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UK Home Broadband Performance

The performance of fixed-line broadband delivered to UK residential consumers

Research report

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About this document

The report contains data and analysis regarding the performance of UK fixed-line broadband services delivered to residential consumers in November 2016. Specifically, it provides information on the average performance of ADSL, cable and fibre-to-the-cabinet broadband packages, presented at a national level, as well as separately for a number of the UK's most popular ISP packages.

We have produced this report to provide consumers with useful information on the performance of broadband services. We have also published a short consumer guide to home broadband,[1] which includes high-level summaries of some of the analysis in this report, and an interactive data visualisation tool. This report is published in accordance with Ofcom's duty to carry out and publish research on the experience of consumers.

[1] https://www.ofcom.org.uk/__data/assets/pdf_file/0018/100755/UK-home-broadband-performance,-November-2016-Consumer-guide.pdf

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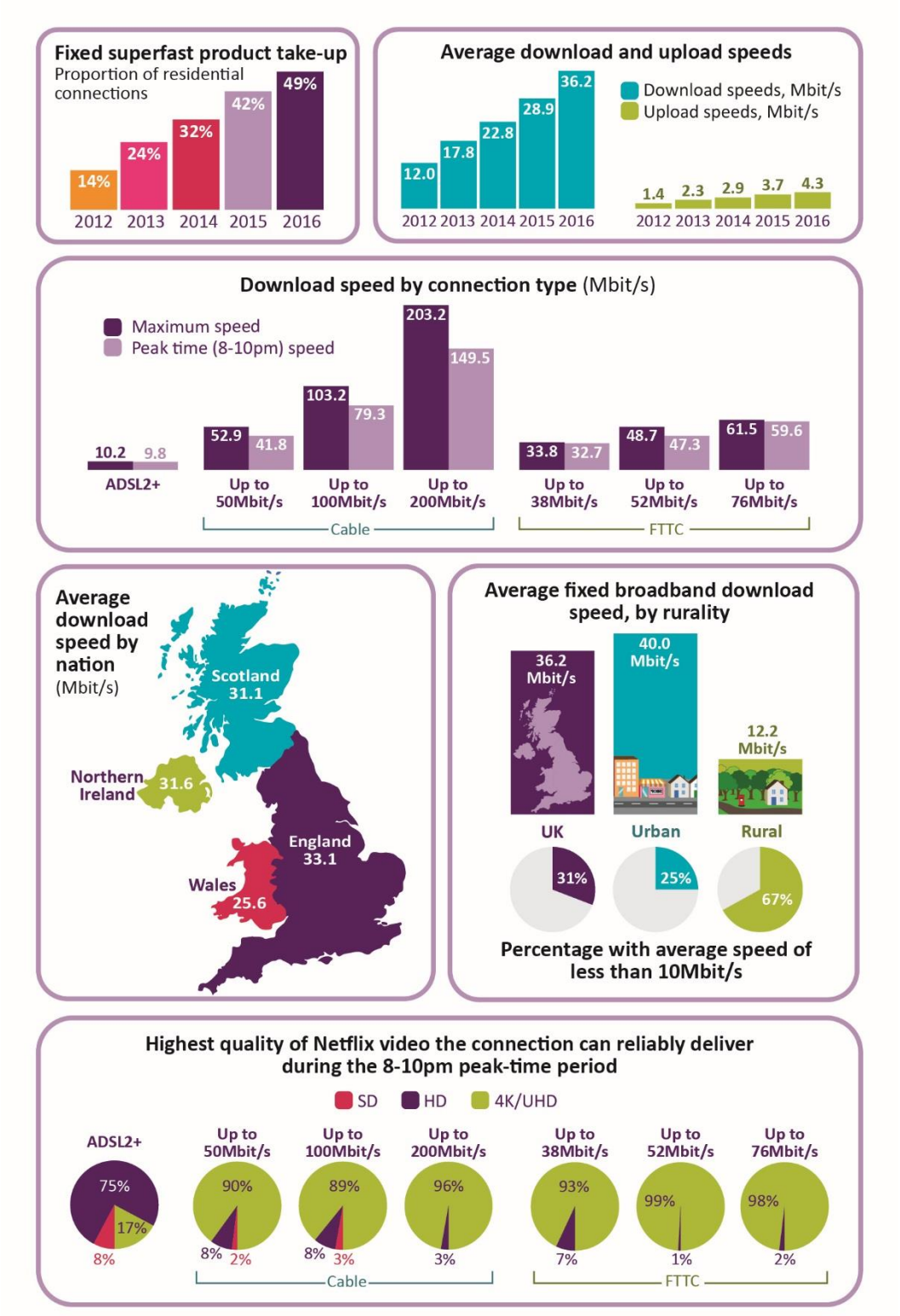
Section 1

Dashboard



Source: Ofcom, using data provided by SamKnows

Section 2

Executive summary

Communications services play a central role in the UK economy and affect the personal and professional lives of everyone.

By June 2016, almost all UK premises could receive standard broadband services,[2] and 89%[3] could receive superfast download speeds of 30Mbit/s or higher.[4] However, fixed broadband speeds are slow for a significant number of consumers and, even where available, the nature of the technologies used to deliver superfast fixed broadband means that performance is not consistent across all parts of the country. The availability of ultrafast services (offering actual download speeds of 300Mbit/s or higher) remains low,[5] and Ofcom is working to improve the availability and quality of fixed broadband services.

We carry out research into the performance of residential fixed broadband services as part of our work to monitor the UK communications industry, and this report presents a summary of our findings. This report is based on research undertaken in November 2016 in conjunction with our technical partner, SamKnows Ltd, and our panel-based approach means that our findings may not reflect the user experience of all residential fixed broadband users. Below we present some of the key points from this year's findings, which we expand on later in the document.

Average actual fixed broadband download speeds increased by 25% in 2016

The average actual fixed broadband download speed delivered to UK homes is improving, and increased by 25% to 36.2Mbit/s in the year to November 2016. Over the same period, average upload speeds increased by 16% to 4.3Mbit/s. The main driver for increases in both download and upload speeds is the growing take-up of superfast fibre and cable services, and almost half of residential fixed broadband connections (49%) had an advertised speed of 'up to' 30Mbit/s or higher by November 2016, a seven percentage point increase since 2015.

Three in ten fixed broadband connections deliver a peak-time average speed below 10Mbit/s

Data collected from broadband providers show that, in November 2016, 5% of UK residential fixed broadband connections had a headline speed below 10Mbit/s. However, actual speeds are typically lower than headline speeds, particularly for connections provided using copper-based technologies such as ADSL and superfast fibre-to-the-cabinet (FTTC), and network congestion can reduce the speed of all connection types at busy times. [6]

[2] Standard broadband services are those delivering a download speed of less than 30Mbit/s.
[3] https://www.ofcom.org.uk/__data/assets/pdf_file/0035/95876/CN-Report-2016.pdf
[4] Note that the UK Government defines 'superfast' as having a download speed of greater than 24Mbit/s.
[5] Ofcom's *Connected Nations 2016* report found that 2% of UK premises could receive ultrafast full-fibre services in June 2016
[6] In the 2016 Connected Nations report, we also reported that around 5% of UK premises were unable to receive a download sync speed greater than 10Mbit/s. The sync speed of a connection is the maximum speed achievable between a consumer's premises and their internet service provider's (ISP's) network. This may be different to the headline speed operators use to market their broadband services.

Our research shows that 31% of lines had a peak-time (8pm-10pm) average actual speed below 10Mbit/s. This was an improvement since November 2015, when 40% of lines received less than 10Mbit/s during the 8-10pm peak period. The improvement is driven, in part, by greater availability and take-up of superfast broadband services. We reported in our 2016 Connected Nations report that superfast services were available to around 90% of homes meaning that most households receiving less than 10Mbit/s could receive faster connection speeds if they were to upgrade their service.

The UK Government has set out its ambition to introduce a broadband universal service obligation (USO) across all of the UK with a minimum download speed of 10Mbit/s. This is considered to be the speed which enables full participation in a digital society. Ofcom provided technical advice and recommendations to the Government to support the design of a broadband USO[7].

Rural consumers receive much lower average speeds than those in urban areas

A significant minority of UK homes cannot benefit from superfast broadband, either due to a lack of availability of superfast cable and fibre services, or because of the limitations of the copper used to provide last-mile connectivity in superfast FTTC deployments.[8] These homes tend to be in rural areas, and our analysis shows that the average download speed in rural areas of the UK was 12.2Mbit/s in November 2016, compared to 40.0Mbit/s in urban areas. Two-thirds (67%) of rural connections received an average speed of less than 10Mbit/s, compared to 24% of urban connections. Our research also shows differences in performance across the UK nations, with average actual download speeds ranging from 25.6Mbit/s in Wales to 33.1Mbit/s in England.

Network congestion reduces average connection speeds at busy times

As consumers embrace online services, average data consumption has increased, placing additional capacity demands on broadband networks. Our research shows that download speeds fall at busy times, averaging 33.6Mbit/s during the 8-10pm peak-time period, compared to average maximum speeds of 39.1Mbit/s. This slowdown varies by service type; the proportion of the maximum speed that is delivered in the 8-10pm peak-time period ranges from 74% for superfast 'up to' 200Mbit/s cable connections (75% of the headline speed) to 97% for FTTC services.

Cable broadband is typically faster than copper-based services, but a significant minority of users experience severe slowdowns in peak times

Contention occurs closer to the customer in superfast cable networks, making it more difficult to add new capacity to reduce the effects of network congestion. But despite suffering from higher levels of slowdown than ADSL and FTTC, superfast cable services still had the highest average download speeds throughout the day. There was also much greater variation in the levels of contention experienced by superfast cable customers, with a significant minority experiencing severe slowdowns. For example, while 47% of 'up to' 50Mbit/s cable panellists had a peak-time average speed of 50Mbit/s or higher, 9% received less than 10Mbit/s. There was less variation in the performance of FTTC connections; less than 1% of our FTTC panellists received a peak-time average speed of less than 10Mbit/s, while less than 5% had a maximum speed equal to or above the advertised speed, compared to 90% of superfast cable panellists.

[7] https://www.ofcom.org.uk/__data/assets/pdf_file/0028/95581/final-report.pdf
[8] According to *Ofcom's Connected Nations Report 2016*, 11% of UK premises were unable to receive fixed broadband services at superfast speeds.

Actual download speeds vary by ISP service and technology

We also compare the performance of different home broadband packages, and find that while many consumers can receive better performance by switching to a different technology or upgrading to a product with a higher advertised speed, it is unlikely that they will experience a substantial increase in performance by switching from an ADSL or FTTC package to another of the same speed. Virgin Media's 'up to' 200Mbit/s cable service provided the fastest average download speed of the packages included in the report, over the whole day (173.1Mbit/s), and in the peak 8-10pm period (149.5Mbit/s). Standard ADSL2+ broadband delivered over a copper telephone line had an average speed of 9.9Mbit/s, while 'up to' 38Mbit/s, 52Mbit/s and 76Mbit/s FTTC services had average speeds of 33.1Mbit/s, 48.0Mbit/s, and 60.5Mbit/s respectively. Virgin Media's 'up to' 50Mbit/s and 100Mbit/s cable services had average download speeds of 47.9Mbit/s and 91.4Mbit/s respectively.

Cable and FTTC outperform ADSL2+ in terms of disconnections and Netflix streaming

Our research also compares the performance of different ISP packages in terms of disconnections and Netflix video streaming quality. We found that ADSL2+ services, on average, suffered from 1.1 disconnections of 30 seconds or longer per day, compared to between 0.2 and 0.4 per day for superfast cable and FTTC services. Superfast services also outperformed ADSL2+ in terms of video streaming quality over the 24-hour period, managing to reliably access between 93% and 99% of content at the highest possible resolution, 4K (UHD), compared to just 18% of streams over ADSL2+.

Ofcom is working to improve the availability and quality of fixed broadband services

Ofcom is working to promote the roll-out of ultrafast, 'full-fibre', broadband networks, whereby fibre-optic cable is laid direct to homes and offices. To do this we are making it quicker and easier for rival providers to build fibre networks using BT's network of telegraph poles and underground ducts. BT has also agreed to the legal separation of its network division, Openreach. This should help promote future investment in infrastructure as Openreach makes investment decisions on behalf of all ISPs that use its network.

We continue to work with the UK Government and devolved administrations to help improve the availability and performance of fixed broadband services, including through providing technical advice on the proposed broadband universal service obligation.

The UK's largest ISPs are signatories to the voluntary *Code on Broadband Speeds*, which requires that speed estimates are provided ahead of sale, and gives consumers the right to exit their contract penalty-free if speeds fall below a minimum guaranteed level. We are seeking to update the code so that speed estimates reflect the impact of contention, and to ensure that customers have better information about their right to exit. We plan to consult on an updated code in summer 2017.

Section 3

Background

Introduction

Ofcom's principal duty under the Communications Act 2003 (the Act) in carrying out its functions is to further the interests of UK citizens and consumers. In doing so we are required to secure several things, including the availability of a wide range of electronic communications services, which includes fixed broadband services. We must also have regard to the desirability of encouraging investment and innovation in relevant markets, the availability and use of high-speed data services throughout the UK, and the interests of consumers in respect of choice, price, quality of service and value for money.

The Act also requires us to make arrangements to find out about consumers' experience in their use of, and access to, electronic communications services, and we do this by carrying out research. Subject to certain exceptions, we have a duty to publish the results of our research and to take account of it in carrying out our functions.

To understand the performance of UK fixed-line residential broadband connections, we commission research to measure and report on the consumer experience of using these services. We believe that our technical methodology (see Annex 1), combined with the scale of data collection and the sophistication of the statistical analysis (see Annex 2), makes this a robust presentation of UK fixed-line broadband performance. Ofcom has undertaken this research since 2008, using data collected by our research partner SamKnows Limited from a volunteer panel of UK residential broadband users.

The approach differs to that used in our *Connected Nations 2016* report, which includes analysis of broadband speeds based on information on the 'sync speed' or 'configured speed' of each active line, which is provided to Ofcom by ISPs. This gives a measure of the maximum connection speed achieved between the ISP's access network and the consumer's premises, which does not vary significantly during the day, and is usually slightly higher than the 'end-to-end' line speed measurements we present here.

Since the last *UK Home broadband performance report*,[9] we have made several changes to the research, most notably:

- Through additional panellist recruitment we have increased and rebalanced the research panel to allow more robust analysis of performance in rural areas of the UK.
- Based on consumer behaviour, the peak-time metric relates to tests run between 8pm and 10pm seven days a week, rather than the previous weekday 8pm-10pm, to better reflect consumer use of fixed broadband services.
- The panellist-level maximums which feed into the maximum speed metrics included in the report are the means of the daily maximums recorded in the measurement period. Previously, they were the point maximums recorded during the month.[10]
- We have introduced a new minimum speed metric, which is calculated from the mean of the daily minimums recorded during the measurement period.

[9] https://www.ofcom.org.uk/__data/assets/pdf_file/0017/71540/fixed-bb-speeds-nov15-report.pdf
[10] This avoids the published data being unduly effected by outlying results.

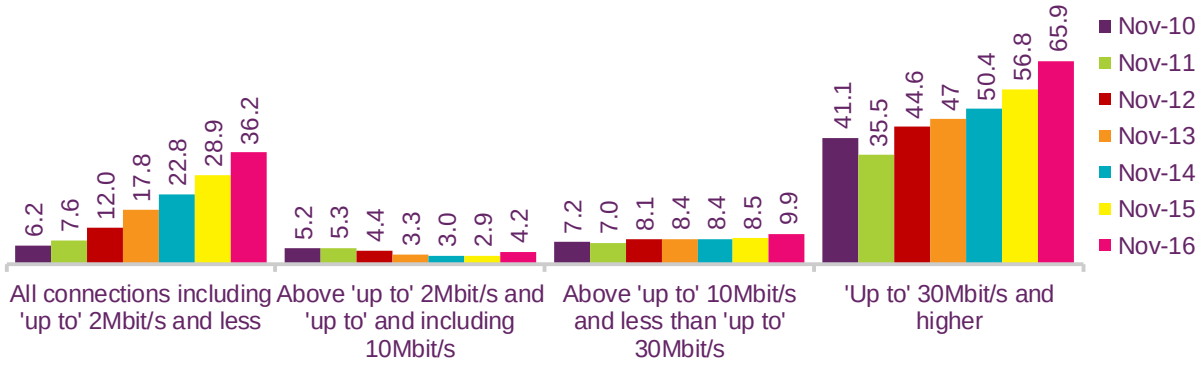
Section 4

Overview of fixed broadband speeds

Average download speeds increased by 25% in the year to November 2016

- The average actual speed of UK residential fixed broadband services increased by 25% to 36.2Mbit/s in the year to November 2016, a higher rate than for any of the speed bands shown below, suggesting that the key driver was homes upgrading to superfast services.
- This high rate of increase may not therefore be sustainable; the migration to superfast services may slow as some households decide to stick with standard broadband services. However, it is the case that faster services continue to be launched; for example, in January 2016 Virgin Media launched a 300Mbit/s package.

Figure 1: Average actual broadband speeds: November 2010 to November 2016 (Mbit/s)

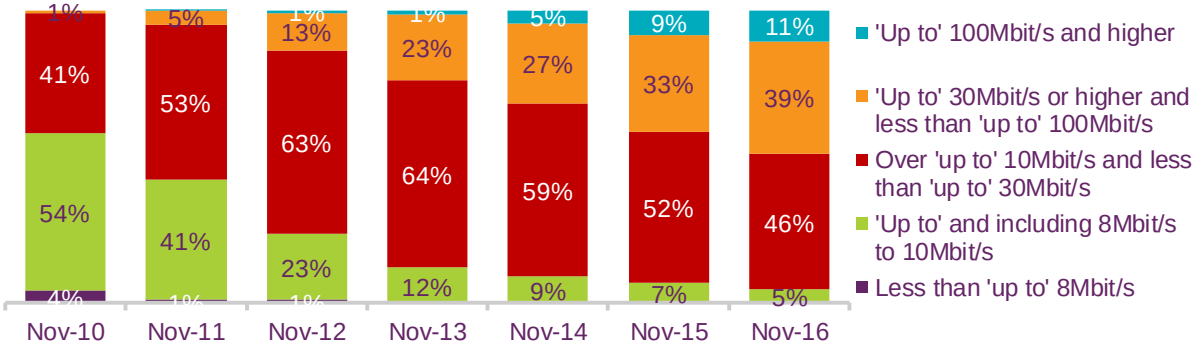


Source: Ofcom, using data provided by SamKnows; see note [1] in the sources section

Growing take-up of superfast products is driving average speed increases

- Continuing the trend from previous years, customers are upgrading to higher-speed broadband packages, including superfast services.
- In November 2016, 49% of connections had a headline speed of ‘up to’ 30Mbit/s or higher, while 11% had an advertised speed of ‘up to’ 100Mbit/s or higher.

