DCMS Future Telecoms Infrastructure Review: Call for Evidence

BT's response (January 2018)

Annex 2 Sources of Demand for ultrafast networks

Executive summary

New technologies are set to continue the transformation in connectivity between people, organisations and machines. The 'use cases' potentially made possible are many and varied, reflecting the ongoing digitisation of the entire economy and, whilst there is an overlap between developments in fixed and mobile applications, there are still differences between key drivers for investment in fixed networks and mobile.

The ultra-connected world will increasingly be one of wireless connections, both in terms of the numbers of devices connected to networks and in usage. Cisco estimates that by 2021, 73% of global internet traffic will be via a wireless connection (Wi-Fi and mobile) and only 27% will be wholly wired.[1]

- In mobile, the increase in 4G availability and take-up contributed to a 44% year-on-year increase in average monthly mobile data consumption to 1.86 Gb per connection in June 2017 (from 0.86 Gb per month in 2015).[2] The UK has the highest average mobile connection speeds in the world, at 26Mbps, up from 20.4Mbps in 2015[3]. Across the four UK operators, Ookla reports that EE has the leading median download speed of 28.8Mbps.[4]
- Average fixed connection speeds have increased from 29 Mbps to 44 Mbps in just the last two years, whilst usage has been increasing at over 50% per year.

Investment to date in fixed and mobile network capabilities have been able to meet this significant increase in usage.

This growth in traffic and overall bandwidth usage is forecast to continue, although there is no direct relationship between demand for data speeds and total traffic. Globally, Cisco forecasts a near threefold increase in total traffic in five years, with the fastest growth to come from mobile devices. Increases in traffic are driven by (i) more connected devices; (ii) services being used more intensively; and (iii) more bandwidth hungry applications. More advanced video-based applications will dominate usage in both fixed and mobile.

In the near term in mobile, this increase in bandwidth demand (particularly in terms of improved capacity during peak hours, and in congested areas and in the main transport corridors) will require investment in the continuing evolution of 4G networks, including small cell deployments. 5G is essential in the medium term to meet this demand through

[1] Cisco Infographic "Forecasting the world's digital transformation" at; https://www.cisco.com/c/m/en_us/solutions/service-provider/vni-complete-forecast/infographic.htm

[2] Ofcom, Connected Nations 2017, Figure 29

[3] Akamai, State of the Internet Q1 2017 Report

[4] Ookla, Speed test Report UK, January 2018)

new technologies and techniques, and by new spectrum being made available which is 5G centric. New 5G capabilities and use cases including those requiring very high speeds and low latency for mission-critical applications such as self-driving cars or remotely controlled industrial processes will drive increases in demand in the medium to longer term.

Demand for full fibre will be driven by demand for bandwidth at fixed locations (ie, 'fixed broadband') as well as demand from wireless devices requiring fibre deployed deeper into the access network to connect data back to core networks.

Given the existing connection speeds in most of the UK, tangible benefits of full fibre for the majority of customers appear limited.[5] That said:

- some consumers are willing to pay a premium for improved quality and speeds of full fibre and their number is likely to increase
- full-fibre investments are made for the very long-term and are likely to occur incrementally, with fibre to 5G and alternative fixed network technologies as options
- demand for greater speeds tends to grow as it becomes available, spurring on new use cases and applications
- the total economic benefits are not limited to the private benefits captured by individual customers alone.

As regards the latter point, in Frontier Economics' assessment for the NIC, much of the 'total economic benefits' of network upgrades will not be realised by the individual consumer, but are externalities. This means that their economic assessment includes public policy benefits which will not be captured by companies in their commercial appraisals.

Given the size and long-term nature of the investments required, and coupled with significant demand uncertainty, Government policy needs to identify measures to stimulate demand, reduce risk and help lower deployment costs.

