the speeds that can be provided only when the network is congested is however entirely insufficient. How the network performs when it is less heavily loaded is similarly important to the customer experience.

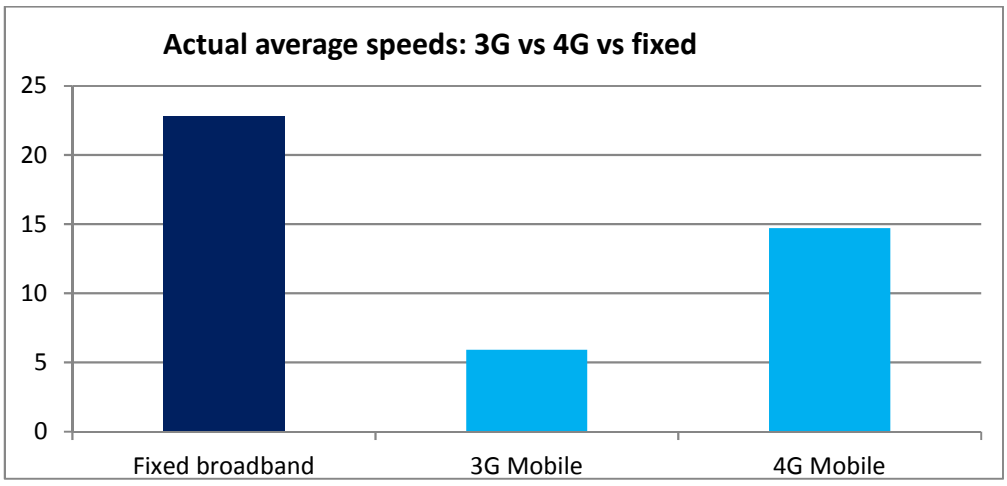
3. It follows from the points above that an MNO's customer proposition will inevitably be considered inferior to that of its competitors if it offers materially lower speeds. The significance of speed in how consumers choose between different MNOs is explored further in the Brunel University study at Annex 4.

Speeds available affect consumer behaviour in important ways

4. The speeds available to consumers on both fixed and mobile networks have increased dramatically over the last decade or so.

5. In 2004, mobile customers faced maximum theoretical download speeds of 0.4Mbit/s on 3G UMTS networks[1] (and far less on the 2G networks that were more commonly used). A decade later, in 2014, the maximum theoretical download speeds had increased by 500 times to 200Mbit/s on 4G LTE networks[2] and the speeds achievable continue to increase all the time.

6. Despite these increases in theoretical maximum speeds, customers continue to experience higher speeds on fixed networks (as shown below) and consequently continue to have a thirst for faster mobile speeds.



Source: Ofcom, Fixed-line broadband performance, November 2014

[1] Ofcom, Communications Market Report 2015, 5 August 2015, Page 267.
[2] Idem.

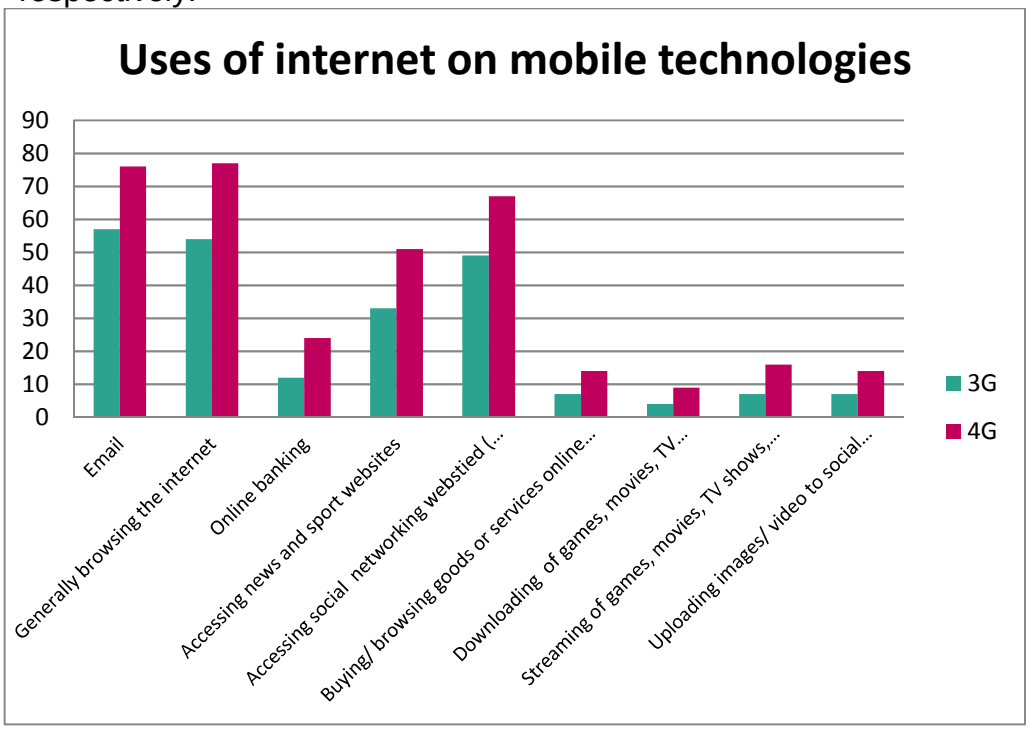
7. The dramatic increases in speed over the last decade or so have provided useful data on how consumers react.