Figure 2: UK residential broadband connections, by headline speed

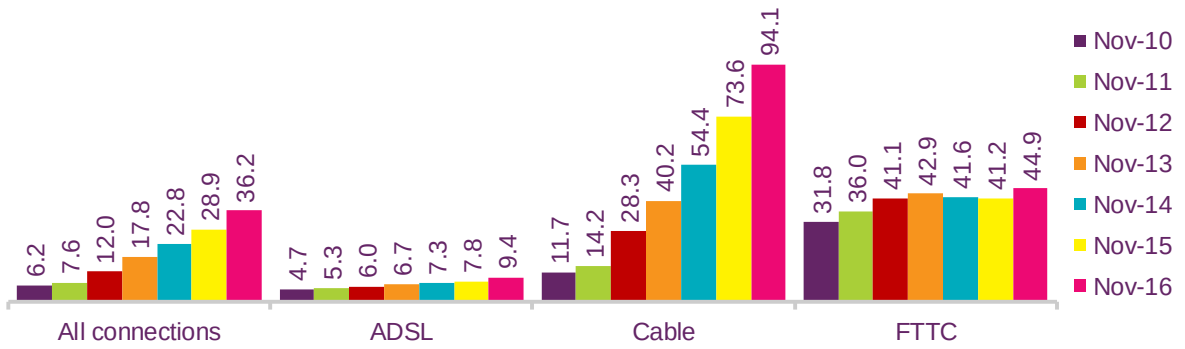


Source: Ofcom / operators; see note [2] in the sources section

Cable connections had the fastest average download speed in November 2016

- Our analysis indicates that the average download speed of ADSL, cable and FTTC connections all increased in the year to November 2016. Cable services had experienced the largest proportional increase during the year, up 28% to 94.1Mbit/s.
- This was than more than twice the average download speed achieved by FTTC services, which increased by 9% to 44.9Mbit/s over the same period.

Figure 3: Average download speeds for fixed broadband connections, all connections including 'up to' 2Mbit/s and less, by technology (Mbit/s)

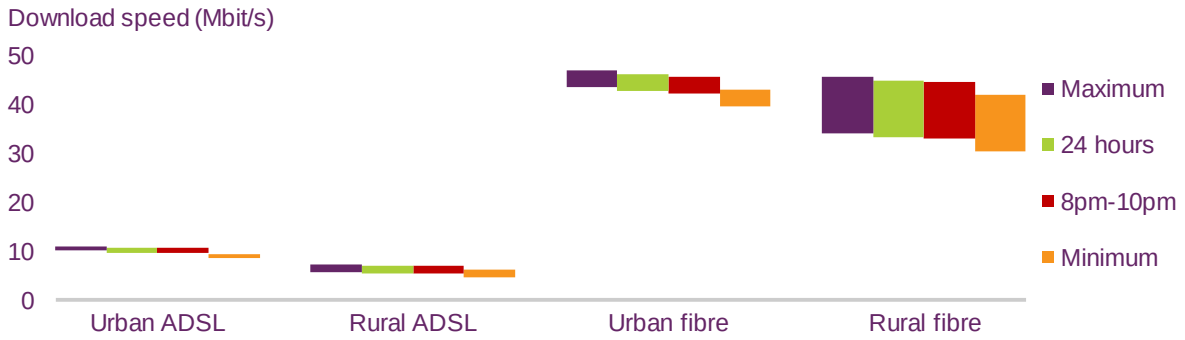


Source: Ofcom, using data provided by SamKnows; see note [3] in the sources section

Longer line lengths result in lower rural speeds for copper-based technologies…

- The 24-hour average download speeds for ADSL connections in urban and rural areas of the UK were 10.3Mbit/s and 6.3Mbit/s respectively in November 2016, while for urban and rural fibre connections they were 44.6Mbit/s and 39.2Mbit/s.
- Despite rural ADSL and fibre speeds tending to be being lower than urban ones, most rural ADSL customers will experience a significant increase in performance by upgrading from ADSL to a fibre service where it is available.

Figure 4: Average ADSL and fibre download speeds, by rurality: November 2016

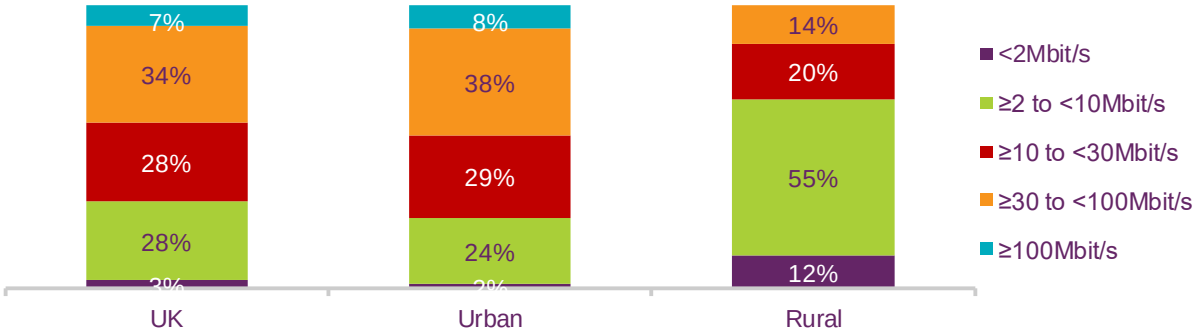


Source: Ofcom, using data provided by SamKnows; see note [4] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists within our sample) falls within the ranges shown

…which, combined with lower superfast availability, results in lower actual speeds

- Overall, 41% of UK broadband connections had a peak-time (8pm-10pm) average actual download speed of 30Mbit/s or higher in November 2016, compared to the 49% of connections which had an advertised speed of 30Mbit/s or higher, shown previously in this section.
- Thirty-one per cent of connections had a peak-time average actual speed of less than 10Mbit/s, compared to just 5% with an advertised speed of less than 10Mbit/s.[11]
- Forty-six per cent of panellists in urban areas received superfast download speeds at peak time in November 2016, compared to just 14% in rural areas.

Figure 5: Distribution of average 8-10pm peak-time fixed broadband download speeds, by rurality: November 2016



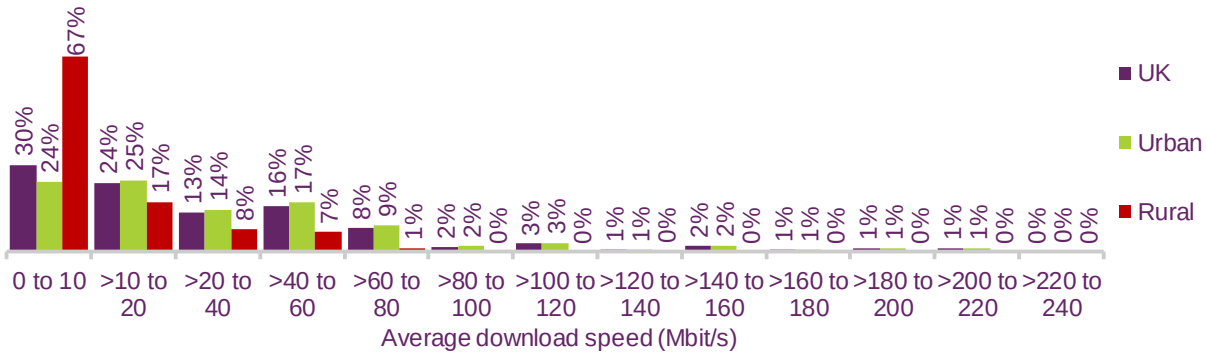
Source: Ofcom, using data provided by SamKnows; see note [5] in the sources section

Many rural consumers do not receive a decent broadband service

- Our research shows that in November 2016, two-thirds (67%) of panellists in rural areas of the UK received an average actual speed of less than 10Mbit/s, considered to be the speed which enables full participation in a digital society.
- This proportion was much higher than for the UK as a whole (30%) and in urban areas (24%).
- However, many rural and urban consumers would be able to achieve higher speeds by switching to fibre or cable services. Ofcom's *Connected Nations* report shows that 89% of UK premises, and 59% of rural premises, are in areas with access to superfast broadband.

[11] The Government aims to give people the right to request an affordable broadband connection, at a minimum speed, from a designated provider, up to a reasonable cost threshold.

Figure 6: Distribution of average fixed broadband download speeds, by rurality: November 2016

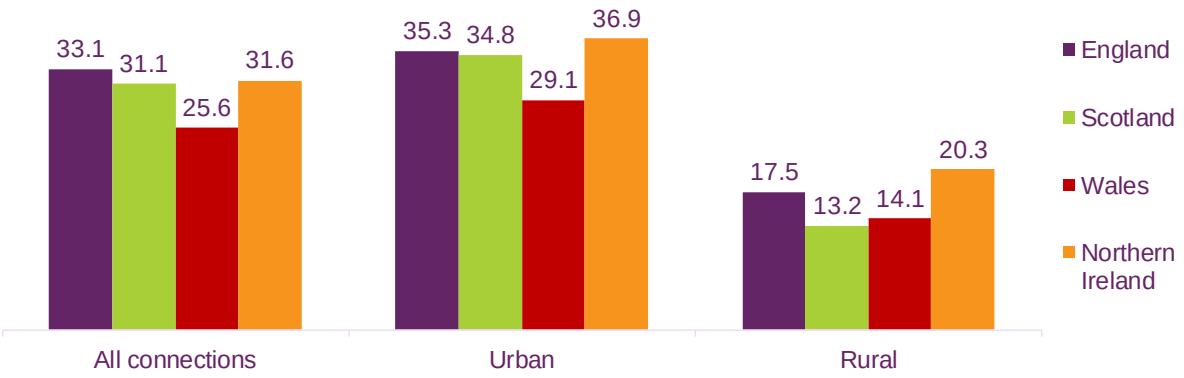


Source: Ofcom, using data provided by SamKnows; see note [5] in the sources section

Broadband performance varies across the UK nations

- Our research shows that, overall, England had the highest average fixed broadband download speed among the UK nations in November 2016, at 33.1Mbit/s.
- Northern Ireland had the highest average urban and rural download speeds, at 36.9Mbit/s and 20.3Mbit/s respectively, although it ranked second overall because a larger proportion of its population than the population of England live in rural areas.
- Wales recorded the lowest overall and urban speeds among the UK nations in November 2016, at 25.6Mbit/s and 29.1Mbit/s respectively, while Scotland had the lowest average download speed in rural areas, at 13.2Mbit/s.

Figure 7: Average download speeds, by UK nation: November 2016 (Mbit/s)

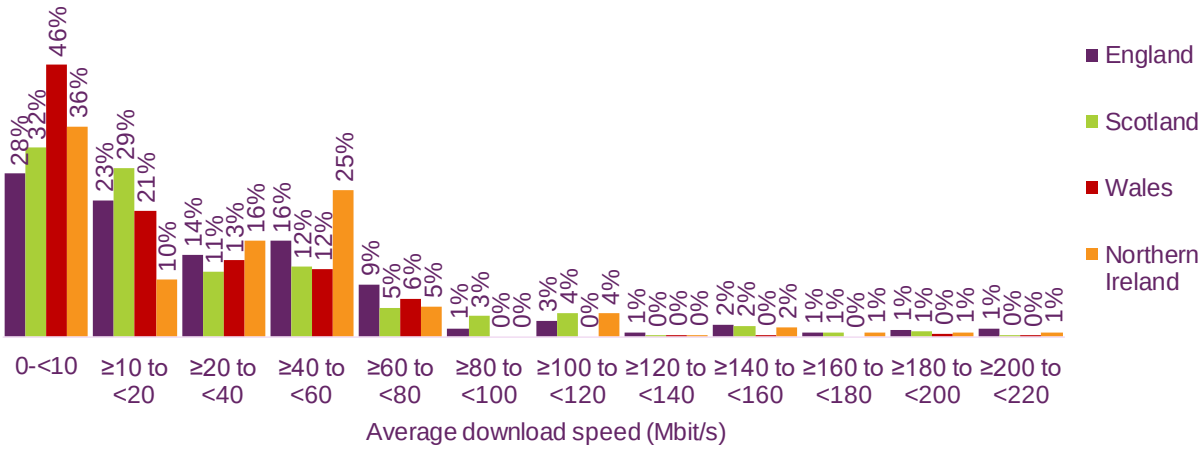


Source: Ofcom, using data provided by SamKnows; see note [6] in the sources section
Note: The additional weights used to calculate these figures means that they are not directly comparable to the UK average figures included elsewhere in this report.

Half of connections in Northern Ireland had an average speed of 30Mbit/s or higher

- Northern Ireland had the highest proportion of connections receiving an average speed of 30Mbit/s or higher in November 2016 (50%), compared to 46% in England, 37% in Scotland and 30% in Wales.
- Wales had the highest proportion of connections receiving an average download speed below 10Mbit/s in November 2016, at 46%, which compared to 36% of connections in Northern Ireland, 32% in Scotland and 28% in England.

Figure 8: Distribution of average fixed broadband download speeds, by nation

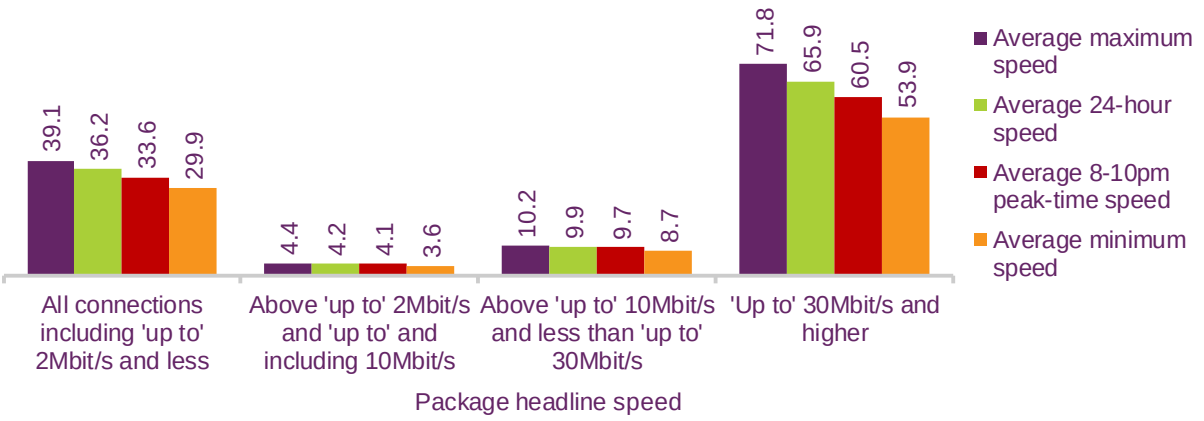


Source: Ofcom, using data provided by SamKnows; see note [6] in the sources section

Actual download speeds vary significantly during the day

- The performance of broadband services varies by time of the day, with speeds slowing down during busy periods when traffic volumes are highest.
- Across all connections, the average minimum speed (29.9Mbit/s) was 76% of the average maximum speed (39.1Mbit/s).
- The average download speed recorded during the 8pm-10pm peak-time period was 33.6Mbit/s, 86% of the average maximum speed.

Figure 9: Average UK fixed broadband download speeds: November 2016 (Mbit/s)



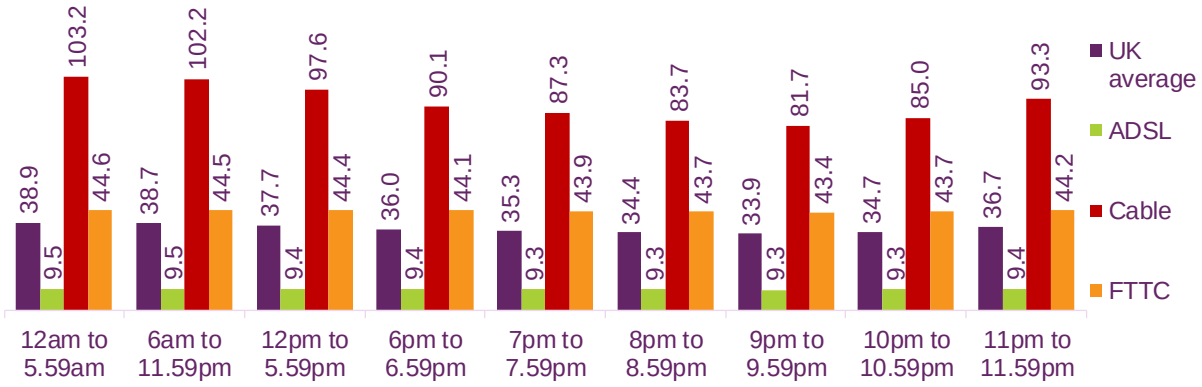
Source: Ofcom, using data provided by SamKnows; see note [1] in the sources section

The lowest average download speeds were recorded between 9pm and 10pm

- Our analysis suggests that the part of the day when broadband use is heaviest is between 9pm and 9.59pm, as this is when the lowest average download speeds were recorded for all technologies, giving an average of 33.9Mbit/s across all connection types.
- Similarly, the period when the highest average speeds for all three technologies were recorded was between 12am and 6am, when the UK average speed was 38.9Mbit/s.

- The data also show that while cable services suffer from contention to a greater degree than ADSL and FTTC (average cable speeds from 9pm to 9.59pm were 79% of those from midnight to 5.59am, compared to 97% for ADSL and FTTC), they still offered higher average speeds at all times of the day.

Figure 10: Variations in download speed by time of day: November 2016 (Mbit/s)



Source: Ofcom, using data provided by SamKnows; see note [3] in the sources section

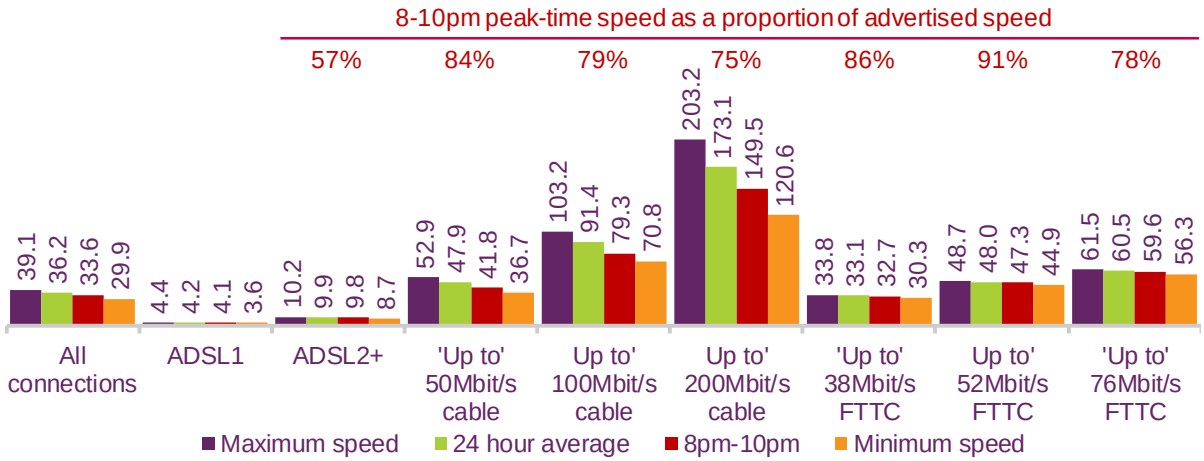
Some technologies suffer from slowdown more than others

There are two main reasons why the majority fixed broadband connections do not provide their headline (advertised) speed at all times of the day. For copper-based technologies such as ADSL and FTTC, the maximum speed that a line can support is dependent on the length and quality of the line from the end-user's home to the local exchange (ADSL) or street cabinet (FTTC). Current ASA guidelines require that the advertised speed is the maximum speed available to at least 10% of the customer base for a broadband service. It must be preceded by the words 'up to', and qualified where appropriate. While at least 10% of customers on a package must be able to receive its advertised speed, this means that, potentially, up to 90% of customers might not be able to receive it.