The following sections provide an overview of:

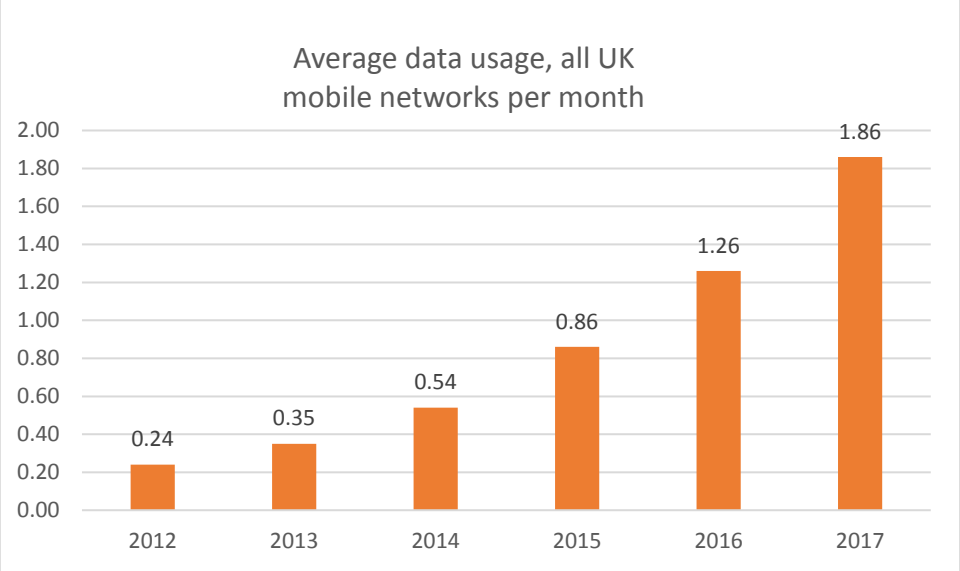
- past mobile and fixed traffic and usage growth in the UK and some forecasts (Section A)
- an overview of the main future mobile use cases including for 5G; as well as fixed ultrafast broadband (Section B)
- what we know about today's willingness to pay for ultrafast broadband at a fixed location (Section C)
- possible future demand (Section D).

[5] The Frontier Economics report for the National Infrastructure Commission found that G.Fast/DOCSIS will be able to provide bandwidth to meet the needs even for their "ambitious innovation scenario" up to 2033 and for longer under their other scenario.

A) Growth in aggregate bandwidth demand is likely to continue, yet not necessarily translating into equivalent growth in demand for higher speeds

- *Total UK fixed broadband traffic has grown more than 10 times in the last six years. Average data consumption per mobile connection has increased almost eightfold between 2012 and 2017.*
- *This growth is forecast to continue, driven principally by video traffic (around 80% of all internet data).*
- *Internet traffic will increasingly be consumed via wireless devices, which will account for the majority of traffic.*
- *Demand for significantly higher speeds than those available today will depend on possible future uses consumers might make of bandwidth available.*

1. Regarding mobile, average monthly data consumption per connection has increased almost eightfold, rising from 0.24 Gb in June 2012 to 1.86 Gb in June 2017, as shown below. According to Akamai, UK consumers also benefit from the fastest average mobile connection speeds in the world at 26Mbps, up from 20.4Mbps in 2015.[6]