Customer data usage increases as speeds increase

8. As the speeds on mobile networks increase the expectations from customers also increase. Improved capabilities on mobile networks allow more data heavy applications to run smoothly. This, in turn, drives customers towards an increasing demand for data use on the mobile networks. In 2014, Ofcom[3] reported on trends showing faster download speeds are reflected in higher data usage, 4G subscribers use more data than 3G users, and customers start to use more data hungry applications.

9. ✂.

10. A YouGov report in March 2015 also shows a clear behavioural change between 3G and 4G subscribers. Their study looked at the activities used on the internet through subscriber's mobile devices, and the frequency with which they occur for 3G and 4G subscribers respectively.



Source YouGov: March 2015 Survey Results.

[3] Ofcom Infrastructure Report

11. The YouGov study shows that the availability of 4G services increases the frequency with which customers access data-heavy services through their mobile devices.

    Customers are willing to pay more for higher speeds

12. YouGov's study also looked into the question of why customers want to get 4G contracts. Unsurprisingly, perhaps, the main driver was speed – as shown in the charts below.

13. Moreover, customers are willing to pay a premium for increased speeds. This can be seen from EE's launch of 4G in October 2012 and its success in selling 4G services since then. 4G services were made available to customers at a premium of £5 above the existing 3G services being offered by all other mobile operators. A premium service offering "4GEE" has since been offered providing even faster speeds than EE's other 4G service. Speeds up to 80 Mbps could be experienced, but this again came with a further price premium. EE reported in their recent financial statement that nearly 50% of its post-paid consumer connects were on the 4GEE double speed plans.

14. It follows from the discussion above that there are profits to be made from offering higher speeds.

Network churn increases as congestion and speeds reduce

15. The converse is also true. An MNO that cannot keep pace with its competitors on speeds will see customers leave.

16. ✂.

Speeds are important and differentiate operators because they significantly affect the real world consumer experience

17. As already mentioned above, 4G customers use more data overall than 3G customers and also have a much greater propensity to use data-heavy services such as video streaming.

18. The obvious reason why this happens is because some feature of 4G services makes the applications consumers are interested in using function better than using 3G services, which in turn encourages greater usage amongst 4G subscribers. The only significant difference between 4G and 3G from a consumer perspective will be the data speeds offered. There is latent demand amongst consumers for existing mobile data applications, which can be addressed once the network speed is high enough to offer the quality of experience that consumers require. The fact that higher data speeds prompt a change in consumer behaviour suggests to Three that these higher data speeds must be useful to consumers. In the remainder of this annex we explore the reasons why in more detail.

19. Higher data speeds impact real world consumer experience by providing tangible benefits when using common applications of mobile data services. These common applications currently include:

    - Video streaming
    - Web browsing
    - File downloading

20. In all three cases higher data speeds will always improve the customer experience. In the 2G and 3G world, voice services were circuit switched and hence coverage could be thought of in a binary way: either there was or there was not coverage of the voice service at a given location. Unlike circuit switched voice services however, packet switched data 'coverage' is not binary. Improvements in service quality can be measured on a sliding scale whereby the user experience on a mobile network is always better when incrementally higher data speeds are available. Indeed, in all three applications cited above there is no 'cut-off speed' beyond which no further performance improvement is evident. Furthermore, whilst these applications all require high data speeds now, they will likely require even higher speeds in the future as video becomes higher resolution, web pages become larger and more content rich, and file sizes become larger.