Additionally, the actual speeds of all connection types tend to fall at busy times, when ISPs' networks are busy. The variation in speeds at busy times is more notable for cable connections, due to cable network topologies, which mean that network congestion occurs nearer to the customer (in the access network rather than the backhaul network) making it more difficult (and expensive) to add the additional capacity required to alleviate the effects of congestion.

- Our research shows that 24-hour, peak-time and minimum download speeds were lower than the average maximum and advertised speeds for all connection types in November 2016.
- During the 8pm-10pm peak-time period, 'up to' 38Mbit/s, 52Mbit/s and 76Mbit/s FTTC services delivered 86%, 91% and 78% of their respective advertised speeds in November 2016.
- This compared to 84%, 79% and 75% for 'up to' 50Mbit/s, 100Mbit/s and 200Mbit/s cable services, respectively.
- ADSL2+ services, on average, achieved just 57% of the advertised speed during peak times.

Figure 11: Variations in download speed, by time of day: November 2016 (Mbit/s)

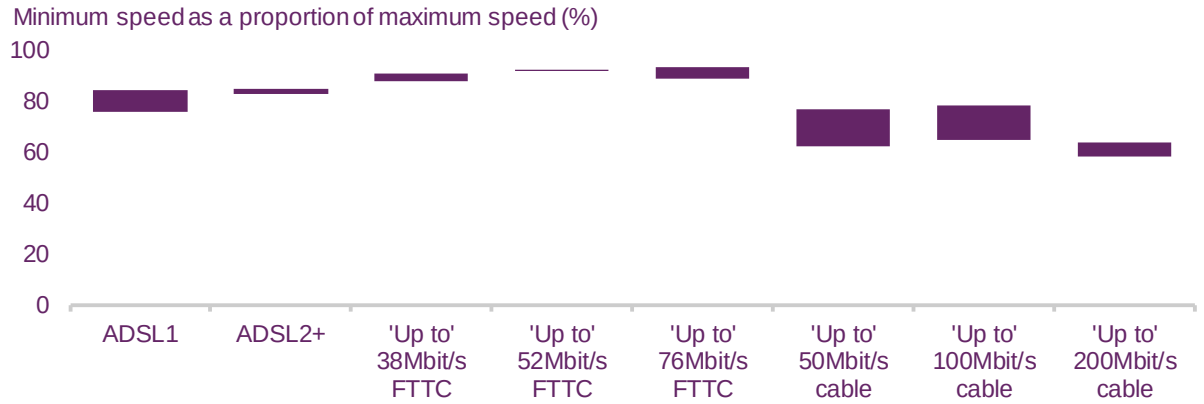


Source: Ofcom, using data provided by SamKnows; see note [7] in the sources section.

Contention varies by network technology

- We measure network contention (slowdown during busy periods) by comparing ISP packages' average minimum and maximum speeds, our assumption being that the main reason for any differences between the two is network congestion.
- For 'up to' 50Mbit/s, 100Mbit/s and 200Mbit/s cable services, the minimum download speeds were 70%, 71% and 61% of the average maximum speeds).
- For 'up to' 38Mbit/s, 52Mbit/s and 76Mbit/s FTTC services, the minimum download speed dropped to 89%, 92% and 91% of their maximum download speeds respectively, while for ADSL2+ services this proportion was 84%.

Figure 12: Minimum speed as a proportion of maximum speed: November 2016



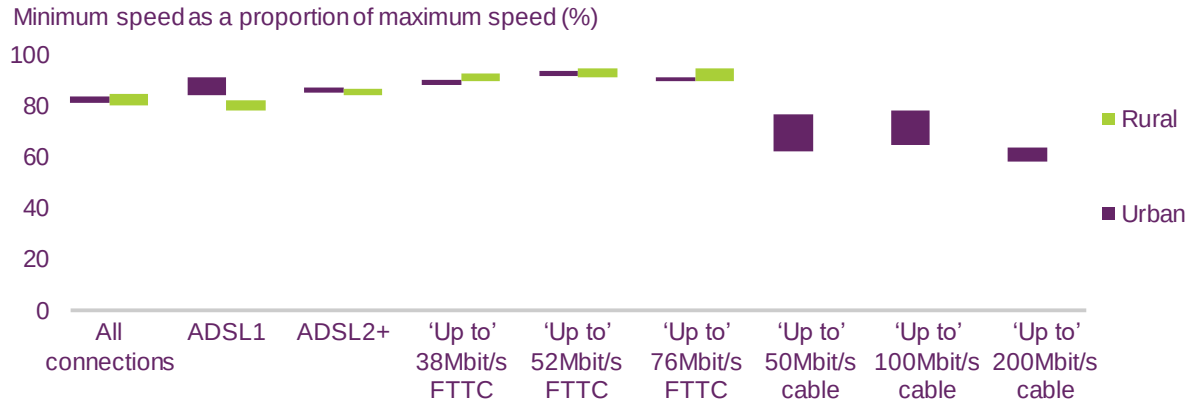
Source: Ofcom, using data provided by SamKnows; see note [8] in the sources section
Notes: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; where a panellist's maximum speed is higher than the advertised speed of their service, the advertised speed has been used to calculate the figures above.

Slowdown during busy periods is similar for urban and rural connections

- Overall, we found that there were no statistically significant differences between contention in urban and rural areas of the UK in November 2016.

- The only technology for which there was a difference in contention levels was for ADSL1; its performance was better in urban areas than in rural ones.

Figure 13: Minimum speed as a proportion of maximum speed, by rurality: November 2016

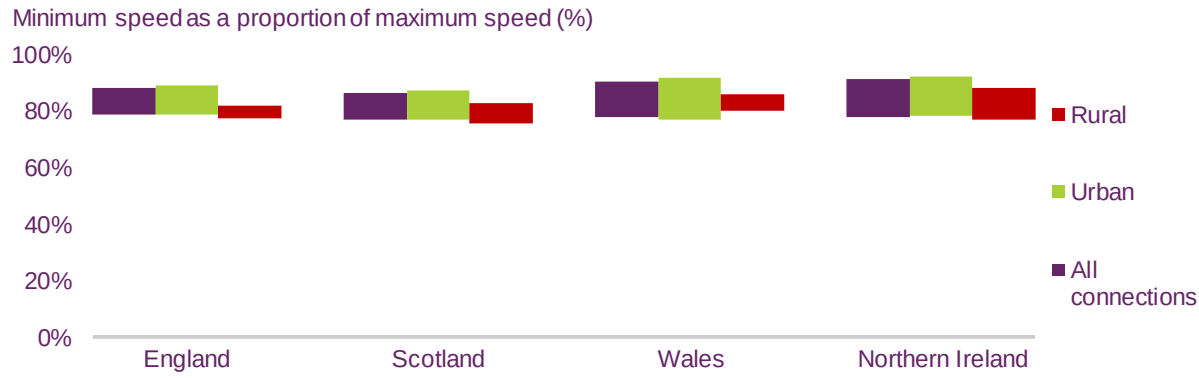


Source: Ofcom, using data provided by SamKnows; see note [9] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; where a panellist's maximum speed is higher than the advertised speed of their service, the advertised speed has been used to calculate the figures above.

The effects of contention are equally evident across the UK nations

- Our analysis also finds that there were no statistically significant differences in levels of contention between the UK nations in November 2016.
- This was the case overall, and when comparing contention in urban and rural areas of each nation.

Figure 14: Minimum speeds as a proportion of maximum speed, by UK nation: November 2016



Source: Ofcom, using data provided by SamKnows; see note [10] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown.

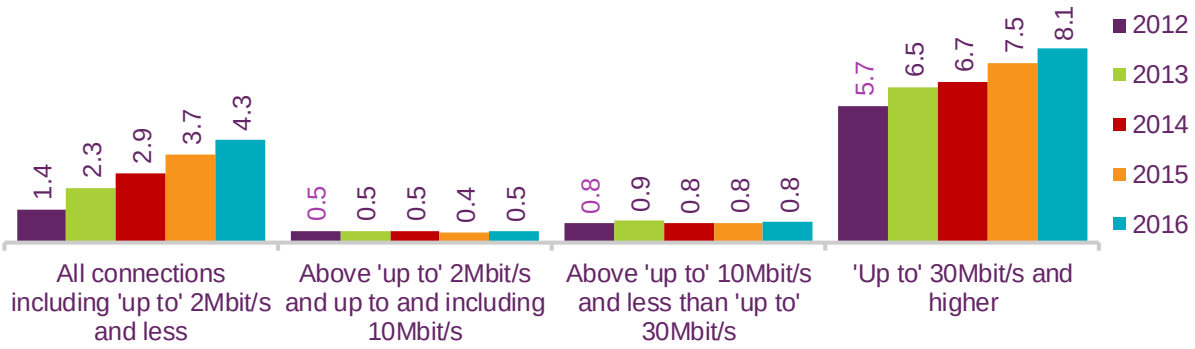
Upload speeds

Upload speeds are important to users who use real-time video communication services, or who need to upload or share files.

The UK average upload speed increased by 16% in the year to November 2016

- The average upload speed of UK residential fixed broadband services increased by 0.6Mbit/s (16%) to 4.3Mbit/s in the year to November 2016.
- Over the same period, the average upload speed of 'up to' 30Mbit/s or higher services increased to 8.1Mbit/s from 7.5Mbit/s.

Figure 15: Average UK fixed broadband upload speeds (Mbit/s)

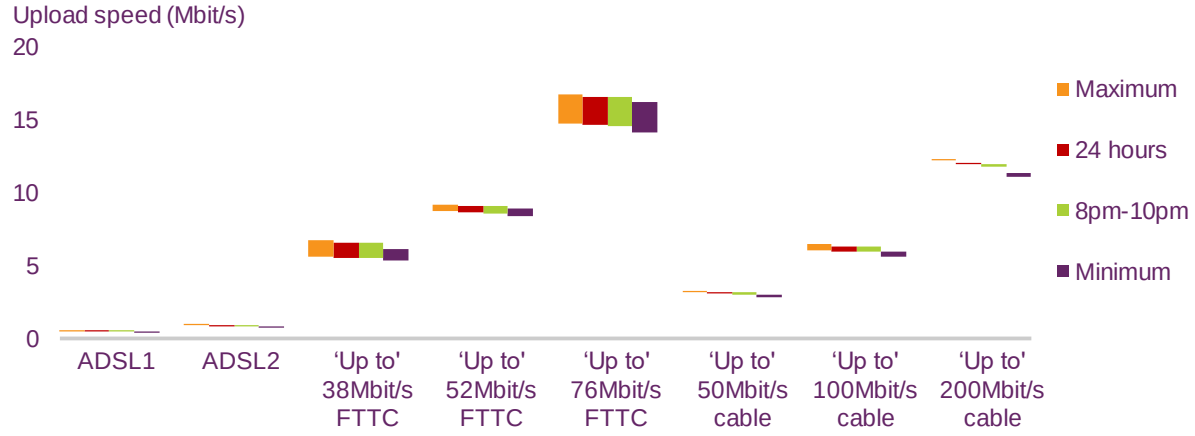


Source: Ofcom, using data provided by SamKnows; see note [11] in the sources section

Upload speeds vary widely by technology and speed tier

- There is significant variation in upload speeds between technology and service tiers.
- Average upload speeds were highest for 'up to' 76Mbit/s FTTC services, in the 24-hour and 8-10pm peak-time periods, both at 15.6Mbit/s. This was followed by 'up to' 200Mbit/s cable services, at 12.0Mbit/s and 11.9Mbit/s respectively.
- For FTTC connections, the 24-hour average upload speeds of 'up to' 38Mbit/s and 'up to' 52Mbit/s services were 6.1Mbit/s and 8.9Mbit/s.

Figure 16: Maximum, average, peak-time and minimum upload speeds, by technology and service tier: November 2016



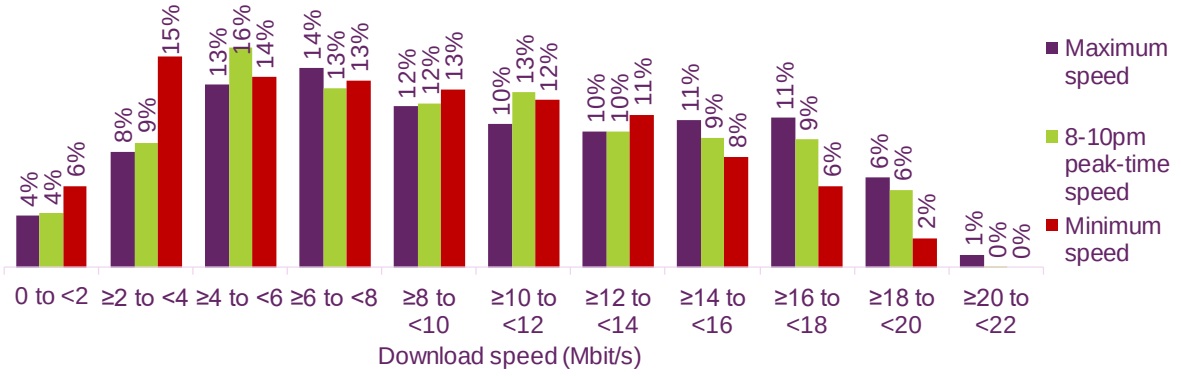
Source: Ofcom, using data provided by SamKnows; see note [12] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown.

Distribution of download speeds

Broadband speed received is influenced by the underlying technology of the service

- For ADSL2+ packages, more than half of panellists (51%) received a maximum speed below 10Mbit/s in November 2016.
- Around 61% of ADSL2+ panellists received a minimum speed below 10Mbit/s, while 53% had an average 8pm-10pm peak-time speed of less than 10Mbit/s.

Figure 17: Distribution of maximum, 8-10pm peak-time and minimum download speeds for ADSL2+ packages

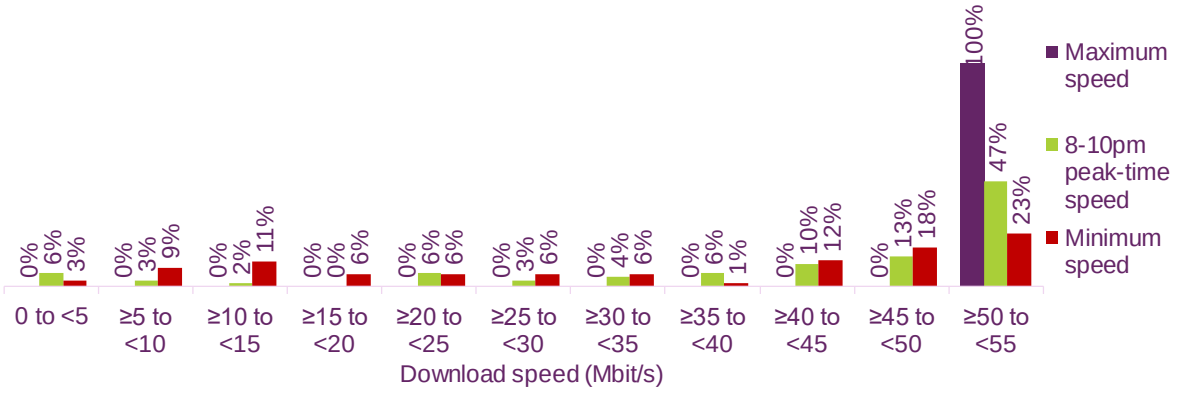


Source: Ofcom, using data provided by SamKnows; see note [13] in the sources section

Distribution of 'up to' 50Mbit/s cable connections' maximum, peak-time and minimum speeds

- Our research shows that there is more variation in minimum cable speeds than there is for either ADSL2+ or FTTC services, which is partly because the topology of cable networks makes them more susceptible to contention at peak times.
- For 'up to' 50Mbit/s cable connections, all panellists achieved a maximum speed greater than the service's headline speed, but only 23% received a similar minimum speed.
- Eleven per cent of 'up to' 50Mbit/s cable lines received a minimum speed of less than 10Mbit/s, while 9% had an average 8pm-10pm peak-time speed of less than 10Mbit/s.

Figure 18: Distribution of maximum, peak-time and minimum download speeds for 'up to' 50Mbit/s cable connections

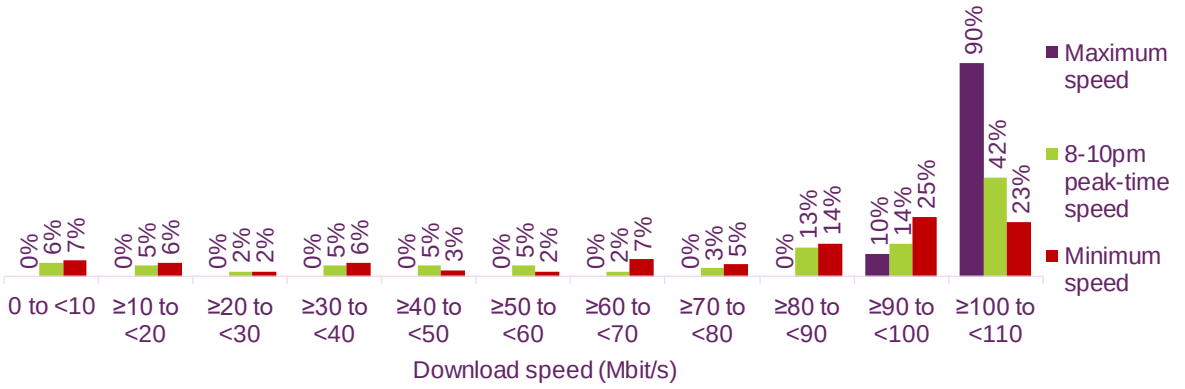


Source: Ofcom, using data provided by SamKnows; see note [14] in the sources section

Distribution of 'up to' 100Mbit/s cable connections' maximum, peak-time and minimum speeds

- For 'up to' 100Mbit/s cable connections, 90% of the panellists achieved maximum speed greater than headline speed.
- Seven per cent of 'up to' 100Mbit/s cable panellists received a minimum speed of less than 10Mbit/s, while 6% had an average 8pm-10pm peak-time speed of less than 10Mbit/s.
- Twenty-three per cent of 'up to' 100Mbit/s cable panellists received a minimum speed greater than the headline speed.