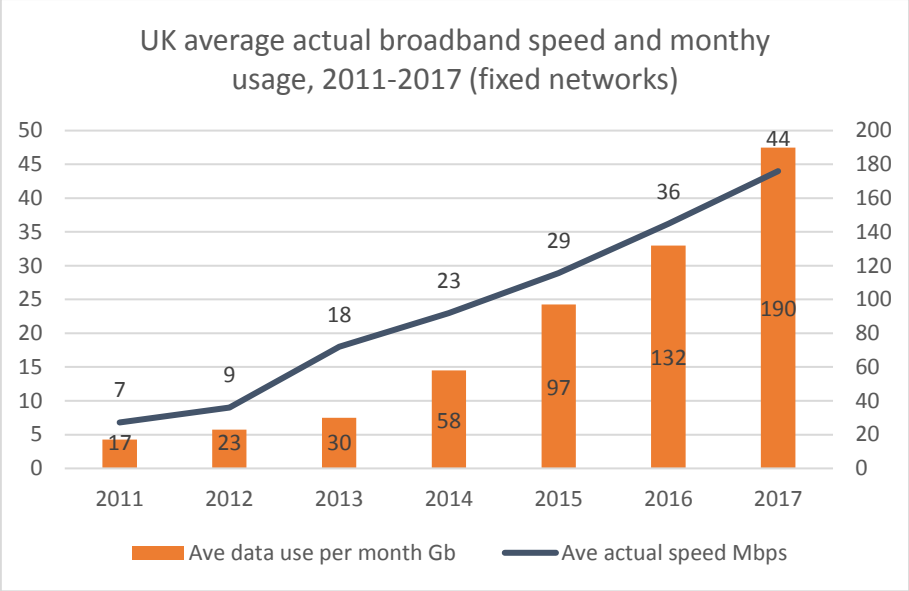


Source: Ofcom Connected Nations Report 2017

2. Regarding fixed broadband, Ofcom data shows that usage in the UK (in terms of the amount of data consumed) increased from 97 Gb to 190 Gb per customer per month between 2015 and 2017,[7] and at a CAGR of nearly 60% over the last six years. Average download speed meanwhile has increased from 7 Mbps to 44 Mbps, as shown in the chart below.

[6] Akamai, State of the Internet Q1 2017 Report

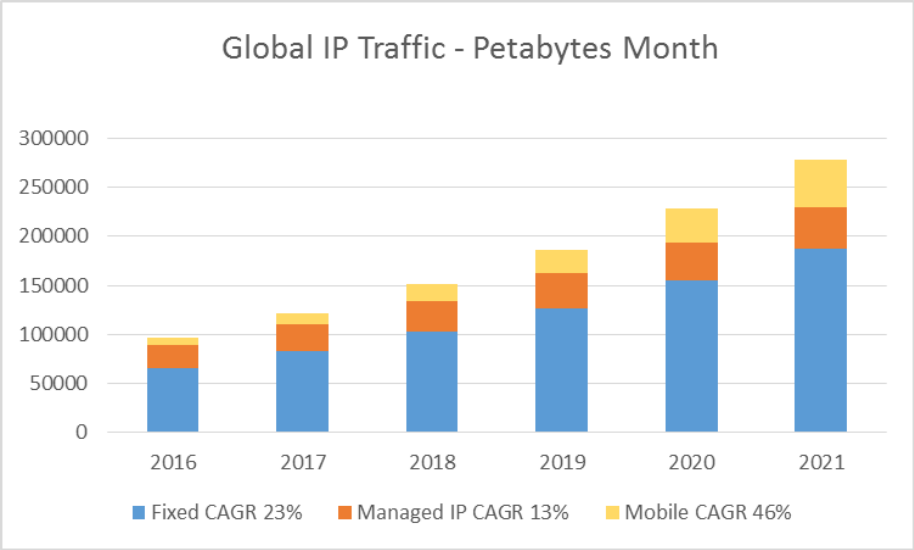
[7] Figures from Ofcom Connected Nations Reports, various https://www.ofcom.org.uk/__data/assets/pdf_file/0024/108843/summary-report-connected-nations-2017.pdf



Source: Ofcom Connected Nations Reports, various years

3. Whilst forecasting is difficult in such a fluid situation, there is consensus that for internet data traffic, video-based applications will increasingly dominate usage (accounting for c80% of bandwidth consumed) and be the key network upgrade driver.

4. In terms of global IP traffic, Cisco forecasts[8] a near threefold increase between 2016 and 2021, as in the chart below. The fastest growth (CAGR of 46%) is forecast to come from mobile handsets, notebook cards, and mobile broadband gateways. (Cisco forecasts internet traffic as fixed, mobile or managed, with the latter including corporate usage and TV / video on demand).



[8] Cisco "The Zettabyte Era: Trends and Analysis", June 2017
https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/vni-hyperconnectivity-wp.html#_Toc484556816

5. Cisco also forecasts that in 2021, smartphone traffic (33% of total IP traffic) will surpass PC traffic (25%). Globally, IP video traffic will be 82% of all IP traffic (business and consumer) by 2021, up from 73 percent in 2016. Cisco estimates that by 2021, 73% of global internet traffic will be wireless (Wi-Fi and mobile) and only 27% will be wired.[9]

6. There is no direct relationship between data speeds and total traffic. The latter has been increasing significantly as customers spend more time online. Customers are using fixed-line connections ever more intensively, streaming HD content requires a connection speed of around 5Mbps,[10] and people can double their data consumption by watching twice as much content, but without demanding higher speeds. Demand for higher usage does not therefore directly feed into demand for higher speeds, and the drivers for each are distinct albeit both reflect digitalisation in its many forms.