21. Looking forward, beyond the applications currently used, it is also likely that new applications will develop to make use of mobile data. It is likely that these future applications will further benefit from higher data speeds. Below we discuss in turn the three current applications listed above and some possible future applications.

    Video streaming

22. ✂. Video traffic requires high data speeds to be maintained on a mobile network in order to avoid buffering and to allow the user to watch the video seamlessly. The actual bandwidth required depends on the quality (i.e. resolution and frame rate) of the video stream. However, in all cases the bandwidth is significant, as shown by YouTube's current recommendations on required bandwidths for different qualities of video, summarised in Table 1 below

Table 1: YouTube recommended data rate requirements for different qualities of video stream

	Data rate requirement (kbps)		
Quality	**Min**	**Max**	**Recommended**
240p	300	700	400
360p	400	1000	750
480p	500	2000	1000
720p	1500	4000	2500
720p@60fps	2250	6000	3800
1080p	3000	6000	**4500**
1080p@60fps	4500	9000	6800
1440p@30fps	6000	13000	
1440p@60fps	9000	18000	

Source:YouTube, https://support.google.com/youtube/answer/2853702?hl=en-GB visited in late 2016.

23. Good quality video has already become the norm for users of mobile data. This requires a recommended sustainable bandwidth of 2.5-4.5Mbit/s, with the top end of this range being required for HD (1080p) at present. More generally, the greater the data speed available, the higher the quality of video the user can enjoy.

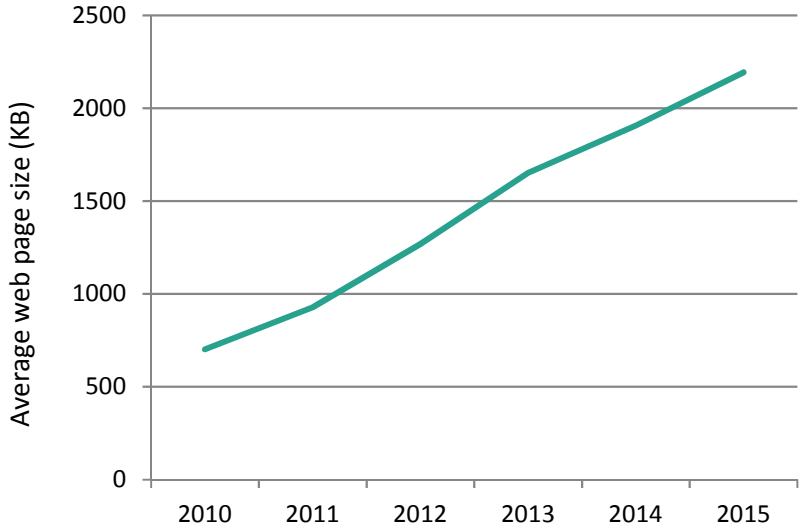
24. Whilst at least 4.5Mbit/s are required for a good HD experience, content producers will continue to provide increasing amounts of content at even higher qualities. A recent NIC report for Government recommends a rate of 8Mbit/s for HD video in the coming years. YouTube recommends that speeds of up to 18Mbit/s will continue to improve the experience for 1440p content at 60fps, this standard is already superseded by 4k (Ultra HD) content (2160p). For this quality both Amazon and Netflix, which both already offer content of this quality in the UK, recommend sustainable data speeds of **at least 25Mbit/s**. [4]

[4] For example, Netflix makes its recommendation on required data speeds here: https://help.netflix.com/en/node/13444

Web browsing

25. Web pages are getting larger and more content-rich. The larger the webpage the longer, all else being equal, it will take to open. To maintain levels of consumer experience when web browsing, and avoid unacceptable delays to load web pages, it is also necessary for data speeds to increase commensurately. Figure 1 below shows the evolution of the size of the average web page from 2010 to 2015. The size of the average page has roughly trebled in this period from around 700kB in 2010 to over 2100kB in 2015, and this trend shows no sign of abating.