Figure 19: Distribution of maximum, peak-time and minimum download speeds for 'up to' 100Mbit/s cable connections

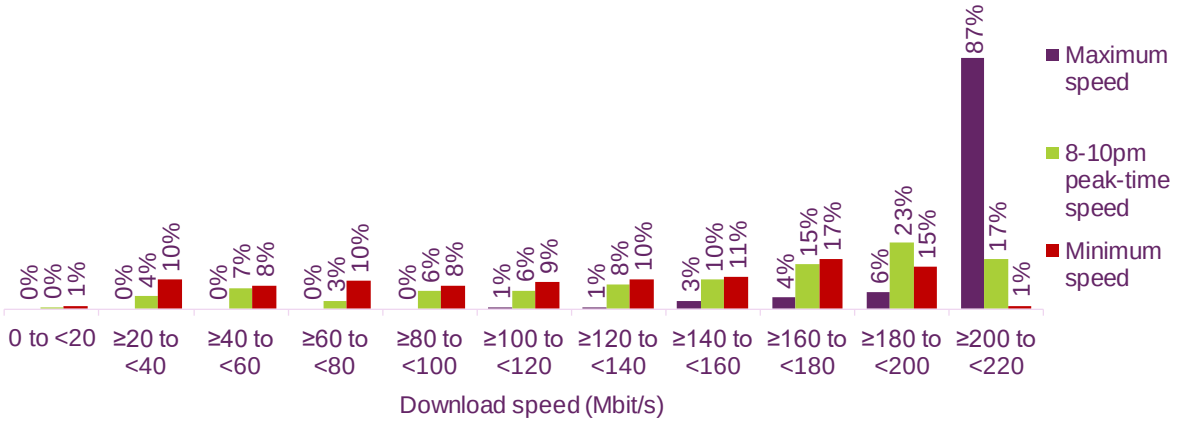


Source: Ofcom, using data provided by SamKnows; see note [15] in the sources section

Distribution of 'up to' 200Mbit/s cable connections' maximum, peak-time and minimum speeds

- For 'up to' 200Mbit/s cable connections, 87% of panellists achieved a maximum speed greater than the headline speed.
- Sixty-two per cent of 'up to' 200Mbit/s cable panellists received minimum speeds of less than 75% of the headline speed, while 1% received a minimum speed greater than the headline speed.

Figure 20: Distribution of maximum, peak-time and minimum download speeds for 'up to' 200Mbit/s cable connections

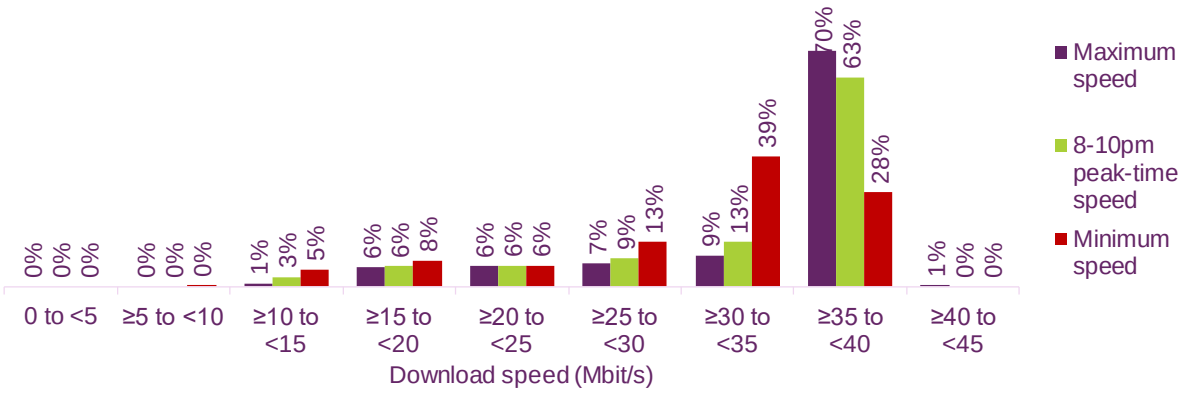


Source: Ofcom, using data provided by SamKnows; see note [16] in the sources section

Distribution of 'up to' 38Mbit/s FTTC connections' maximum, peak-time and minimum speeds

- For 'up to' 38Mbit/s FTTC connections, 84% of panellists achieved a maximum speed within 25% of the headline speed.
- The minimum speed distribution for FTTC services is much narrower than that of cable services, as FTTC networks do not currently suffer from contention to the same degree as cable services.
- Less than 1% of panellists receive a minimum speed of less than 10Mbit/s, and 75% of the panellists received a minimum speed within 25% of the headline speed.

Figure 21: Distribution of maximum, peak-time and minimum download speeds for 'up to' 38Mbit/s FTTC connections

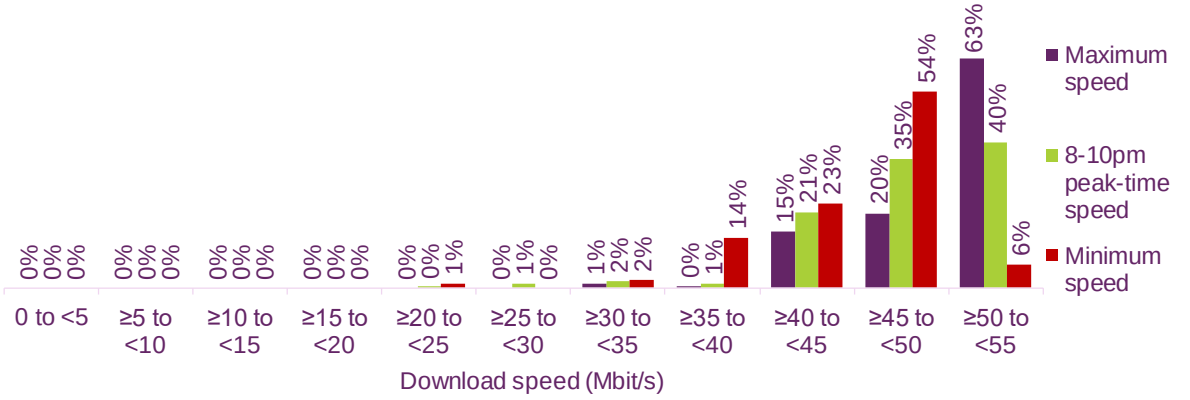


Source: Ofcom, using data provided by SamKnows; see note [17] in the sources section

Distribution of 'up to' 52Mbit/s FTTC connections' maximum, peak-time and minimum speeds

- For 'up to' 52Mbit/s FTTC connections, 86% of panellists achieved a maximum speed within 25% of the headline speed.
- None of the panellists received a minimum speed of less than 10Mbit/s, and 99% of panellists received a minimum speed greater than 30Mbit/s.

Figure 22: Distribution of maximum, peak-time and minimum download speeds for 'up to' 52Mbit/s FTTC connections

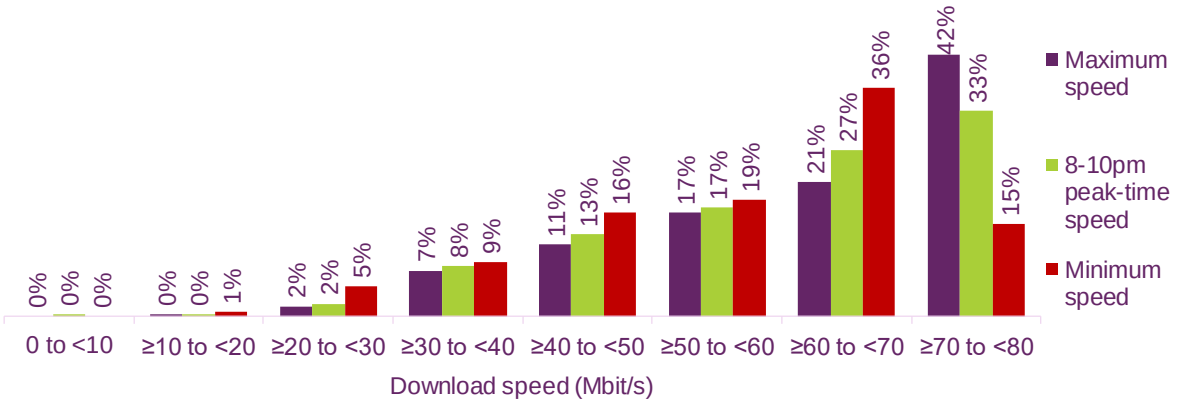


Source: Ofcom, using data provided by SamKnows; see note [18] in the sources section

Distribution of 'up to' 76Mbit/s FTTC connections' maximum, peak-time and minimum speeds

- For 'up to' 76Mbit/s FTTC connections, 65% of panellists achieved a maximum speed within 25% of the headline speed.
- None of the panellists received a minimum speed of less than 10Mbit/s, and 60% of the panellists received minimum speeds within 75% of the headline speed.

Figure 23: Distribution of maximum, peak-time and minimum download speeds for 'up to' 76Mbit/s FTTC connections



Source: Ofcom, using data provided by SamKnows; see note [19] in the sources section measurement data for panel members with a connection in November 2016.
Notes: Data collected from multi-thread download speed tests

Section 5

Netflix streaming performance

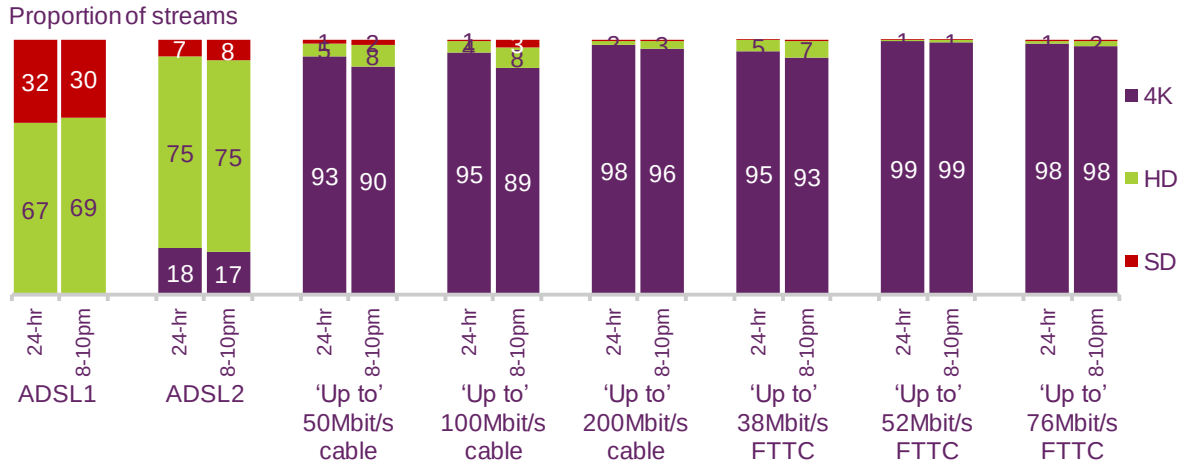
Video streaming services have become increasingly popular over the last few years, and the streaming of video content is one of the most capacity-hungry activities that consumers use their broadband connection for. To understand how well various fixed broadband connection types handle the streaming of video content, we measure the streaming performance of broadband connections when accessing content from Netflix.[12]

The charts below show the proportions of Netflix video streams that were delivered in the most commonly available resolutions: standard definition (SD), high definition (HD) and ultra-high definition (4K) for each connection type. It should be noted that these results represent a case where only one user is streaming on a broadband connection, and the streaming quality that can be reliably achieved may drop when multiple users are simultaneously using the same connection.

In most cases, superfast products can stream Netflix videos at 4K resolution

- More than 90% of FTTC and cable Netflix video streams were delivered at 4K resolution during the 8pm-10pm peak-time period, except for 'up to' 100Mbit/s cable services.
- Over the 24-hour period, 'up to' 100Mbit/s cable services achieved 4K resolution for more than 90% of the streams, although the numbers dropped to 89% at peak times.
- For ADSL2+ services, 93% of Netflix videos were streamed at HD or 4K resolution, and 92% during the 8-10pm peak-time period.

Figure 24: Proportion of Netflix videos reliably delivered at the given video quality over 24 hours and at peak times, by technology (%)



Source: Ofcom, using data provided by SamKnows; see note [20] in the sources section

[12] We have suspended BBC iPlayer streaming testing, as new TV licence rules introduced in 2016 mean that a TV licence is required to download or watch almost all on-demand and catch-up iPlayer content. We have excluded YouTube test results, which were in the report covering November 2015, from this report, as not all YouTube streams are available in 4K, meaning that the results are not as informative as those for Netflix, for which all of the content used in testing is available in 4K.

Section 6

Disconnections

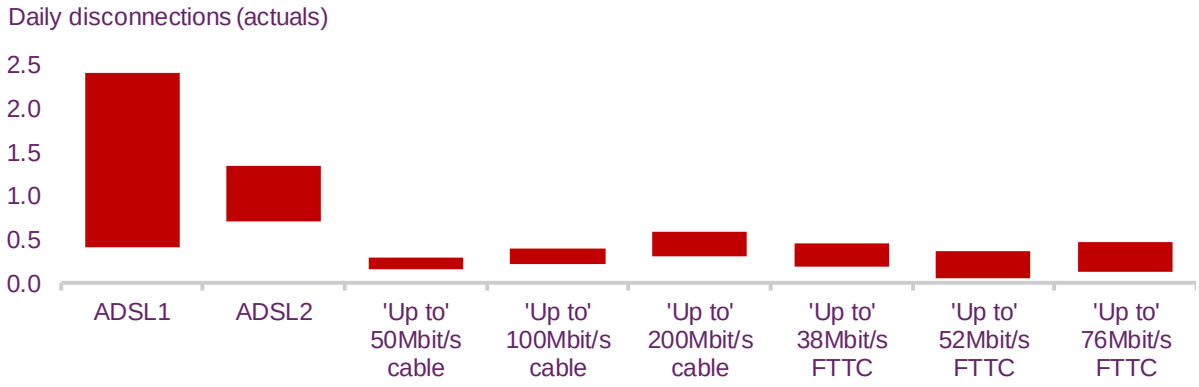
The average daily disconnections metric measures the frequency of broadband service disconnections lasting longer than 30 seconds.

Users cannot undertake any online activities when their service loses internet connectivity, and interruptions to the fixed broadband service can be inconvenient and frustrating for users.

Superfast products tend to suffer from fewer disconnections than standard services

- We tested very frequently, running an average of around 5,200 tests every day, and found that disconnections for longer than 30-seconds were rare across all technologies.
- Our research shows that ADSL services tend to suffer from more frequent disconnections of 30 seconds or longer than cable and FTTC services.
- In November 2016, ADSL connections had an average of 1.1 disconnections of 30 seconds or longer per day (1.4 for ADSL1 and 1.0 for ADSL2+) compared to an average of 0.3 across the cable and FTTC services included in the analysis.

Figure 25: Average daily disconnections (30 seconds or longer). (Lower values indicate better performance)



Source: Ofcom, using data provided by SamKnows; see note [21] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown.

Section 7

Performance by internet service provider (ISP) package

Background

This section sets out the performance of individual ISP packages in terms of their connection speed, comparing the average maximum, peak-time, 24-hour and minimum download and upload speeds of ADSL2+, cable and fibre-to-the-cabinet (FTTC) ISP packages. With the assistance of BT and KCOM, we undertook additional recruitment of FTTP users prior to the November 2016 measurement period, although we were unable to add sufficient panellists to include any FTTP packages in this report.

Apart from connections provided by KCOM, the incumbent provider in Kingston upon Hull, all ADSL2+ and FTTC packages included in the report are provided over the BT copper line from the local exchange/street cabinet to the end-user's home. This means it is unlikely that consumers will experience a substantial increase in the performance of their service by switching from one ADSL2+ package to another, or from one FTTC package to a similar one, unless the speed of their existing service is being limited by factors within their ISP's control, such as network congestion or the ADSL line configurations in their systems.

Presentation of results

All results are presented in terms of bars showing the 95% confidence interval. This means that there is a 95% probability that the actual average performance for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown.

The sample size for each group, and the variation of performance among panellists within the same group, combine to determine the size of the bars. We must emphasise that these bars indicate the average (mean) performance rather than the range of performance delivered. The sampling and statistical methodologies have been designed to allow us to compare ISP packages on a like-for-like basis. For details, see the research methodology set out in Annex 1 and the statistical methodology set out in Annex 2.

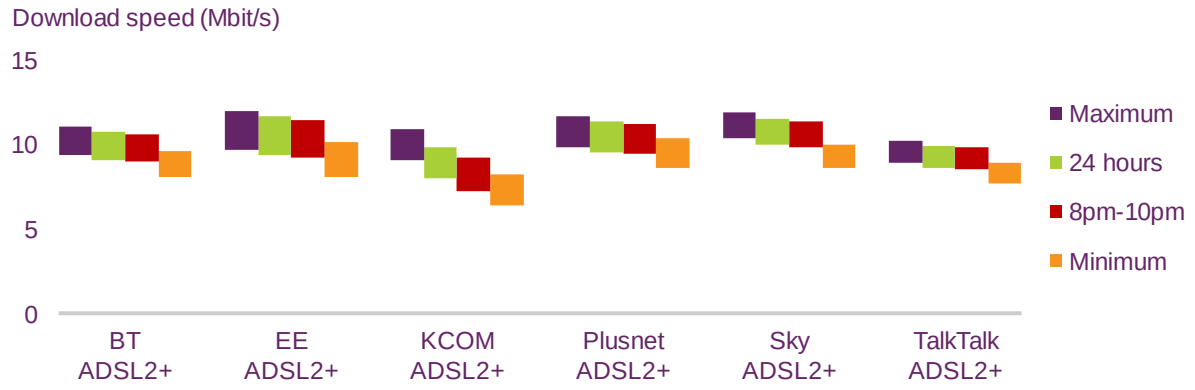
ADSL2+ connections: download speeds

The main variable affecting the speeds delivered by ADSL2+ is the distance from the exchange to the end-user's premises, over which the ISP has no control. Therefore, when looking at fixed-line broadband speeds, we exclude premises that are more than 5km from the local exchange, and we normalise the test results by distance from the exchange, to enable a like-for-like comparison of ISP packages. Further information on how we do this can be found in Annex 2 of this report.

Variation in performance of ADSL2+ packages

- The average actual 24-hour download speed of the ADSL2+ ISP packages included in our report ranged from 9.0Mbit/s for KCOM's service to 10.8Mbit/s for Sky's.
- The highest drop in minimum speed was observed for KCOM's ADSL2+ service, where the 8-10pm peak-time speed was 73% of the maximum speed.

Figure 26: Maximum, average, peak-time and minimum download speeds for ADSL2+ ISP packages, and significant differences, to a 95% level of confidence



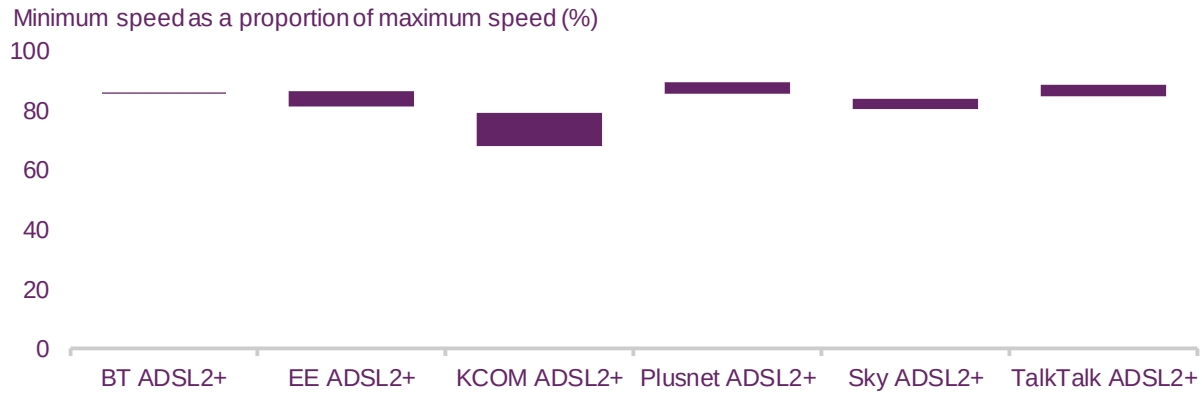
	Maximum	24-hour average	8pm-10pm	Minimum
ISP Package	**was faster than...**	**was faster than...**	**was faster than...**	**was faster than...**
Sky	TalkTalk*	TalkTalk* & KCOM*	TalkTalk* & KCOM	KCOM*
Plusnet	No differences	No differences	KCOM*	KCOM*

Source: Ofcom, using data provided by SamKnows; see note [22] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; the table shows significant differences to a 95% confidence level; an asterisk (*) denotes that a difference is not significant to a (higher) 99% level of confidence.