B) Sources of future demand for faster networks

- *In the near future demand placed on wireless networks will mostly be driven by demand for increased capacity and coverage, with video likely to remain a key demand driver. For business and the public-sector cloud computing, and, further in the future industry verticals are likely to drive demand for fully converged networks including 5G (see also Annex 5 on converged networks).*
- *In the longer term, there are numerous potential new use cases for ultrafast broadband connections, either at fixed locations or on the move. However, it is difficult to forecast how and when such services will develop and reach mass adoption, and thus what such innovation will mean for future demand and willingness to pay for ultrafast services.*
- *Whilst it is argued that the creation of extra bandwidth capacity can create new use cases, which will in turn improve returns on investment and stimulate further innovation, even with such a virtuous circle there is significant uncertainty around timing and extent.*

Wireless use cases: 4G evolution and 5G

7. 5G benefits cannot easily be separated from benefits of mobile services in general given that 5G is a 'system of systems' and will, in the long-term, encompass 4G capabilities, Wi-Fi, and fixed networks (for backhaul and wireless access, as well as end user services).

8. In the near future, investment in 4G is still progressing in particular to meet demand for high quality in areas of high footfall outdoors and indoors; improving indoor coverage and coverage along transport routes as well as improved rural coverage. In the near term, 5G is expected to help meet much of this demand more efficiently.[11]

[9] Cisco Infographic "Forecasting the world's digital transformation" at; https://www.cisco.com/c/m/en_us/solutions/service-provider/vni-complete-forecast/infographic.htm

[10] Bandwidth requirements for HD depend on factors such as whether 720 or 1080P, refresh rates and whether the content is live or pre-recorded (compression techniques cannot be applied in real time in live content to the same extent).

[11] Areas of dense demand for consumer mobile services include stadia, city centre shopping areas and transport hubs. We see challenges today in the most dense areas of demand where 4G and WiFi may not currently provide an adequate user experience.

9. In the longer term (ie, from the mid-2020s), 5G will underpin a variety of emerging new applications by connecting machines to each other, the Internet of Things (IoT). A number of use cases can already be identified:

    - **high-quality content delivery, particularly video across multiple technologies** One of the biggest drivers of mobile traffic is video, and the rise of streaming, primarily short form content which is delivered over unicast so every customer increases demand. Although 4G has a broadcast capability which can help for a small number of specific broadcast channels, this capability is most likely to be deployed network wide in 5G timescales. As use of video continues to grow, a more comprehensive solution will be required that is able to leverage fixed and Wi-Fi infrastructure for broadcast and on demand content which is being developed through standardisation processes such as 5G Xcast[12].

    - **supporting the needs of vertical industries** Many verticals have unmet communication requirements, many of which could be described as mission-critical, machine-type communication, such as:

        - ***Health*** – reliability, patient privacy, legal and regulatory issues impede uptake in telehealth and efficient provision of services. Reliability of communication is essential for automation while meeting these requirements. Looking further ahead, with high-capacity, low-latency services, there is potential for completely different ways of streamlining health services, such as remote diagnostics and even surgery for wider distribution of health services normally found in centralised hospitals

        - ***Industrial and manufacturing*** use cases demand specific capabilities for Massive Machine Type Communications (mMTC) to enhance manufacturing processes and monitor the safety of industrial solutions. 4G is already delivering improvements in this area, particularly for logistics, but transformational capabilities such as robotics require a level of reliability and latency of communication that a comprehensive end-to-end 5G system will provide