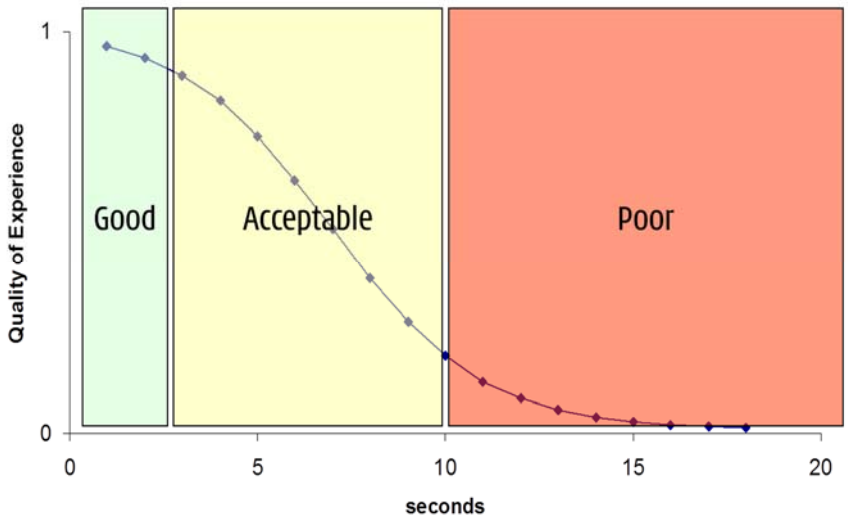
Figure 1: Trend of growth in average web page size



Source: http://httparchive.org/compare.php

26. Based on the 2015 average web page size it is likely to take around 10 seconds for a web page to load over a 2Mbit/s connection. This is a long time to load a web page and is likely to be considered unacceptable by many consumers. This is demonstrated by data published by the Open Mobile Alliance on consumer perceptions of application performance, shown in Figure 2 below. To get the time required to load a web page of this size down to around the 3 second mark, which represents the provision of a consistently good customer experience, a data speed of around 8-10Mbit/s is likely to be necessary.

Figure 2: Customer perception of quality of experience based on time to load web pages



Source: Open Mobile Alliance – OMA-RPT-ApplicationPerformance-V1.0-20030925

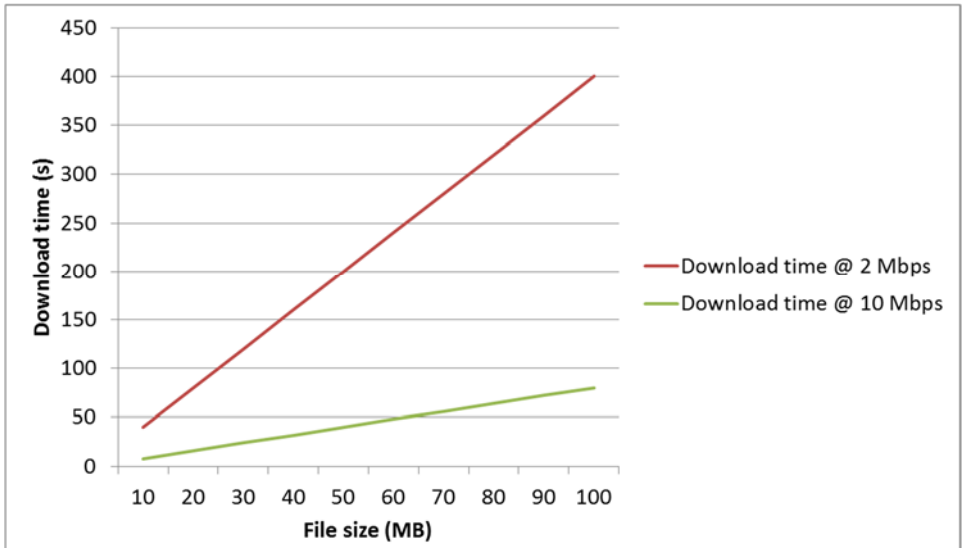
27. We note that in practice mobile users will be likely to access a mixture of full web pages, as discussed above, and mobile-tailored web pages. We have therefore considered whether mobile web pages should be considered materially different to full web pages. By September 2016, HTTP Archive shows that the average size for a full web page has arisen to approximately 2.5MB, with the average size for a mobile web page, while somewhat lower, still over 2MB per page[5]. The slightly smaller size of mobile web pages does not therefore affect Three's view that data speeds will be very important in determining the quality of experience for users when web browsing.