Contention in ADSL2+ connections

- We measure contention by comparing average minimum and maximum speeds, which enables us to compare connection slowdowns during the day.
- KCOM's ADSL2+ service had the highest level of contention with minimum speeds at 74% of the maximum speeds.

Figure 27: Minimum speed as a proportion of maximum speed for ADSL2+ ISP packages, and significant differences, to a 95% level of confidence: November 2016



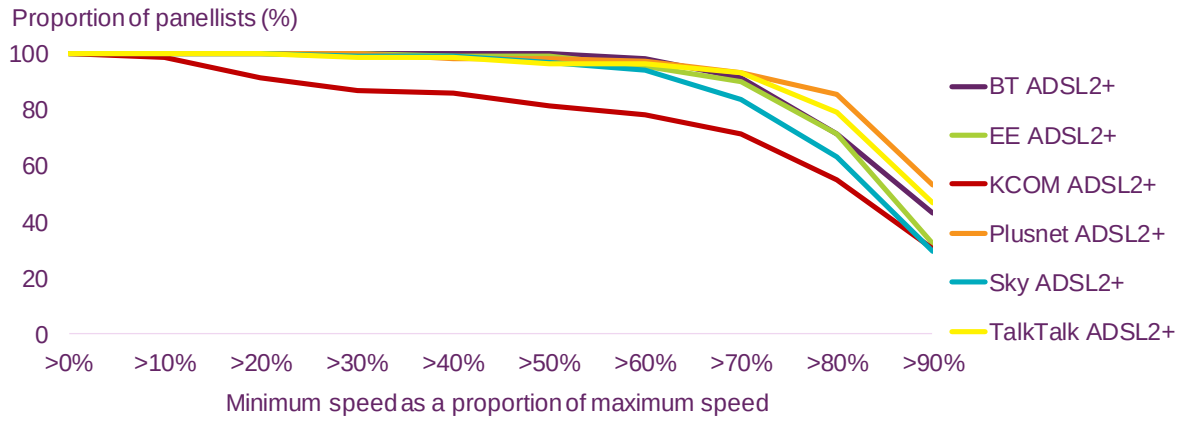
ISP Package	performed better than...
Plusnet	BT*, Sky, KCOM
TalkTalk	Sky*, KCOM
BT	Sky, KCOM
EE	KCOM*
Sky	KCOM*

Source: Ofcom, using data provided by SamKnows; see note [22] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; where a panellist's maximum speed is higher than the advertised speed of their service, the advertised speed has been used to calculate the figures above; the table shows significant differences to a 95% confidence level; an asterisk (*) denotes that a difference is not significant to a (higher) 99% level of confidence.

Distribution of contention for ADSL2+ connections

- Among the ADSL2+ ISP packages included in our analysis, the proportion of panellists whose connection had a minimum speed that was more than 90% of its maximum speed ranged from 29% for Sky's service to 53% for Plusnet's service.
- The proportion of panellists whose connection had a minimum speed that was less than half its maximum speed ranged from 0% for BT's ADSL2+ service to 18% for KCOM's.

Figure 28: Distribution of average minimum speed as a proportion of maximum speed for ADSL2+ ISP packages



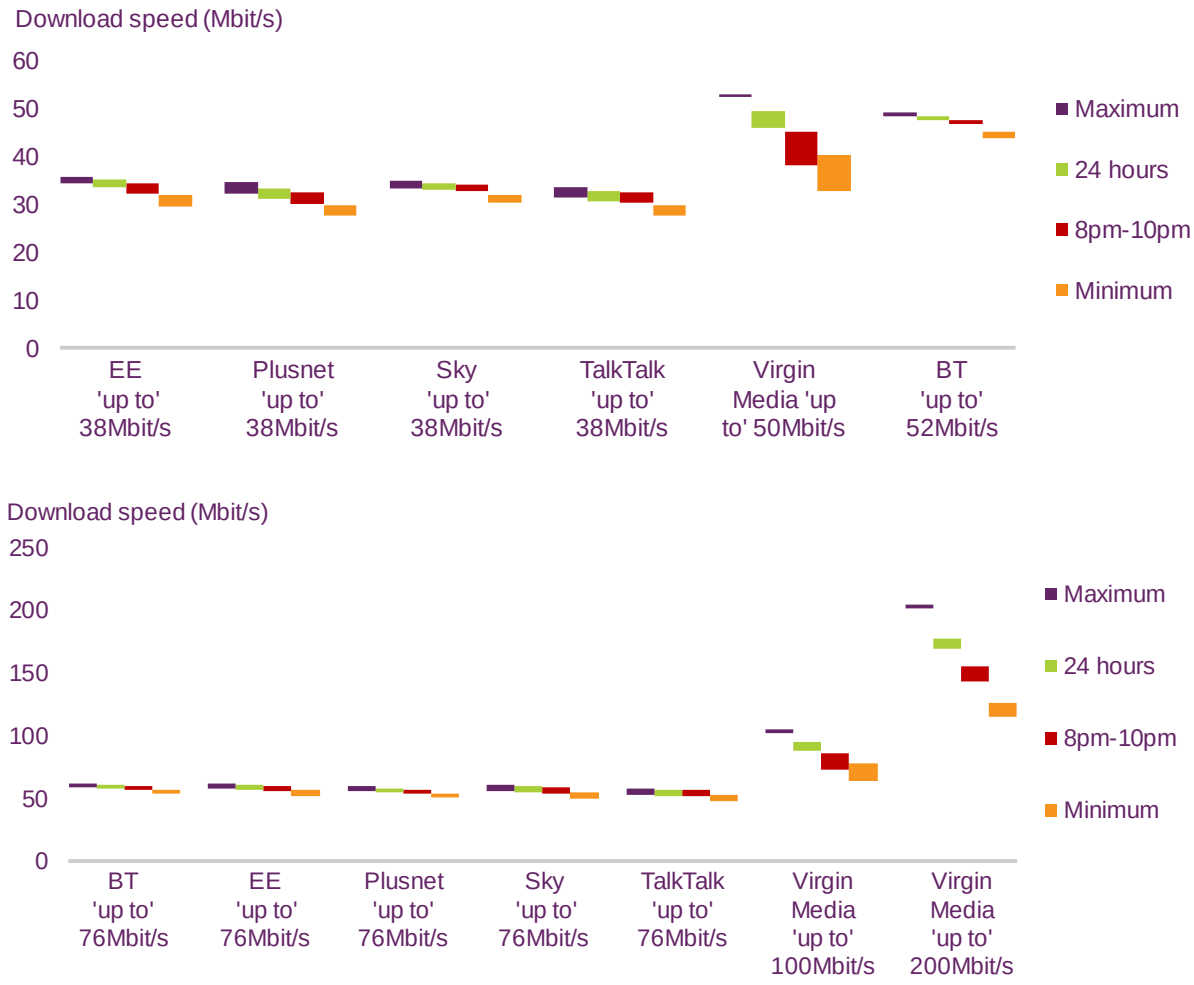
Source: Ofcom, using data provided by SamKnows; see note [23] in the sources section
Note: Where a panellist's maximum speed is higher than the advertised speed of their service, the advertised speed has been used to calculate the figures above.

Variation in performance of superfast broadband packages

- Our research indicates that for all FTTC packages, the 24-hour average and peak-time average download speeds do not vary much from their maximum speeds.
- For all FTTC packages, the 24-hour average speed is within 1% to 4% of their maximum speed and the peak time average download speeds drops by 2% to 5% when compared to their maximum speed.
- For cable packages, the maximum speed was higher than for FTTC packages in comparable service tiers. However, our research indicates that the 24-hour average, peak-time average and minimum speed showed more variation than did FTTC

packages. The peak-time speeds for cable packages was within 21% to 26% of their headline speeds.

Figure 29: Maximum, average, peak-time and minimum download speeds for 'up to' 30Mbit/s and above ISP packages and significant differences, to a 95% level of confidence: November 2016



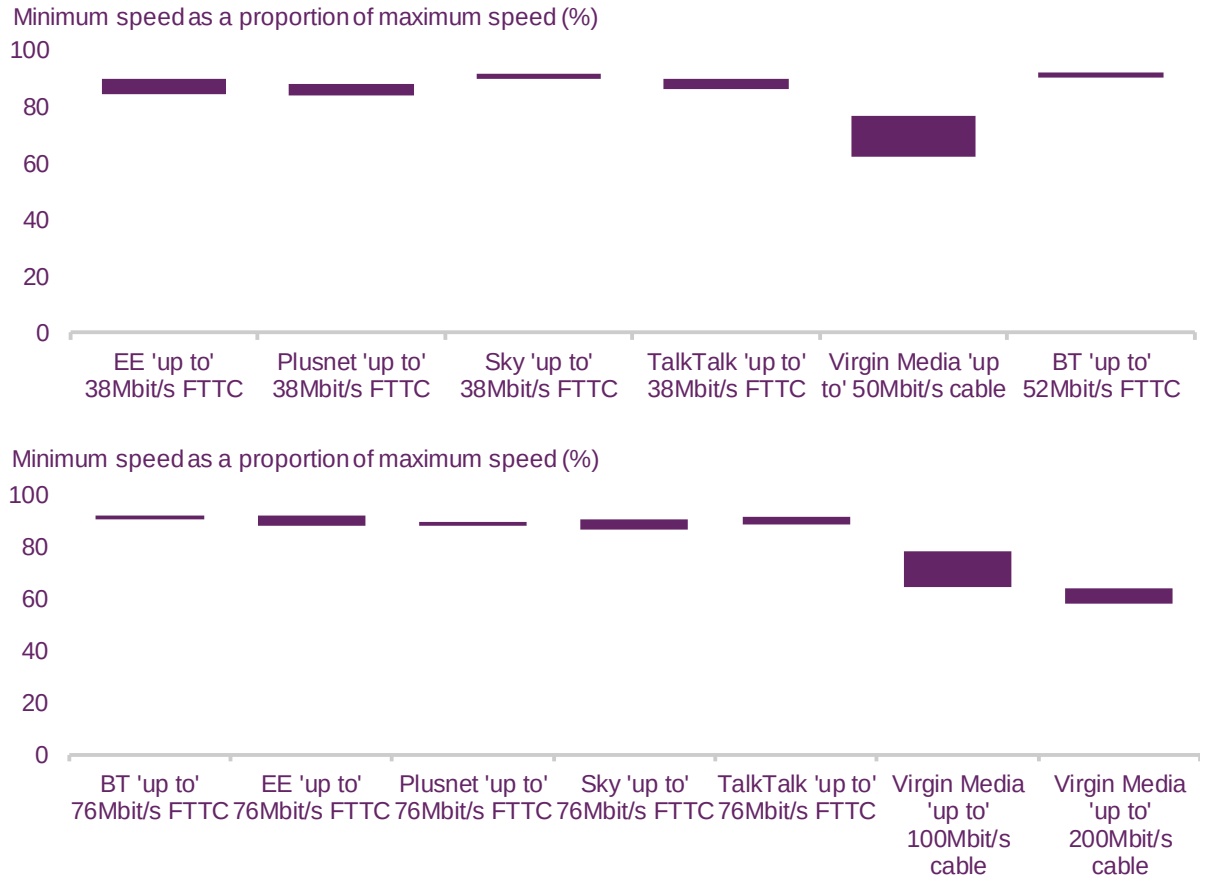
	Maximum	24-hour average	8pm-10pm	Minimum
ISP Package	**was faster than...**	**was faster than...**	**was faster than...**	**was faster than...**
Virgin Media 'up to' 200Mbit/s cable	VM100, BT76, EE76, Sky76, PN76, TT76, VM50, BT52, EE38, Sky38, PN38, TT38	VM100, BT76, EE76, Sky76, PN76, TT76, BT52, VM50, E 38, Sky38, PN38, TT38	VM100, BT76, EE76, Sky76, TT76, PN76, BT52, VM50, Sky38, EE38, PN38, TT38	VM100, BT76, EE76, PN76, Sky 76, TT76, BT52, VM50, Sky38, EE38, TT38, PN38
Virgin Media 'up to' 100Mbit/s cable	BT76, EE76, Sky76, PN76, TT76, VM50, BT52, EE38, Sky38, PN38, TT38	BT76, EE76, Sky76, PN76, TT76, BT52, VM50, EE38, Sky38, PN38, TT38	BT76, EE76, Sky76, TT76, PN76, BT52, VM50, Sky38, EE38, PN38, TT38	BT76, EE76, PN76, Sky 76, TT76, BT52, VM50, Sky38, EE38, TT38, PN38
BT 'up to' 76Mbit/s FTTC	VM50, BT52, EE38, Sky38, PN38, TT38	PN76,* TT76*, BT52, VM50, EE38, Sky38, PN38, TT38	PN76*, BT52, VM50, Sky38, EE38, PN38, TT38	PN76,* TT76,* BT52, VM50, Sky38, EE38, TT38, PN38
EE 'up to' 76Mbit/s FTTC	VM50, BT52, EE38, Sky38, PN38, TT38	BT52, VM50, EE38, Sky38, PN38, TT38	BT52, VM50, Sky38, EE38, PN38, TT38	BT52, VM50, Sky38, EE38, TT38, PN38
Sky 'up to' 76Mbit/s FTTC	VM50, BT52, EE38, Sky38, PN38, TT38	BT 52, VM50, EE38, Sky38, PN38, TT38	BT52, VM50, Sky38, EE38, PN38, TT38	BT52, VM50, Sky38, EE38, TT38, PN38
Plusnet 'up to' 76Mbit/s FTTC	VM50, BT52, EE38, Sky38, PN38, TT38	BT 52, VM50, EE38, Sky38, PN38, TT38	BT52, VM50, Sky38, EE38, PN38, TT38	BT52, VM50, Sky38, EE38, TT38, PN38
TalkTalk 'up to' 76Mbit/s FTTC	BT52, EE38, Sky38, PN38, TT38	BT52, VM50, EE38, Sky38, PN38, TT38	BT52, VM50, Sky38, EE38, PN38, TT38	BT52, VM50, Sky38, EE38, TT38, PN38
BT 'up to' 52Mbit/s FTTC	EE38, Sky38, PN38, TT38	EE38, Sky38, PN38, TT38	VM50, Sky38, EE38, PN38, TT38	VM50, Sky38, EE38, TT38, PN38
Virgin Media 'up to' 50Mbit/s cable	BT52, EE38, Sky38, PN38, TT38	EE38, Sky38, PN38, TT38	Sky38, EE38, PN38, TT38	Sky38,* EE38,* TT38, PN38
EE 'up to' 38Mbit/s FTTC	TT38	PN38,* TT38	No differences	No differences
Sky 'up to' 38Mbit/s FTTC	No differences	TT38*	No differences	No differences

Source: Ofcom, using data provided by SamKnows; see note [24 & [25]] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; the table shows significant differences to a 95% confidence level; an asterisk (*) denotes that a difference is not significant to a (higher) 99% level of confidence.

Contention in superfast broadband services

- Cable services had higher levels of contention in their network compared to FTTC services.
- The minimum speeds for FTTC packages were between 9% and 14% lower than their maximum speeds.
- The minimum speeds for cable services were between 29% and 39% lower than their maximum speeds.

Figure 30: Minimum speed as a proportion of maximum speed for 'up to' 30Mbit/s and above ISP packages, and significant differences, to a 95% level of confidence: November 2016



ISP Package	performed better than...
BT 'up to' 76Mbit/s FTTC	Plusnet 76*, TalkTalk 38*, EE 38*, Plusnet 38, Virgin Media 100, Virgin Media 50, Virgin Media 200
BT 'up to' 52Mbit/s FTTC	Plusnet 76*, TalkTalk 38*, EE 38*, Plusnet 38, Virgin Media 100, Virgin Media 50, Virgin Media 200
Sky 'up to' 38Mbit/s FTTC	Plusnet 38, Virgin Media 100, Virgin Media 50, Virgin Media 200
TalkTalk 'up to' 76Mbit/s FTTC	Plusnet 38*, Virgin Media 100, Virgin Media 50, Virgin Media 200
EE 'up to' 76Mbit/s FTTC	Virgin Media 100, Virgin Media 50, Virgin Media 200
Plusnet 'up to' 76Mbit/s FTTC	Virgin Media 100, Virgin Media 50, Virgin Media 200
Sky 'up to' 76Mbit/s FTTC	Virgin Media 100, Virgin Media 50, Virgin Media 200
TalkTalk 'up to' 38Mbit/s FTTC	Virgin Media 100, Virgin Media 50, Virgin Media 200
EE 'up to' 38Mbit/s FTTC	Virgin Media 100, Virgin Media 50, Virgin Media 200
Plusnet 'up to' 38Mbit/s FTTC	Virgin Media 100, Virgin Media 50, Virgin Media 200

Source: Ofcom, using data provided by SamKnows; see note [26] & [27] in the sources section

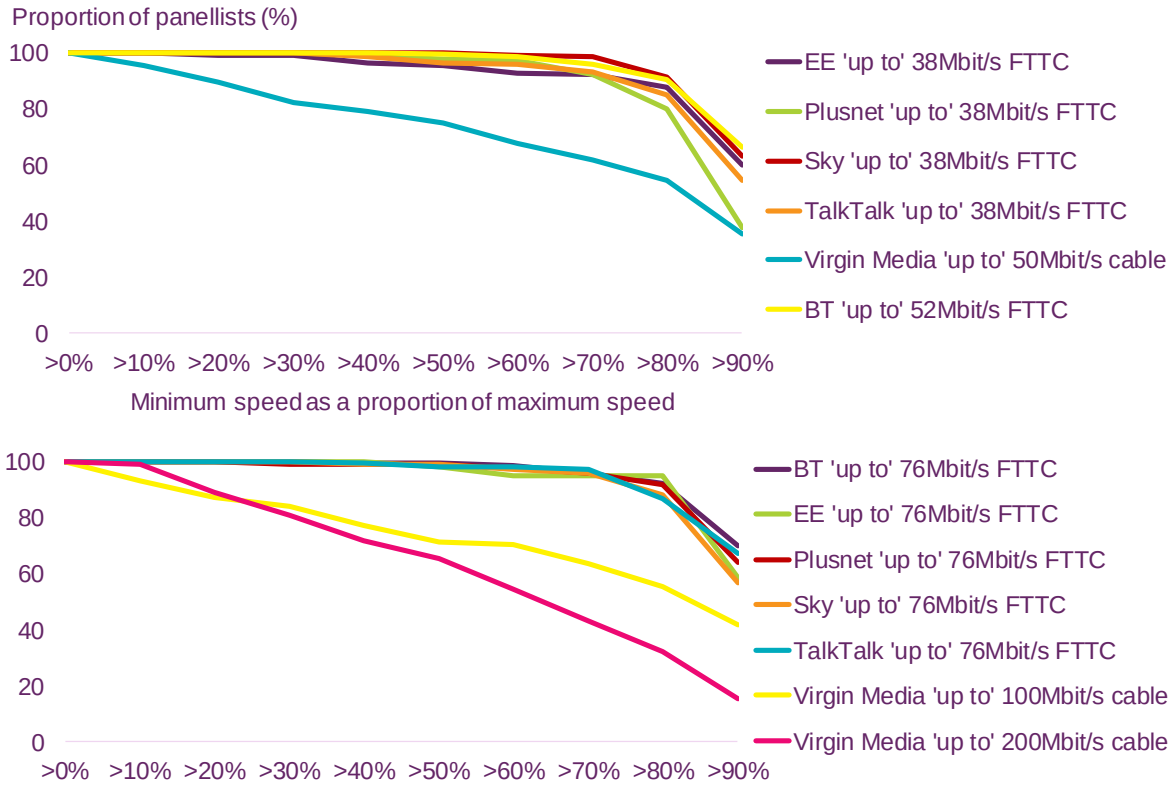
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; where a panellist's maximum speed is higher than the advertised speed of their service, the advertised speed has been used to calculate the figures above; the table shows significant differences to a 95%

confidence level; an asterisk (*) denotes that a difference is not significant to a (higher) 99% level of confidence.