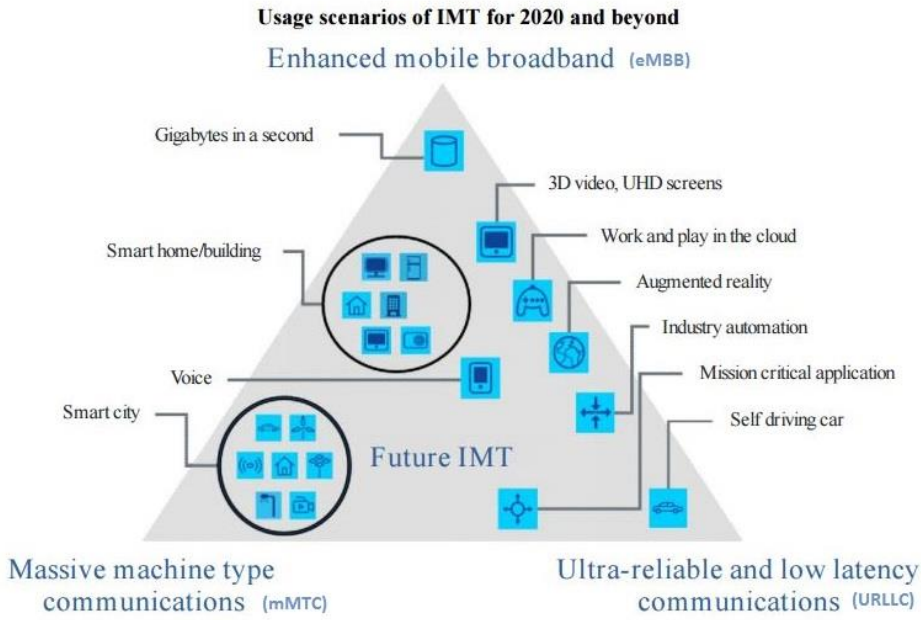
        - ***Automotive*** is a key area of study, requiring both low latency and high reliability for certain functions (such as collision avoidance), as well as a huge capacity demand for telematics and entertainment/remote office which stretch beyond what is possible today

        - ***Massive sensor networks*** are also discussed in the IoT space, but we believe that 5G will enable very low cost, low capability networks to support a vast range of permanent and temporary use cases

        - ***Enhanced retail experience*** – consumers' shopping experiences may be enhanced by artificial reality or virtual reality (AR/VR) applications, allowing them to test products in a virtual world, access product information and visualise products in their homes. The use of AR/VR will be enabled by 5G's high-speed connectivity, allowing rich content delivery.

10. The graphic below, from the ITU, summarises 5G as enhanced mobile broadband that will deliver ultra-reliable and low latency communications while dynamically supporting mMTC.

[12] Explained further at http://www.bbc.co.uk/rd/projects/5g-xcast



11. Many of the above potential use cases remain speculative, and are unlikely provide significant revenue until the mid-2020s. Moreover, dependence on 5G in the high frequencies will vary between use cases; all will require it to some degree but, initially, many will evolve while relying on the evolution of current networks, including 4G.

Fixed ultrafast broadband

12. Emerging services that could drive demand for higher upload and download speeds to fixed locations in future include:

- **new format video** - the bandwidth required for video delivery is likely to increase as screens get bigger. New formats at increased resolutions (4K and 8K+), and higher frame rates (90+ frames per second) may emerge and become mainstream

- **ehealth and telecare services** will become increasingly sophisticated, and include diagnosis, treatment and monitoring, as well as personalised health services and access to advice

- **virtual and augmented reality services** may become popular, offering much higher levels of immersion, allowing users to move within and interact with virtual environments

- **social media** could be used to share content of increasing complexity and size. 4K resolution is already appearing on new smartphones; widespread adoption of live streaming would drive the need for substantially higher upload speeds

- **online gaming** will become increasingly sophisticated, requiring low latency, high-resolution video and support for multiple concurrent users

- **cloud computing** - customers will require increasingly high speeds, in particular SoHo and SME customers that rely on software as a service (SaaS) and cloud models.

- **4-8K cameras** will enable high resolution digital pan-and-zoom. When combined with broadband-enabled cloud analytics and AI (artificial intelligence), this will enable cloud-based recognition of objects and actions, leading to advanced new services in multiple sectors, such as for security and retail.

13. Such applications, as for the 5G use cases, will only realise their full potential in the medium to longer term. However, it is difficult to forecast how exactly services will develop and whether and when they could reach mass adoption.