[5] With reference to statistics for the period 2-15 Sep 2016 on HTTP Archive here http://mobile.httparchive.org/interesting.php?a=All&l=Sep%2015%202016

File downloading

28. Mobile networks are increasingly being used for cloud applications, software downloads and handling large media files. In these cases, the customer experience is directly impacted by network speeds (i.e. the wait time for files to download). Figure 3 below shows how download times vary in direct proportion to file size and data speed. The difference in wait time between a fast network and a slow network is clearly higher for large file sizes, which are becoming more and more common.

Figure 3: Illustration of download time for files on networks of different speeds



Source: Three

Possible future applications

29. In its recent mobile data strategy update, Ofcom notes that:

> *"Many of the [5G] use cases we have identified* ***require high throughput/bandwidth****. Adoption of high bandwidth applications will drive growth in data traffic, as consumers time online is likely to move from mostly browsing and email* ***to higher bandwidth applications, as we are starting to see with 4G users and video streaming"*** [6] *[Emphasis added]*

[6] Ofcom, Mobile data strategy update, 30 June 2016, Paragraph 3.13

These statements are supported by the summary of illustrative use cases provided by Ofcom in Table 2 of the same document.

Figure 4: Illustrative use cases for 5G

Table 2 – Illustrative use cases

Use cases (where services are needed) and network requirements	High throughput	Low latency	Full mobility / consistent coverage	
Very high speed internet browsing at home/office	✓			Noma
HD Video conferencing "in every room" (A large amount of concurrent video streams)	✓	✓		
Smart Office	✓	✓		
Nomadic online gaming / VR	✓	✓✓		
Smart buildings / homes (including sensors / home surveillance)				
Cloud services along transport routes	✓	✓	✓	Mobil
High quality cloud services everywhere	✓	✓	✓	
High speed internet browsing while out and about"			✓	

Source: Ofcom, Mobile data strategy update, 30 June 2016, Table 2

30. Cloud services, which are reliant on file upload and download, are becoming more important and, as Ofcom observes, this is likely to be particularly apparent when 5G becomes available. For these and other possible use cases listed by Ofcom data speeds will be very important. Three considers that if data speeds are likely to be so important for 5G services of the future then they must also be important for the 4G services of today. Put another way, if 4G speeds were considered sufficient then there would be considerably less focus on delivering very high speed data services through 5G networks.

Average speeds on a network can be misleading because they do not guarantee a consistent user experience.

31. Peak speeds are in practice rarely received by users and hence average speeds, defined as the amount of traffic delivered over a period of time to a user, are often measured. These average speeds depend on both:

    - The peak achievable speed available to the user in that location; and
    - The number of active users sharing the site and the amount of traffic demanded by each user

32. Average speeds are often considered as a relevant metric when discussing the data speeds offered by a network. Although the average speed is extremely important, it does not tell the whole story. In particular, it should not be assumed that because an operator provides data at an average speed that is deemed to be adequate, this means that the overall quality of the data service provided is adequate[7]. This is because the variance of speeds that will actually be received by consumers over mobile networks is inherently high, and this consideration needs to be appropriately factored in to any assessment of what constitutes an adequate average data speed.

33. ✂.

[7] This is separate to the issue that simply providing an 'adequate' data speed is not necessarily sufficient since it will likely still mean that it is competitively disadvantaged compared to an operator with a greater share of spectrum that is able to offer higher data speeds.

Figure 5:

Source: Three simulation

34. Average speed in isolation is not therefore a good measure because it can mask the fact that a significant proportion of consumers receive a speed that is below an acceptable level for even “standard” applications today, never mind more demanding or future applications. Alongside average speeds, the proportion of the time that user experience falls below a minimum acceptable threshold also needs to be considered. Otherwise even a high average speed across a site’s coverage area can still leave many customers with a sub-standard experience due to the effects of interference and distance from the site [redacted].

Figure 6: Average speed versus distance from site chart for a simulation on Three's network

Source: Three simulation

Average speeds need to be high in order for an MNO to provide an acceptable level of service

35. As a result of the variance in speeds that a user of a mobile network will receive, it is important not only that the average speed delivered by the network is high but also that the proportion of time that the speed falls below a minimum threshold is also sufficiently low. Average speeds can potentially be used as a proxy to measure the proportion of time that the speed falls below a given threshold. However, if this approach is taken it is vitally important that the level of average speed required to provide a user experience of sufficient consistency and quality is seen in this context.

36.

Figure 7: Drive survey measurement of the download speed on Three's network

Source: P3 drive survey, Q1 2015

37. .