Distribution of contention for superfast broadband services

- Among the superfast products included in our analysis, the proportion of panellists whose connection had a minimum speed that was more than 90% of its maximum speed ranged from 15% for Virgin Media's 'up to' 200Mbit/s cable service to 70% for BT's 'up to' 76Mbit/s service.
- The proportion of panellists whose connection had a minimum speed that was less than half its maximum speed ranged from 0% for Sky's 'up to' 38Mbit/s FTTC service to 34% for Virgin Media's 'up to' 200Mbit/s cable service.

Figure 31: Distribution of average minimum speed as a proportion of maximum speed for 'up to' 30Mbit/s and above ISP packages



Source: Ofcom, using data provided by SamKnows; see note [28] & [29] in the sources section
Note: Where a panellist's maximum speed is higher than the advertised speed of their service, the advertised speed has been used to calculate the figures above.

Summary of average download speeds of all ISP packages

Figure 32: Summary of average download speed, by ISP package: November 2016

ISP Package	Maximum speed	24-hour average	8pm-10pm average	Minimum speed
BT ADSL2+	9.4Mbit/s-11.1Mbit/s	9.1Mbit/s-10.8Mbit/s	9.0Mbit/s-10.6Mbit/s	8.1Mbit/s-9.7Mbit/s
EE ADSL2+	9.7Mbit/s-12Mbit/s	9.4Mbit/s-11.7Mbit/s	9.2Mbit/s-11.4Mbit/s	8.1Mbit/s-10.2Mbit/s
KCOM ADSL2+	9.1Mbit/s-10.9Mbit/s	8.1Mbit/s-9.9Mbit/s	7.3Mbit/s-9.3Mbit/s	6.4Mbit/s-8.3Mbit/s
Plusnet ADSL2+	9.9Mbit/s-11.7Mbit/s	9.6Mbit/s-11.4Mbit/s	9.5Mbit/s-11.3Mbit/s	8.7Mbit/s-10.4Mbit/s
Sky ADSL2+	10.4Mbit/s-11.9Mbit/s	10.1Mbit/s-11.5Mbit/s	9.9Mbit/s-11.4Mbit/s	8.6Mbit/s-10Mbit/s
TalkTalk ADSL2+	8.9Mbit/s-10.3Mbit/s	8.6Mbit/s-10Mbit/s	8.6Mbit/s-9.9Mbit/s	7.7Mbit/s-9Mbit/s
EE 'up to' 38Mbit/s	34.5Mbit/s-35.9Mbit/s	33.6Mbit/s-35.2Mbit/s	32.4Mbit/s-34.5Mbit/s	29.7Mbit/s-32Mbit/s
Plusnet 'up to' 38Mbit/s	32.3Mbit/s-34.8Mbit/s	31Mbit/s-33.5Mbit/s	30.1Mbit/s-32.7Mbit/s	27.6Mbit/s-30.1Mbit/s
Sky 'up to' 38Mbit/s	33.5Mbit/s-35.1Mbit/s	33Mbit/s-34.6Mbit/s	32.8Mbit/s-34.3Mbit/s	30.5Mbit/s-32.1Mbit/s
TalkTalk'up to' 38Mbit/s	31.7Mbit/s-33.7Mbit/s	30.8Mbit/s-32.8Mbit/s	30.6Mbit/s-32.6Mbit/s	27.8Mbit/s-29.9Mbit/s
Virgin Media 'up to' 50Mbit/s	52.7Mbit/s-53.1Mbit/s	46.1Mbit/s-49.6Mbit/s	38.2Mbit/s-45.4Mbit/s	32.9Mbit/s-40.5Mbit/s
BT 'up to' 52Mbit/s	48.5Mbit/s-49.4Mbit/s	47.7Mbit/s-48.6Mbit/s	46.9Mbit/s-47.9Mbit/s	44.1Mbit/s-45.3Mbit/s
BT 'up to' 76Mbit/s	58.7Mbit/s-61.5Mbit/s	57.9Mbit/s-60.7Mbit/s	57.0Mbit/s-59.8Mbit/s	53.7Mbit/s-56.6Mbit/s
EE 'up to' 76Mbit/s	57.5Mbit/s-62Mbit/s	56.3Mbit/s-60.8Mbit/s	55.3Mbit/s-59.9Mbit/s	51.4Mbit/s-56.3Mbit/s
Plusnet 'up to' 76Mbit/s	56.1Mbit/s-59.2Mbit/s	54.6Mbit/s-57.7Mbit/s	53.9Mbit/s-57Mbit/s	50.4Mbit/s-53.5Mbit/s
Sky 'up to' 76Mbit/s	55.6Mbit/s-61.2Mbit/s	54.3Mbit/s-59.9Mbit/s	53.6Mbit/s-59.1Mbit/s	49.1Mbit/s-54.6Mbit/s
TalkTalk'up to' 76Mbit/s	52.6Mbit/s-57.8Mbit/s	51.6Mbit/s-56.7Mbit/s	51.2Mbit/s-56.3Mbit/s	47.5Mbit/s-52.6Mbit/s
Virgin Media 'up to' 100Mbit/s	101.9Mbit/s-104.5Mbit/s	87.7Mbit/s-95.2Mbit/s	72.6Mbit/s-86.1Mbit/s	64.0Mbit/s-77.6Mbit/s
Virgin Media 'up to' 200Mbit/s	201.5Mbit/s-204.8Mbit/s	169.0Mbit/s-177.2Mbit/s	143.7Mbit/s-155.4Mbit/s	114.7Mbit/s-126.5Mbit/s

Source: Ofcom, using data provided by SamKnows

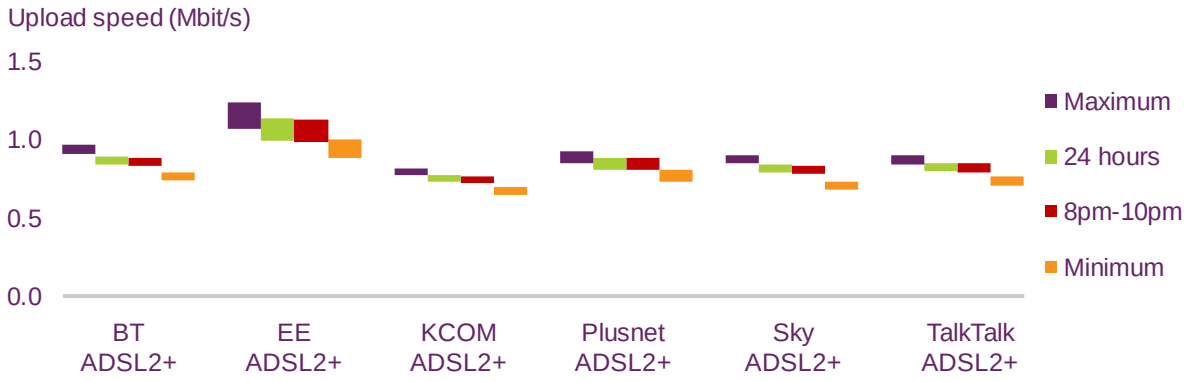
Upload speeds

Upload speeds for ADSL2+ ISP packages

Upload speeds plays an important part in the performance of the broadband services for many consumers, especially for those who use applications that involve uploading data, including sharing files, real-time online gaming and video calling.

- Based on our research, EE's ADSL2+ services had the highest maximum, 24-hour average, 8pm-10pm peak-time speed, and minimum upload speed, across all the ADSL2+ packages we considered.

Figure 33: Maximum, average, peak-time and minimum upload speeds for ADSL2+ ISP packages and significant differences, to a 95% level of confidence: November 2016



	Maximum	24-hour average	8pm-10pm	Minimum
ISP Package	**was faster than...**	**was faster than...**	**was faster than...**	**was faster than...**
EE	BT, Plusnet, Sky, TalkTalk & KCOM	BT, Plusnet, TalkTalk,Sky, KCOM	Plusnet, BT, TalkTalk,Sky, KCOM	Plusnet, BT, TalkTalk, Sky & KCOM
BT	Sky*, TalkTalk*, KCOM	KCOM	Sky*, KCOM	KCOM
Plusnet	KCOM	KCOM	KCOM	KCOM
TalkTalk	KCOM	KCOM*	KCOM	KCOM*
Sky	KCOM	KCOM*	KCOM	No differences

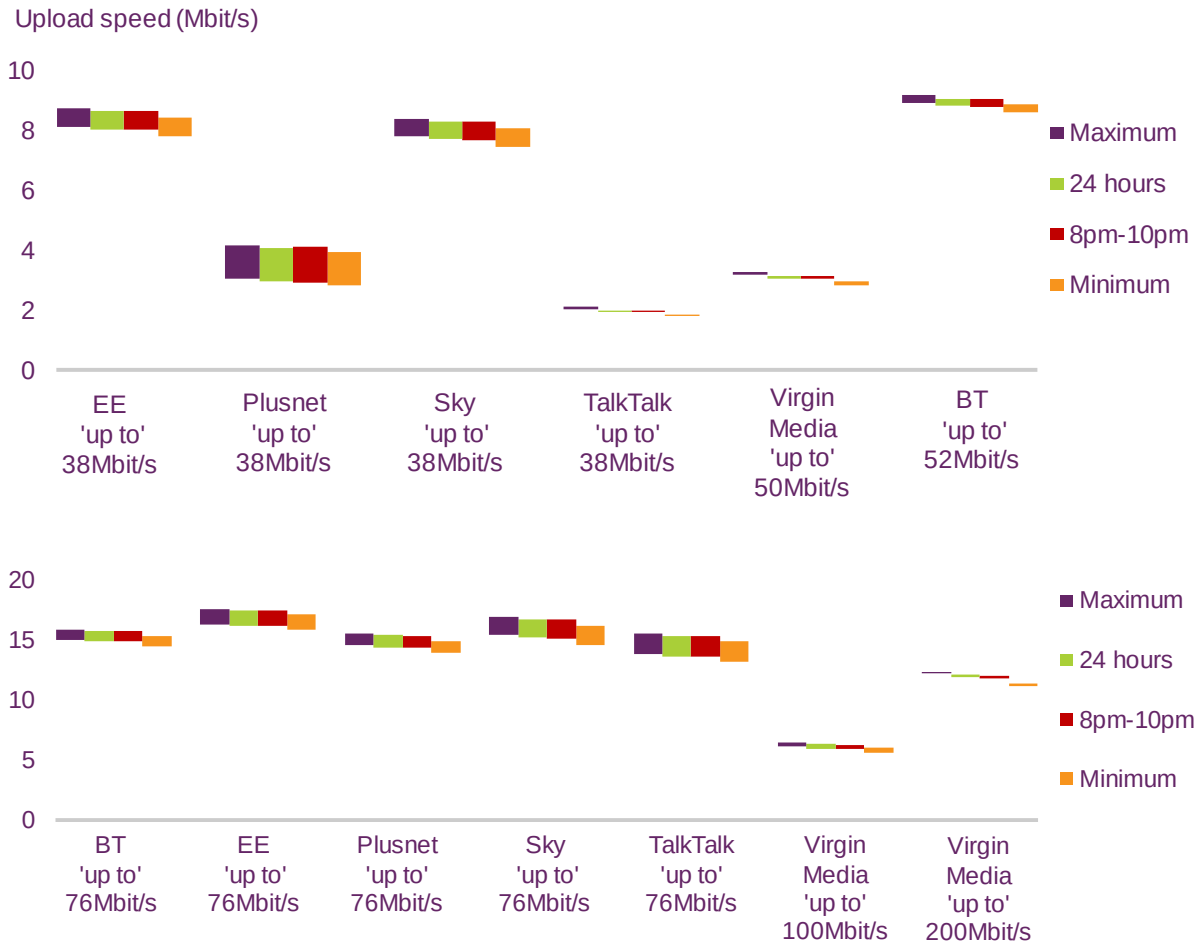
Source: Ofcom, using data provided by SamKnows; see note [30] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges; the table shows significant differences to a 95% confidence level; an asterisk (*) denotes that a difference is not significant to a (higher) 99% level of confidence.

Upload speeds for superfast connections

- Based on our research, 'up to' 76Mbit/s FTTC services had the fastest upload speeds among the superfast products included in our analysis, averaging 15.6Mbit/s over 24-hours and during the 8-10pm peak time period.

- For cable packages, the highest upload speeds were achieved for Virgin Media's 'up to' 200Mbit/s package, which had average 24-hour and peak-time speeds of 12.0Mbit/s and 11.9Mbit/s respectively.

Figure 34: Maximum, average and peak-time upload speeds for ISP packages 'up to' 30Mbit/s and above, and significant differences, to a 95% level of confidence: November 2016



	Maximum	24-hour average	8pm-10pm	Minimum
ISP Package	**was faster than...**	**was faster than...**	**was faster than...**	**was faster than...**
EE 'up to' 76Mbit/s FTTC	BT76, PN76, TT76, VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38	BT76, PN76, TT76, VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38	BT76, PN76, TT76, VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38	BT76, PN76, TT76, VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38
Sky 'up to' 76Mbit/s FTTC	VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38	VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38	VM200, BT52, EE38, Sky38, VM100, PN38, VM50, TT38	VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38
BT 'up to' 76Mbit/s FTTC	VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38	VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38	VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38	VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38
Plusnet 'up to' 76Mbit/s FTTC	VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38	VM200, BT52, EE38 & Sky38, VM100, PN38, VM50 & TT38	VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38	VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38
TalkTalk 'up to' 76Mbit/s FTTC	VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38	VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38	VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38	VM200, BT52, EE38, Sky38, VM100, PN38, VM50 & TT38
Virgin Media 'up to' 200Mbit/s cable	BT52, EE38, Sky38, VM100, PN38, VM50 & TT38	BT52, EE38, Sky38, VM100, PN38, VM50 & TT38	BT52, EE38, Sky38, VM100, PN38, VM50 & TT38	BT52, EE38, Sky38, VM100, PN38, VM50 & TT38
BT 'up to' 52Mbit/s FTTC	VM100, PN38, VM50 & TT38	EE38, Sky38, VM100, PN38, VM50 & TT38	EE38, Sky38, VM100, PN38, VM50 & TT38	EE38, Sky38, VM100, PN38, VM50 & TT38
EE 'up to' 38Mbit/s FTTC	VM100, PN38, VM50 & TT38	VM100, PN38, VM50 & TT38	VM100, PN38, VM50 & TT38	VM100, PN38, VM50 & TT38
Sky 'up to' 38Mbit/s FTTC	PN38, VM50 & TT38	VM100, PN38, VM50 & TT38	VM100, PN38, VM50 & TT38	VM100, PN38, VM50 & TT38
Virgin Media 'up to' 100Mbit/s cable	TT38	PN38, VM50 & TT38	PN38, VM50 & TT38	PN38, VM50 & TT38
Plusnet 'up to' 38Mbit/s FTTC	TT38	TT38	TT38	TT38
Virgin Media 'up to' 50Mbit/s cable	No difference	TT38	TT38	TT38

Source: Ofcom, using data provided by SamKnows; see note [31] & [32] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; the table shows significant differences to a 95% confidence level; an asterisk (*) denotes that a difference is not significant to a (higher) 99% level of confidence.

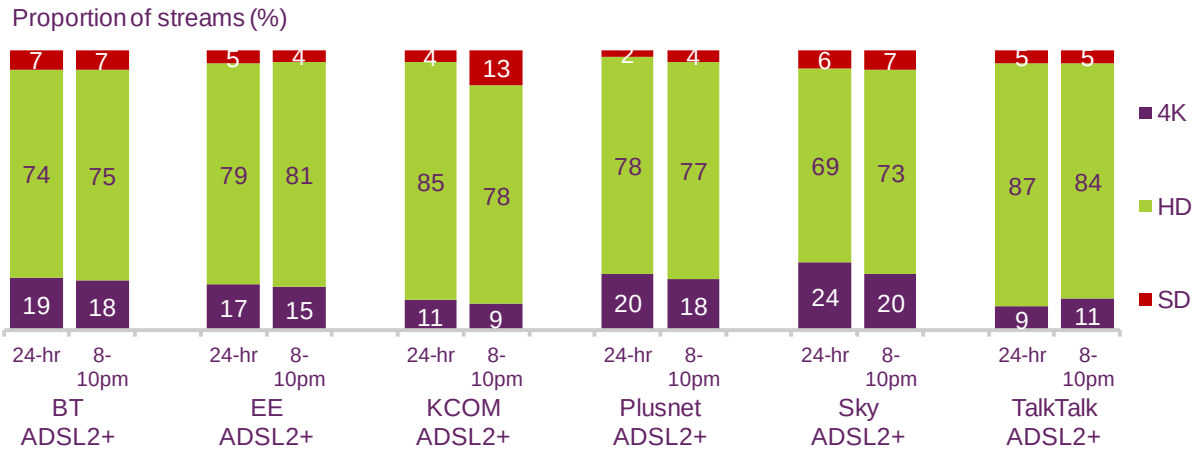
Video streaming quality, by ISP package

Single stream

Streaming Netflix videos over ADSL2+ ISP packages

- At peak times, KCOM's ADLS2+ service performed comparatively poorly, with 13% of Netflix streams achieving only SD resolution.

Figure 35: Proportion of Netflix videos delivered at the given video quality without re-buffering events, for ADSL2+ ISP packages over 24 hours and at peak times (%)



Source: Ofcom, using data provided by SamKnows; see note [33] in the sources section

Streaming Netflix videos over superfast broadband packages

- Other than Virgin Media's 'up to' 100Mbit/s packages, all the superfast services included in our research reliably achieved 4K resolution for more than 90% of Netflix streams.