C) Consumer willingness to pay for full fibre

- *For commercial deployment of full fibre, willingness to pay a price premium over charges for slower speed access is key.*
- *Given average connection speeds available in the UK already, tangible benefits from, and hence willingness to pay for, full fibre appear fairly limited for the majority of consumers.*
- *While some consumers already willing to pay a premium for the improved quality and speeds of full fibre, and their number is likely to rise over time, it is not possible to estimate future willingness to pay by the majority of consumers.*

14. Willingness to pay for higher speeds depends on a number of factors, in particular (i) demand for applications which require ultra-fast speeds, or which work better with full fibre, and (ii) the extent of the premium charged.[13]

15. Evidence to date does not suggest that the majority of customers would pay a significant premium over what they have today. To an extent this reflects the relatively fast speeds consumers receive over superfast copper (up to 80Mbps and with G.Fast over 300 Mbps). The lack of willingness to pay also reflects the absence of applications which require very fast speeds.

16. The difference that speed can make to customers has been illustrated by Ofcom. Its 2017 *Connected Nations* report[14] shows the time saving when downloading files: an HD movie, for example, takes 30 minutes at 30Mbps and under 5 minutes at 300Mbps (and under two minutes at 1Gbps). It is also the case that higher speeds allow simultaneous consumption of content within the home: two HD movies streamed to the same household at once would require around 10 Mbps. However, the end-user experience is not necessarily impacted by the trade-offs between download speed and technology used in the access network. There are many means by which telecoms providers and 'over the top' (OTT) content providers can improve the seamlessness and quality of video enjoyed over broadband. These include the use of content delivery networks (CDNs) and the use of video compression, which continues to evolve.

17. Willingness to pay more is related to the value attributed to incremental benefits. Given that the average connection speed in the UK in 2017 was 44 Mbps[15], and these speeds meet virtually

[13] In the case of full fibre, the question is whether customers are willing to pay higher monthly charges for very high bandwidths (i.e. materially above the current maximum of c.80Mbs using VDSL and c.300Mbs for G.fast and cable) and if so, how much,

[14] Ofcom Connected Nations 2017, Dashboard, Figure 1

[15] Ofcom Connected Nations 2017, Dashboard, page 8

all current needs, tangible benefits for the majority of customers from a 1Gbps full fibre connection today appear limited.

18. Furthermore, Ofcom suggested that to increase take-up of current superfast broadband services suppliers will need to lower their prices: this appears consistent with a limited willingness to pay for faster speeds today.[16] Market evidence supports this as the price differential between copper-based broadband and the entry level fibre to the cabinet services has been decreasing.[17]

19. Nevertheless, not all customers place the same value on speed. Customers' requirements differ markedly, as described in the Openreach Consultation, "Upgrading the Access Network with FTTP":

> "[Openreach] modelling indicates that among customers with the lowest broadband speeds, the peak requirement is currently up to 5 Mbps. [18] The heaviest users (typically large families, with 3+ children living at home) have peak requirements in any given week of up to 30 Mbps. This higher peak demand is typically driven by increased video consumption (for example, two people watching different IP video streams at the same time) and by large file downloads (e.g. operating system updates). In most cases these peak requirements (particularly for brittle demand[19]) can be met comfortably by existing superfast technologies – such as FTTC – with speeds of up to 80Mbps, although some other infrastructure providers may choose to offer customers higher speeds, or to migrate them to higher speeds."[20]

20. Evidence of actual demand in Australia and New Zealand provides relevant market evidence of willingness to pay.

    - In **New Zealand**, where FTTP is being made available to 85% of all homes, fibre take up has reached 35%. Fixed connections and the 100 Mbps service accounts for just over two-thirds of mass market fibre price plans. However, the price premium charged for the 100 Mbps

[16] In 2016 Ofcom noted that "…the rate that new subscribers are migrating from basic broadband services and adopting superfast services appears to be slowing, dropping from 31% in the year to 2014, to 15% over the past year." Ofcom goes on to suggest that "…in order for superfast broadband take up to continue growing at the same rate as it has in the past, providers may need to consider new approaches for attracting customers, including articulating its benefits more clearly and lowering prices further." (Ofcom, *Connected Nations* 2016, paragraphs 4.57 and 4.60).

[17] BT analysis indicates that the price premium typically charged for the entry level residential superfast broadband services (with unlimited data) has decreased since 2014, from £10/month in June 2014 to under £5 in April 2017. BT's own price differentials have closed too, although less sharply – on the basis of standard non-promotional tariffs, in June 2014 BT charged a £7 premium for its entry-level unlimited superfast service, and in April 2017 it charged a £6.50 premium, despite having increased the download speed from up to 38Mbs to up to 52Mbs.