Figure 8: Distribution of download speed measurements on each MNO's network from the P3 drive survey

Source: P3 drive survey, Q1 2015

38. This relationship between average speeds and the proportion of users receiving very low speeds is also demonstrated by measurements taken by Ofcom in November and December 2015 as part of its Smartphone Cities report. An extract of the data gathered by Ofcom is shown in Table 2 below. It is notable that for O2, even though the average speed recorded is 10Mbit/s, the proportion of users receiving less than 2Mbit/s is over 30% - an even more extreme result than was observed for Three in the P3 drive surveys cited above.

39. Three has also included in Table 2 the amount of spectrum that was likely to have been deployed by each operator at the time of the Ofcom measurements. Comparing this to the average download speed recorded for each operator shows a very clear correlation, corroborating the conclusion that the amount of spectrum used is the key determinant of speed on an operator's network. We note that the difference in spectrum deployed at the time of these measurements, and hence the difference in resultant data speeds, is relatively low compared to what it would be if BTEE and Vodafone had deployed all the spectrum available to them and certainly also compared to what is likely to happen in the future.

Table 2: Key metrics from Ofcom's test results for average download speeds compared to 4G spectrum deployed

Operator	Average download speed	Proportion download speeds over 2Mbit/s	4G spectrum deployed currently
EE	20Mbit/s	92%	✂
O2	10Mbit/s	69%	✂
Three	15Mbit/s	87%	✂
Vodafone	12Mbit/s	82%	✂

Source: Ofcom's Smart Cities report, March 2016; Three, 2016

40. The overall message from Ofcom's measurements and the P3 drive survey results is clear: a very high average speed is required to ensure a distribution of speeds that avoids too many bad experiences for users and maximises the good experiences.

41. With this in mind, Three has carried out its own simulation to assess the distribution of end user speeds that would result from use of its network with different amounts of spectrum. The simulation, which is focussed on a small area of Three's network, first considers the use of a 20MHz carrier by an MNO (MNO B) and applies a loading to the network such that only 95% of users will achieve a speed of greater than 4Mbit/s. The average speed for MNO B with this loading level is ✂Mbit/s. The simulation then considers a second MNO (MNO A) with half the amount of spectrum (i.e. a 10MHz carrier) and records the data speeds that it could deliver. The results show that only ✂% of users would receive a speed of over 4Mbit/s from MNO A, even though the average speed received is ✂Mbit/s. Finally, the simulation considers how many sites would be needed for MNO A to offer a similar performance, in terms of delivered data speeds, to MNO B. The results show that around ✂x as many sites would be required for MNO A to provide a comparable service. The simulation results are summarised in Figure 9 below.

Figure 9: Results of Three's simulation of speeds delivered by 2 MNOs on a network with the same loading

Source: Three simulation

42. We draw two main conclusions from this simulation:

- First, whatever the chosen threshold speed, whether above or below 4Mbit/s, the performance of MNO B with the same number of sites far outstrips that of MNO A. Whilst the ratio of average speeds is only around ✂, the ratio of the proportion of users unable to achieve threshold speeds is significantly higher. Taking 4Mbit/s as an example the ratio is nearly ✂. For lower speed thresholds the ratio will be even higher, whilst threshold speeds of around ✂Mbit/s or higher need to be considered before the ratio drops as low as the ratio of average speeds. This illustrates the enormous advantage which having more spectrum confers on an MNO in terms of the data speeds which can be provided, and especially the consistency of user experience which can be provided. The results across a range of different threshold options are summarised in Table 3 below.

- Second, considering the speeds that can be provided only when the network is congested is no longer sufficient in today's market. How the network performs when it is more lightly loaded is similarly important to the customer experience and hence a consideration of the number of users that will receive less than a carefully defined threshold speed is the best approach to assessing the relative performance of two networks. The continuous range of performance offered by a network in terms of data speeds needs to be taken into account as users' experience will be worse where data speeds are lower.

Table 3: Customers receiving throughput below threshold speeds varying with spectrum holding per MNO

Source: Three simulation, 2016

Conclusions

43. Speeds matter because they significantly affect real world consumer experiences. This will be even more the case in the future as favoured applications become more and more data-heavy. This will inevitably affect competition between MNOs.

44. The speeds that matter are not headline or even average speeds but the speeds actually experienced by consumers. Simulations show that it is not realistically practicable to provide a comparable real-life experience for consumers if an MNO has much less spectrum than its competitors.