Figure 36: Proportion of Netflix videos delivered at the given video quality without re-buffering events, for superfast products over 24 hours and at peak times (%)

Source: Ofcom, using data provided by SamKnows; see note [34] & {35] in the sources section

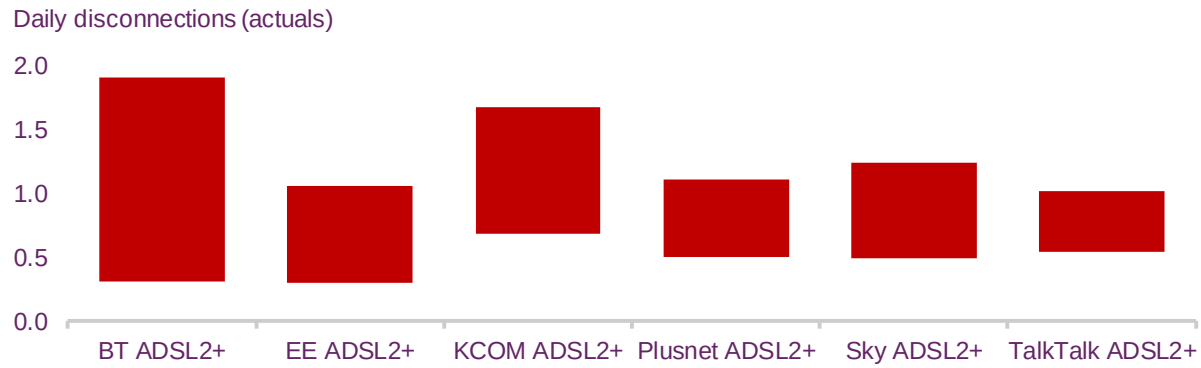
Disconnections, by ISP package

The average daily disconnections metric measures the frequency and duration of broadband service disconnections. Users cannot undertake any online activities when their service loses internet connectivity, and disconnections can be inconvenient and frustrating for users.

Disconnections for ASDL2+ ISP packages

- There were no statistically significant differences between the numbers of actual daily disconnections of the ADSL2+ ISP packages included in our research in November 2016.

Figure 37: Average daily disconnections (30 seconds or longer) for ADSL2+ ISP packages (Lower values indicate better performance)

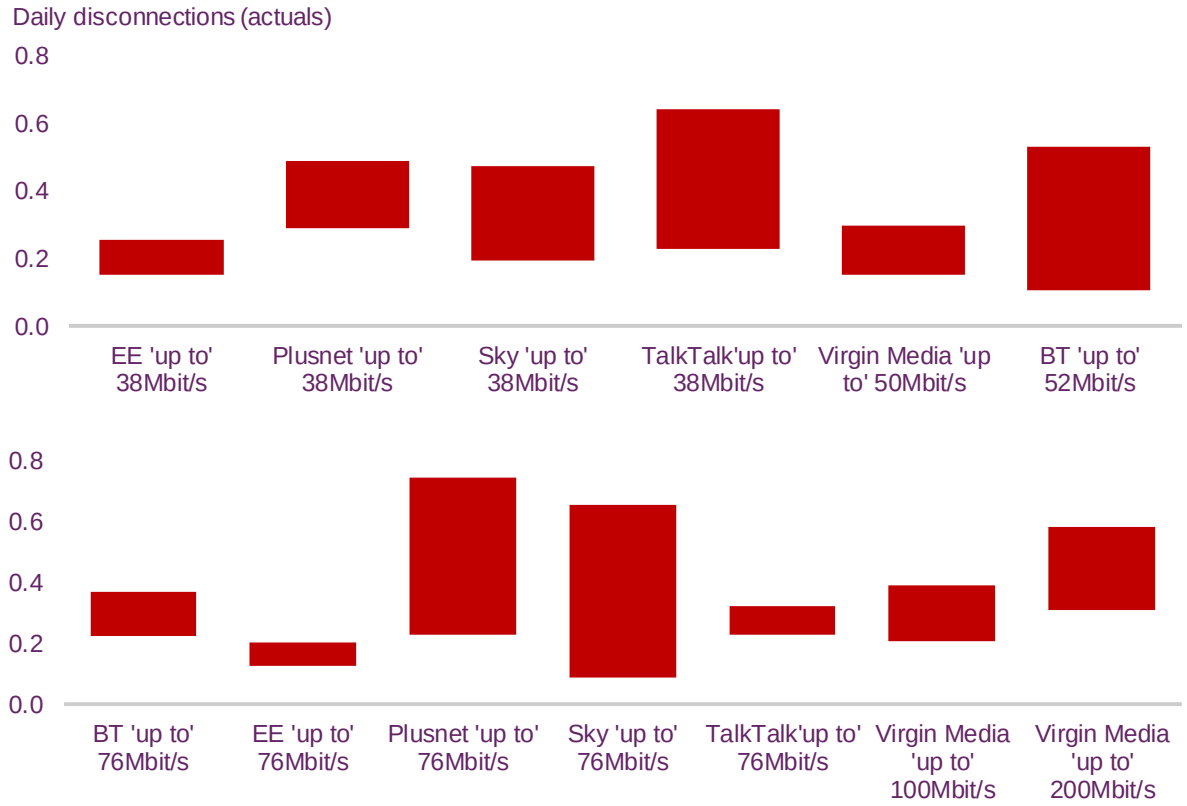


Source: Ofcom, using data provided by SamKnows; see note [36] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown.

Disconnections for superfast broadband packages

- EE's and Sky's 'up to' 76Mbit/s package performed well in terms of the average number of disconnections in November 2016.

Figure 38: Average daily disconnections of 30 seconds or longer for 'up to' 30Mbit/s and above ISP packages, and significant differences, to a 95% level of confidence: November 2016



ISP Package	performed better than...
EE 'up to' 76Mbit/s FTTC	TT76, BT76*, V100*, PN38, TT38*, V200, PN76*
EE 'up to' 38Mbit/s FTTC	PN38*, V200*
Virgin Media 'up to' 50Mbit/s cable	V200*

Source: Ofcom, using data provided by SamKnows; see note [37] & [38] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; the table shows significant differences to a 95% confidence level; an asterisk (*) denotes that a difference is not significant to a (higher) 99% level of confidence.

Section 8

Other metrics affecting performance

There are a number of other metrics which can be used to evaluate the performance of fixed-line broadband services, and the most important of these are outlined in the table below.

As the technologies and providers which deliver the highest download speeds do not necessarily deliver the best performance on other metrics, it is important that consumers also consider other sets of performance measurements to understand the overall performance of individual ISP package.

Figure 39: Summary of additional metrics covered in the research

Variable	Definition and importance
Web browsing speed	**The time taken to fetch the main HTML and assets (text, basic code and content files) from a webpage** *Dependent on download speeds, latency and DNS resolution times*
Latency	**The time it takes a packet of data to travel to a third-party server and back** *A connection with low latency will feel more responsive for simple tasks like web browsing and certain applications perform far better with lower latency*
Packet loss	**The proportion of data packets that are lost in transmission over a connection** *Important to online gamers and those streaming content or using VoIP as extended periods of loss lead to choppy and broken-up video and audio*
DNS resolution	**The time taken for an ISP to translate website names into IP addresses** When *DNS servers operate slowly, web browsing and other activities suffer*
DNS failure	**The proportion of requests for which the DNS server cannot translate a domain name to an IP address** *DNS failure results in error messages such as "Host could not be found"*
Jitter	**Measures the rate of change of latency** *The lower the measure of jitter the more stable a connection is and latency is important to gamers and VoIP users.*

Source: Ofcom

The comparative performance of different ISP packages with respect to these metrics can be found below and in the data visualisation tool that that accompanied this report and can be accessed at:

https://public.tableau.com/views/UKHomeBroadbandPerformanceReport/Story?:embed=y&:display_count=yes

Web browsing

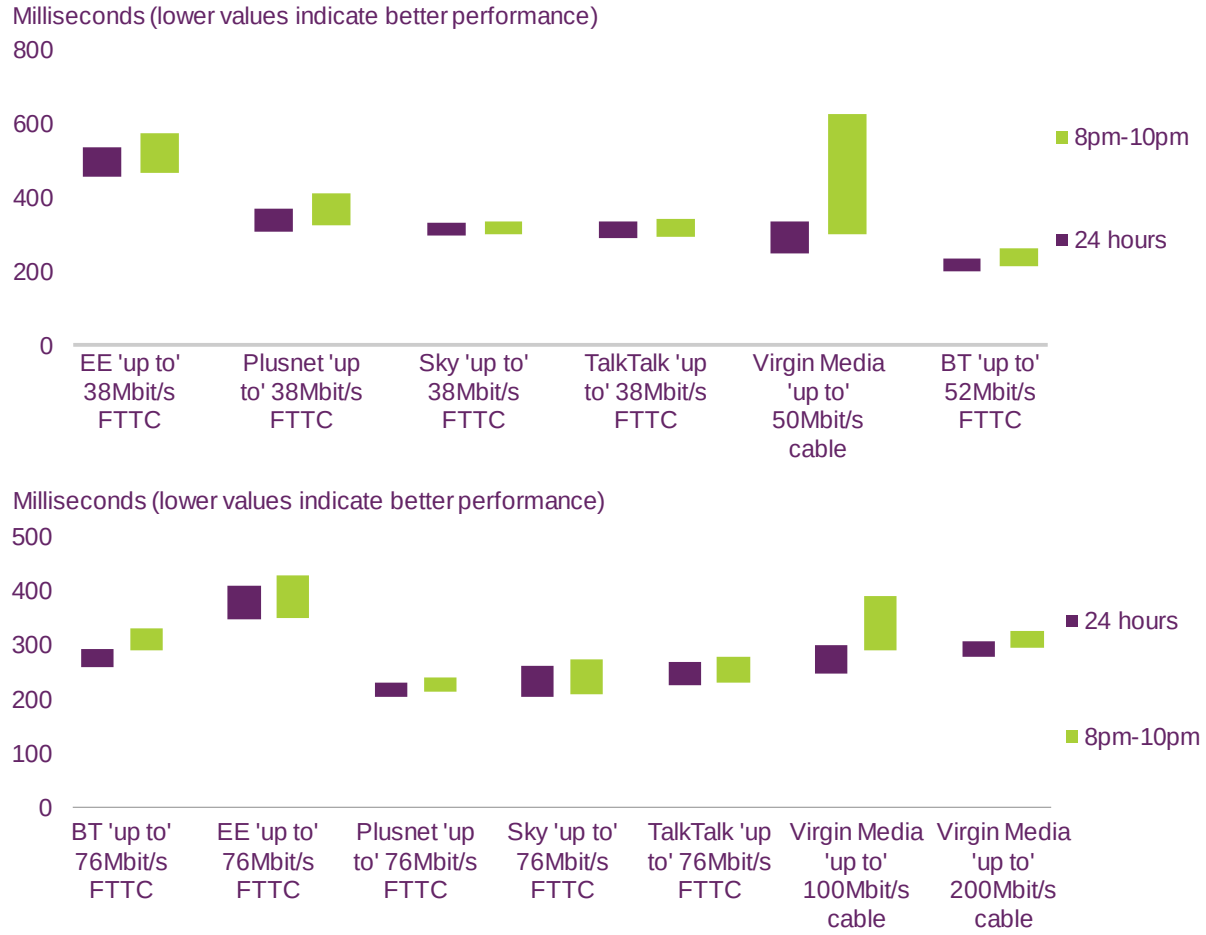
To measure the basic web browsing performance of the different ISP packages, we measured the time in milliseconds to fetch the main HTML and assets (i.e. text, basic code and content files) from three test pages. Better performance is indicated by lower bars.

Figure 40: Average and peak-time loading of web pages for ADSL2+ ISP packages and significant differences, to a 95% level of confidence: November 2016

	24-hour average	Peak time
ISP Package	**performed better than...**	**performed better than...**
Plusnet	KCOM*, Sky*, TT*	No difference
EE	TT*	No difference
BT	TT*	KCOM*, TT*

Source: Ofcom, using data provided by SamKnows; see note [36] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown.

Figure 41: Average and peak-time loading of web pages for ISP packages 'up to' 30Mbit/s and above and significant differences, to a 95% level of confidence: November 2016



	24-hour average	Peak time
ISP Package	**performed better than...**	**performed better than...**
Plusnet "up to" 76Mbit/s FTTC	V100, BT76, V200, V50, TT38, Sky38, PN38, EE76, EE38	BT76, V200, TT38, Sky38, V100, PN38, EE76, V50*, EE38
BT "up to" 52Mbit/s FTTC	V100*, BT76, V200, V50*, TT38, Sky38, PN38, PN38, EE76, EE38	BT76, V200, TT38, Sky38, V100, PN38, EE76, V50, EE38
Sky "up to" 76Mbit/s FTTC	V200*, TT38, Sky38, PN38, EE76, EE38	BT76, V200, TT38, Sky38, V100*, PN38, EE76, V50*, EE38
TalkTalk "up to" 76Mbit/s FTTC	V200*, TT38, Sky38, PN38, EE76, EE38	BT76*, V200, TT38, Sky38, V100*, PN38, EE76, V50*, EE38
Virgin Media "up to" 100Mbit/s cable	PN38*, EE76, EE38	EE38
BT "up to" 76Mbit/s FTTC	TT38*, Sky38*, PN38*, EE76, EE38	EE76, EE38
Virgin Media "up to" 200Mbit/s cable	EE76, EE38	PN38*, EE76, EE38
Virgin Media "up to" 50Mbit/s cable	EE76*, EE38	No differences
TalkTalk "up to" 38Mbit/s FTTC	EE76*, EE38	EE76*, EE38
Sky "up to" 38Mbit/s FTTC	EE76*, EE38	EE76*, EE38
Plusnet "up to" 38Mbit/s FTTC	EE38	EE38
EE "up to" 76Mbit/s FTTC	No differences	EE38

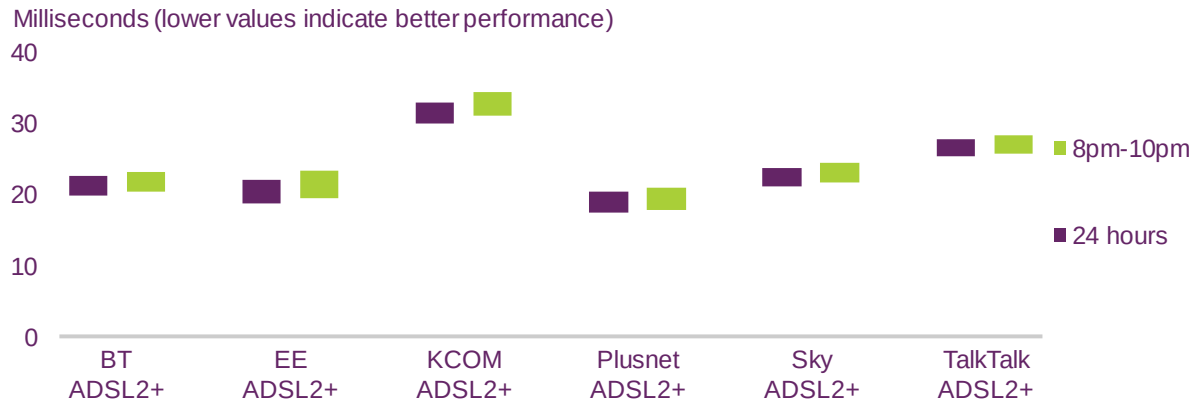
Source: Ofcom, using data provided by SamKnows; see note [37] & [38] in the sources section

Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; the table shows significant differences to a 95% confidence level; an asterisk (*) denotes that a difference is not significant to a (higher) 99% level of confidence.

Latency

Latency is the time that it takes for a single packet of data to travel to a third-party server and back again. The figure is commonly measured in milliseconds, and a connection with low latency will seem more responsive for the delivery of simple tasks such as web browsing. Particular applications also perform significantly better with a low latency, particularly some online games. Better performance is indicated by lower bars.

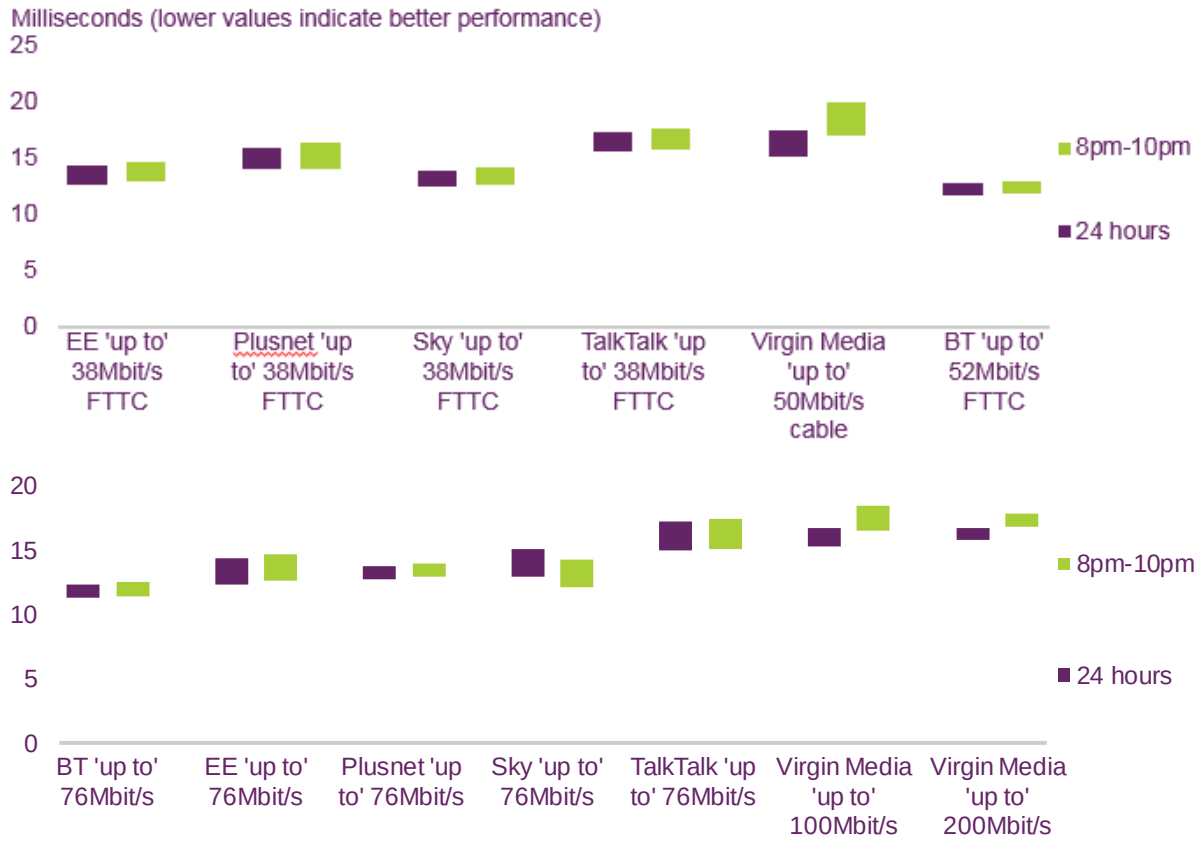
Figure 42: Average and peak-time latency for ADSL2+ ISP packages and significant differences, to a 95% level of confidence: November 2016



	24-hour average	Peak time
ISP Package	**performed better than...**	**performed better than...**
Plusnet	Sky*, TT, KCOM	Sky*, TT, KCOM
EE	TT, KCOM	TT, KCOM
BT	TT, KCOM	TT, KCOM
Sky	TT. KCOM	TT, KCOM
TalkTalk	KCOM	KCOM

Source: Ofcom, using data provided by SamKnows; see note [36] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown.