[18] For access network planning purposes, a key consideration is anticipated peak demand as opposed to total demand across the day or across the week.

[19] The bandwidth required by applications can be either 'brittle – where network congestion has a material impact on the customer experience, eg, buffering of a video stream - or 'soft' where there is no noticeable customer impact, eg, the download of a file as a background task. Total demand is the sum of the two. In general, there is minimal customer tolerance for bandwidth constraints that affect their brittle demand and a range of tolerance for bandwidth constraints on soft demand.

[20] "Upgrading the Access Network with FTTP", Openreach Consultation, 17th July 2017 B.10

wholesale service over that for 50M bps is only 6%, suggesting a fairly limited premium can be earned, whilst around one in ten fibre plans are at speeds of 200Mbps or higher.[21]

- Reports from **Australia** indicate that there is little willingness to pay for high-speed services. NBN, the state access provider, is attempting to recover its costs by charging a premium for higher speeds, but is meeting resistance with four in five homes connected to NBN buying the lower cost 12Mbps and 25Mbps plans.[22]

21. Averages do mask large differences in individual household demand as borne out by BT data. Families with children have notably higher demand for bandwidth and whilst BT data shows a typical weekly peak demand of about 7 Mbps today for a single person household a busy family can derive demand of c.33 Mbps, and activities such as games downloads can push this to over 50 Mbps. However, it is difficult to estimate how much of the demand the customer may be willing to pay for as the 'soft' element of this demand (such as the download of a file as a background task) may not have a noticeable customer impact. Such families are also very much in the minority, and account for under 5% of the UK household base.

22. It is also the case that ultrafast broadband does have appeal to some customers and, whilst market research of retail customers' attitudes shows that a significant proportion are not willing to pay more for faster broadband, there are groups who might be. The size of this addressable market is difficult to estimate, and will change over time, but is currently likely to be only a relatively small proportion of the total customer base.

23. In summary, there is limited evidence that the average consumer is currently willing to pay a material price premium for bandwidth speeds much above those on offer at present, and high-use households who are most likely to have such demand are a small minority. There may also be consumer demand for full fibre as a premium product for reasons of service quality[23], although sizing the value of this today is difficult and carries significant uncertainty. We expect this uncertainty to reduce over time as ultrafast build progresses and consumer demand patterns emerge or are stimulated by the availability of enhanced services.

D) Looking ahead the range of possible estimates of willingness to pay is high, reflecting high levels of uncertainty

- *In the short- to medium-term future, it is not clear that many customers will require 100 Mbps services and above, or be willing to pay for them.*
- *Even under the 'ambitious innovation' scenario described by Frontier Economics in its report* Future Benefits of Broadband Networks *for the NIC, G.Fast/DOCSIS will be able to provide bandwidth to meet the needs up to 2033 (and is able to deliver moderate evolution in all years).*

[21] Figures from Chorus Roadshow Presentation, October 2017, Slide 19 https://company.chorus.co.nz/file/80221/Investor-Roadshow.pdf

[22] As reported by The Australian, 8 January 2018.

[23] fibre is less susceptible to weather (especially rain) than copper and, unlike copper, the speed of services provided over fibre is not dependent on the distance between the customer premises and a street cabinet or exchange building, or on the gauge of the cable. Fibre is also not susceptible to cross-talk, which is a key challenge for services delivered over copper.

- *Given significant demand uncertainty there could be value in waiting for more information, or making incremental investment. The latter may be particularly sensible where there is uncertainty over the likely places where, for example, fibre investment may be needed most to support optimal investment across fixed and mobile networks.*

24. Looking ahead in the short to medium term there have been a number of demand forecasts, some lower end and others higher. For example, a report for the BSG (Broadband Stakeholder Group)[24] forecast that the median household would require 19 Mbps by 2023, whilst the top 1% of high usage households will have demand of 35-39 Mbps. For business customers, BSG forecasts that median downstream demand for small business premises will rise from 5Mbps in 2015 to 8Mbps in 2025, with demand for the 95th percentile rising from 13 Mbps to 41 Mbps[25].

25. An Australian estimate made in 2014[26] came to similar conclusions, using a model of bandwidth demand which assumed that consumers would experience one minute per week of degraded performance (such as a video stream with briefly lower resolution). On this basis, the researchers estimated that in 2023 the median household (the 50 per cent proportion of households) would require bandwidth of 15 Mbps whilst the top 5 per cent of households would have demand of 43 Mbps or more. The authors explain:

> "The figures of 15 Mbps and 43 Mbps for median and top 5 per cent of demand may seem low, particularly by comparison to the results of some other research in this area. However, the most common type of household comprises just two people. Even if those two are each watching their own HDTV stream, each surfing the web and each having a video call all simultaneously, then (in part thanks to the impact of improving video compression) the total bandwidth (in 2023) for this somewhat extreme use case for that household is just over 14 Mbps."

26. The full implications of demand possibilities are considered in the previously mentioned Frontier Economics report, in which two use-case scenarios are developed, in what Frontier describes as being a **moderate evolution scenario** and an **ambitious innovation scenario**. The distinction between these cases plays a key role in the report, as further discussed below. Frontier comments that:

> "Video transmission is ultimately the key driver of network bandwidth across the use cases in both scenarios. Video is central to the use of very high resolution displays; VR and AR technologies; some smart home applications (such as uploading surveillance video); teleheath and telecare (remote healthcare consultation); and remote education. Given that existing broadband networks support video (current networks allow the majority of homes

[24] "Domestic demand for bandwidth", Broadband Stakeholder Group, November 2013

[25] "The broadband requirements of small businesses in the UK", Broadband Stakeholder Group, August 2015

[26] Independent cost-benefit analysis of broadband and review of regulation, Volume II – The costs and benefits of high-speed broadband, Page 34
https://www.communications.gov.au/sites/g/files/net301/f/Cost-Benefit_Analysis_-_FINAL_-_For_Publication.pdf

to receive HD and even UHD videostreams) then the incremental demand enabled by network investment depends to a large extent on how demand for video will evolve."[27]

27. The difficulty is that it is possible, as Frontier shows, to make a case for either future, or to argue that neither is a likely outcome and that the moderate evolution scenario is too aggressive in its assumptions (Frontier states that its two scenarios are not intended to estimate an upper or lower bound). For example, Frontier describes the possible development of next-generation 360^0 VR or AR services which could require from between 50Mbs to 600Mbs, and of 3D VR headsets requiring Gigabits of data.[28] It is just not possible to know with any degree of certainty whether such services will generate demand or be regarded as no more than a technical curiosity. For every technical innovation which has exceeded expectations, many others will fail.

28. Further, Frontier adopts a very conservative assumption regarding advances in video compression technologies, in which huge strides have been made in recent years. With technological advances in compression techniques, the amount of bandwidth needed for any particular service decreases, already a HD video which once required 20 Mbps can be compressed to 5 Mbps or less. Given that Amazon, Apple, Google, Facebook and Microsoft are all part of the Open Media Alliance,[29] which is working on a new compression technology to make online video streaming and downloading use less data, further significant advances must be viewed as being very likely.

29. The distinction between the **moderate evolution** scenario and an **ambitious innovation** scenario has a key impact Frontier's conclusions. Under the former, widespread full fibre does not have the highest net benefit, although this is the case under the latter. Even then, Frontier estimates G.Fast/DOCSIS will be able to provide bandwidth to meet the needs for the ambitious innovation scenario up to 2033 (and is able to deliver moderate evolution in all years).[30]

30. The core of the issue is that the mass full-fibre case therefore depends on mass adoption of very high-bandwidth services (and other unknown developments) which do not exist and cannot be foreseen.

31. A distinction also needs to be made between a public policy case for FTTP and a commercial case. Frontier's assessment is of the 'total economic benefits' of network upgrades, much of which will not be realised by the private purchaser. This means that their economic assessment includes public policy benefits, which will not be captured in commercial appraisals.

[27] "Future benefits of broadband networks", Master Draft, Frontier Economics 12 December 2017 https://www.nic.org.uk/wp-content/uploads/Benefits-analysis.pdf Page 9

[28] Frontier op cit, page 219

[29] https://www.theverge.com/2018/1/4/16850402/apple-joins-open-media-alliance-streaming-online-video-compression-codec

[30] Frontier op cit, Page 59