Figure 43: Average and peak-time latency for ISP packages 'up to' 30Mbit/s and above and significant differences, to a 95% level of confidence: November 2016



	24-hour average	Peak time
ISP Package	**performed better than...**	**performed better than...**
BT "up to" 76Mbit/s FTTC	Sky38*, PN76*, EE76*, EE38*, PN38, V100, TT76, V200, V50, TT38	Sky38*, EE76*, PN76, EE38, PN38, TT76, TT38, V200, V100, V50
BT "up to" 52Mbit/s FTTC	Sky38*, PN76*, EE76*, EE38*, PN38, V100, TT76, V200, V50, TT38	PN76, EE38, PN38, TT76, TT38, V200, V100, V50
Sky "up to" 38Mbit/s FTTC	V100, TT76, V200, V50, TT38	TT76, TT38, V200, V100, V50
Sky "up to" 76Mbit/s FTTC	V100, TT76, V200, V50, TT38	TT76, TT38, V200, V100, V50
Plusnet "up to" 76Mbit/s FTTC	V100, TT76, V200, V50, TT38	PN38*, TT76, TT38, V200, V100, V50
EE "up to" 76Mbit/s FTTC	V100, TT76*, V200, V50, TT38	TT76*, TT38, V200, V100, V50
EE "up to" 38Mbit/s FTTC	V100, TT76*, V200, V50, TT38	TT76*, TT38, V200, V100, V50
Plusnet "up to" 38Mbit/s FTTC	No differences	V200*, V100*, V50*

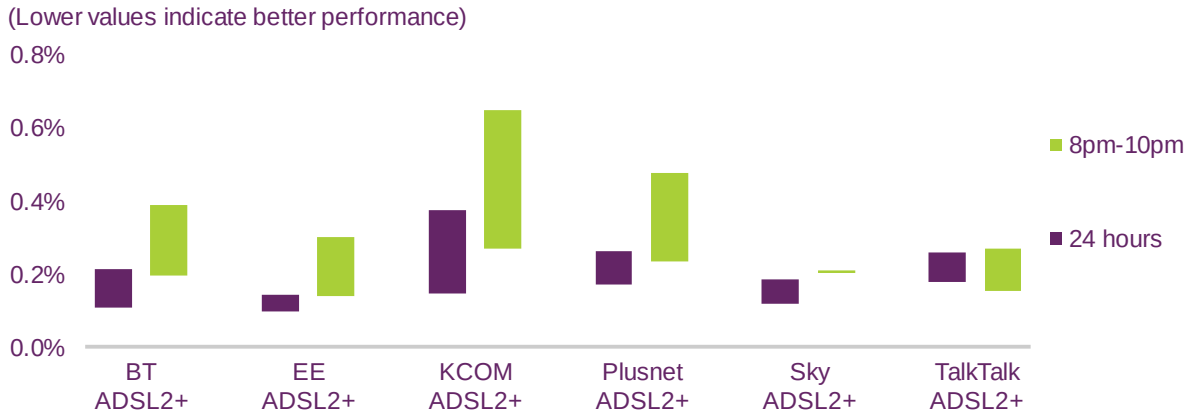
Source: Ofcom, using data provided by SamKnows; see note [37] & [38] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; the table shows significant differences to a 95% confidence level; an asterisk (*) denotes that a difference is not significant to a (higher) 99% level of confidence.

Packet loss

Packets of data can be lost during transmission over an internet connection. Packet loss can degrade the performance of real-time applications, and although network transmission protocols such as transmission control protocol (TCP) automatically deal with packet loss, to minimise the impact to the end-user, there may still be a temporary slowdown.

This is of particular concern to online gamers, users of voice over IP (VoIP) telephony and those streaming audio or video content (a small number of dropped packets is acceptable as each packet in the test accounts for only 0.2 seconds, but extended periods of loss lead to choppy audio or video content). Better performance is indicated by lower bars.

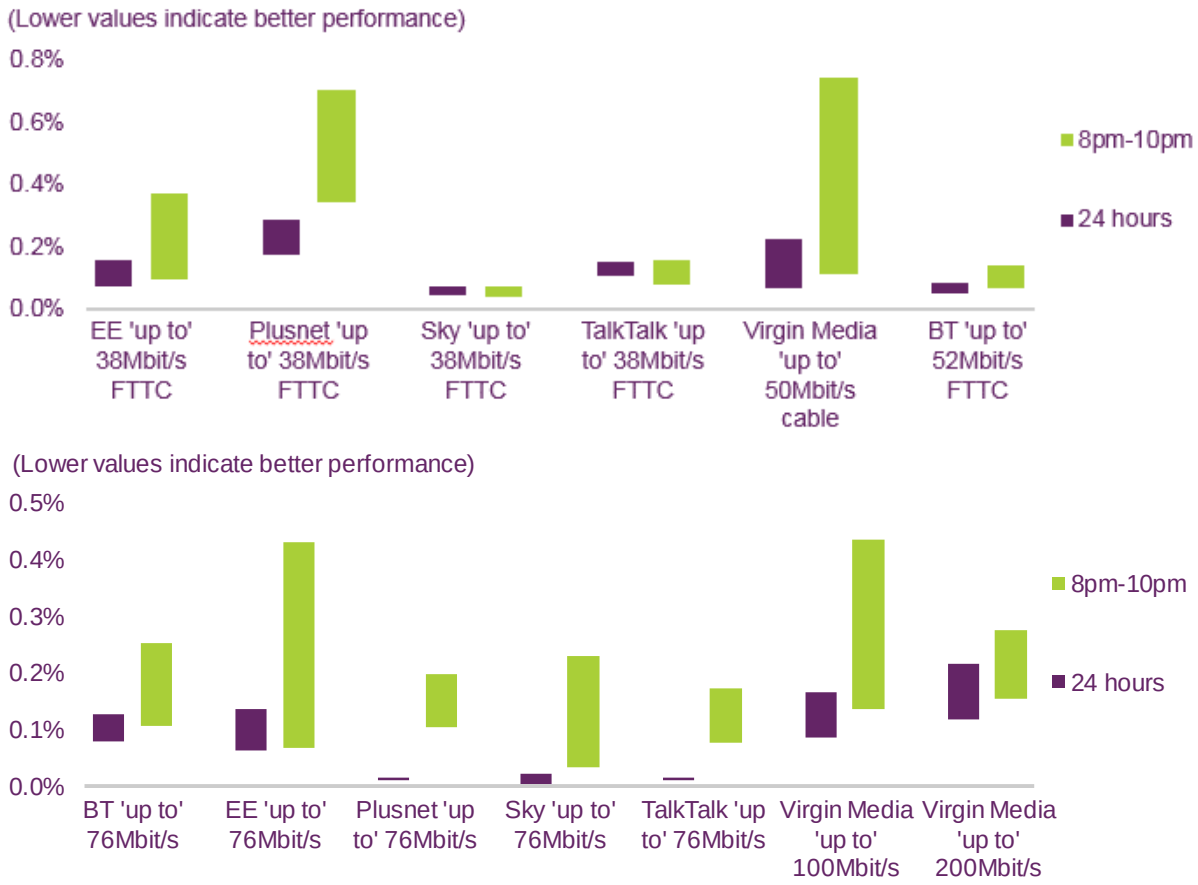
Figure 44: Average and peak-time packet loss for ADSL2+ ISP packages and significant differences, to a 95% level of confidence: November 2016



	24-hour average	Peak time
ISP Package	**performed better than...**	**performed better than...**
EE	KCOM*, PN, TalkTalk	No differences
Sky	No difference	PN*, KCOM*
TalkTalk	No difference	KCOM*

Source: Ofcom, using data provided by SamKnows; see note [36] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown.

Figure: 45 Average and peak-time packet loss for ISP packages 'up to' 30Mbit/s and above and significant differences, to a 95% level of confidence: November 2016



	24-hour average	Peak time
ISP Package	**performed better than...**	**performed better than...**
Sky "up to" 38Mbit/s FTTC	BT76*, EE38*, V100*, TT76, TT38, PN76, V200, PN38	TT38*, TT76*, PN76, BT 76, V200, EE 38*, V100, V50, PN38
BT "up to" 52Mbit/s FTTC	TT38, TT76, PN76, V200, PN38	PN38
BT "up to" 76Mbit/s FTTC	PN38*	PN38
EE "up to" 76Mbit/s FTTC	PN38*	No difference
EE "up to" 38Mbit/s FTTC	PN38*	No difference
TalkTalk "up to" 38Mbit/s FTTC	PN38*	PN38
TalkTalk "up to" 76Mbit/s FTTC	PN38*	PN38
Virgin Media "up to" 100Mbit/s cable	PN38*	No difference
Plusnet "up to" 76Mbit/s FTTC	PN38*	PN38
Virgin Media "up to" 50Mbit/s cable	No difference	No difference
Sky "up to" 76Mbit/s FTTC	No difference	PN38
Virgin Media "up to" 200Mbit/s cable	No difference	PN38*
Plusnet "up to" 38Mbit/s FTTC	No difference	No differences

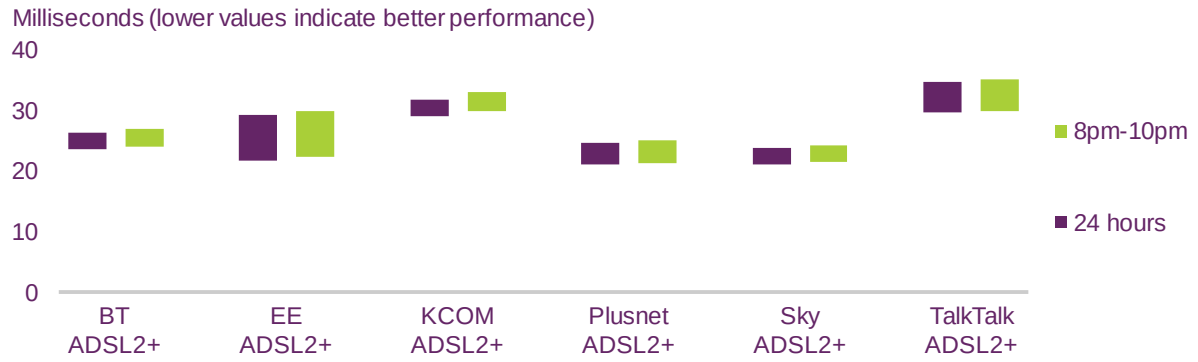
Source: Ofcom, using data provided by SamKnows; see note [37] & [38] in the sources section

Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; the table shows significant differences to a 95% confidence level; an asterisk (*) denotes that a difference is not significant to a (higher) 99% level of confidence.

DNS resolution

DNS (the domain name service) plays a crucial part in the way the internet operates. This protocol translates domain names (such as ofcom.org.uk) into the IP addresses that are used to route traffic (e.g. 194.33.179.25). Every ISP maintains its own DNS servers through which customers' computers issue queries to translate names into IP addresses. When these services fail, or operate slowly, web browsing and other online activities suffer. A slow DNS does not affect download speed, but can severely affect the responsiveness of the internet while browsing. Better performance is indicated by lower bars.

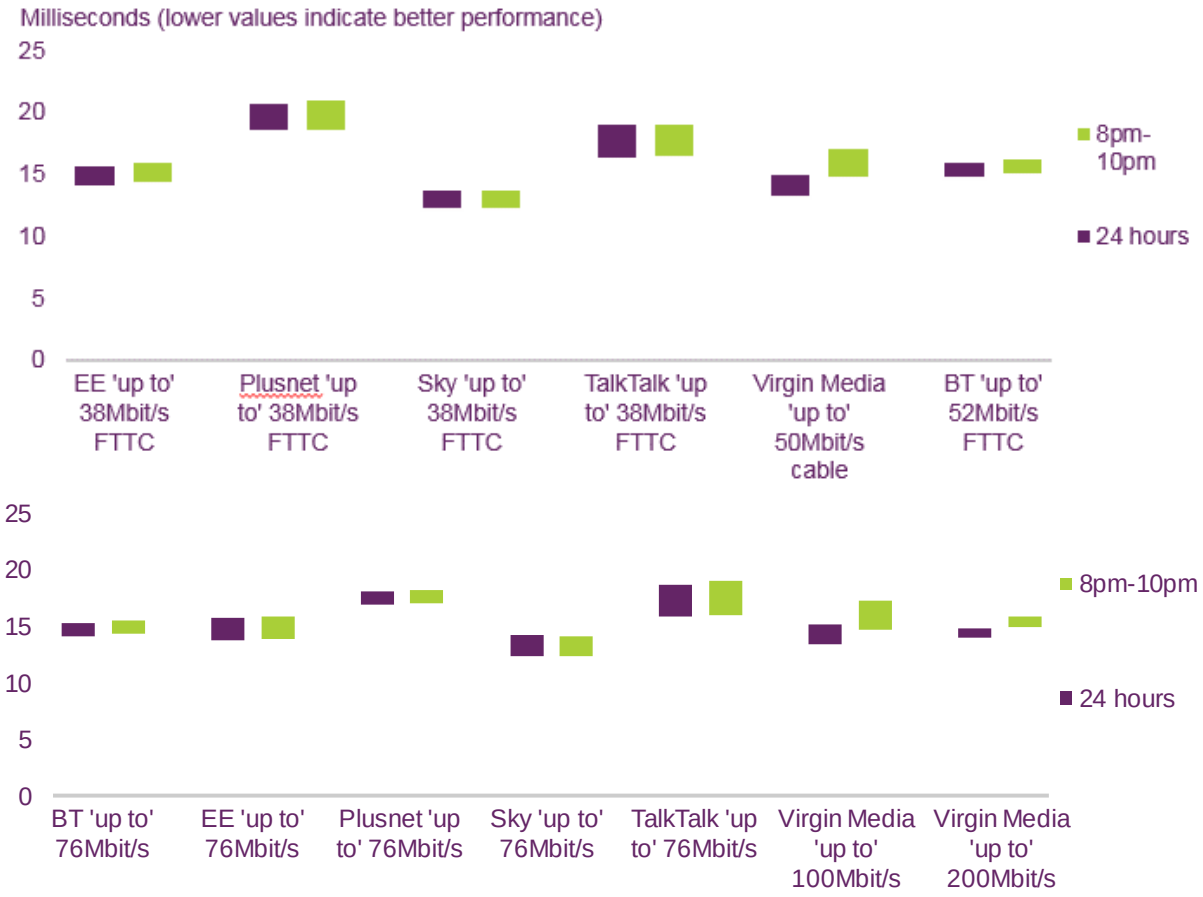
Figure: 46: Average and peak-time DNS resolution time for ADSL2+ ISP packages and significant differences, to a 95% level of confidence: November 2016



	24-hour average	Peak time
ISP Package	**performed better than...**	**performed better than...**
Sky	BT*, KCOM, TT	KCOM, TT
Plusnet	KCOM, TT	KCOM, TT
BT	KCOM, TT	KCOM, TT
EE	TT*	TT*

Source: Ofcom, using data provided by SamKnows; see note [36] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown.

Figure 47: Average and peak-time DNS resolution time for ISP packages 'up to' 30Mbit/s and above, and significant differences, to a 95% level of confidence: November 2016



	24-hour average	Peak time
ISP Package	**performed better than...**	**performed better than...**
Sky "up to" 38Mbit/s FTTC	V200*, BT76, EE76*, EE38, BT52, TT76, PN76, TT38, PN38	EE76*, BT76, EE38, V200, BT 52, V100, V50, TT76, PN76, TT38, PN38
Sky "up to" 76Mbit/s FTTC	BT52*, TT76, PN76, TT38, PN38	BT76*, EE38*, V200, BT 52, V100*, V50, TT76, PN76, TT38, PN38
Virgin Media "up to" 50Mbit/s cable	TT76, PN76, TT38, PN38	PN38
Virgin Media "up to" 100Mbit/s cable	TT76*, PN76, TT38, PN38	PN38
Virgin Media "up to" 200Mbit/s cable	BT52*, TT76*, PN76, TT38, PN38	TT76*, PN76, TT38, PN38
BT "up to" 76Mbit/s FTTC	TT76*, PN76, TT38, PN38	PN76, TT38*, PN38
EE "up to" 76Mbit/s FTTC	TT76*, PN76, TT38*, PN38	TT76*, PN76, TT38*, PN38
EE "up to" 38Mbit/s FTTC	TT76*, PN76, TT38, PN38	PN76, TT38*, PN38
BT "up to" 52Mbit/s FTTC	PN76, TT38*, PN38	PN76, TT38*, PN38
Plusnet "up to" 76Mbit/s FTTC	No differences	PN38*

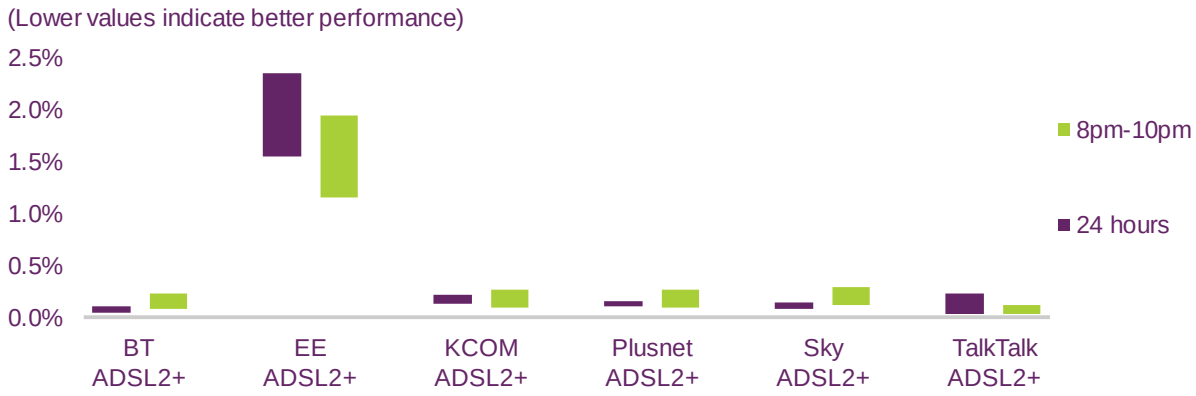
Source: SamKnows measurement data for all panel members with a connection in November 2016.
Source: Ofcom, using data provided by SamKnows; see note [37] & [38] in the sources section

Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; the table shows significant differences to a 95% confidence level; an asterisk (*) denotes that a difference is not significant to a (higher) 99% level of confidence.

DNS failure

DNS failure occurs when an ISP's DNS server is unable to translate a domain name to an IP address in a TCP/IP network. When a DNS failure occurs, the user is presented with an error message such as "this server is unavailable" or "host could not be found", and is unable to access the requested page on that occasion. Better performance is indicated by lower bars.

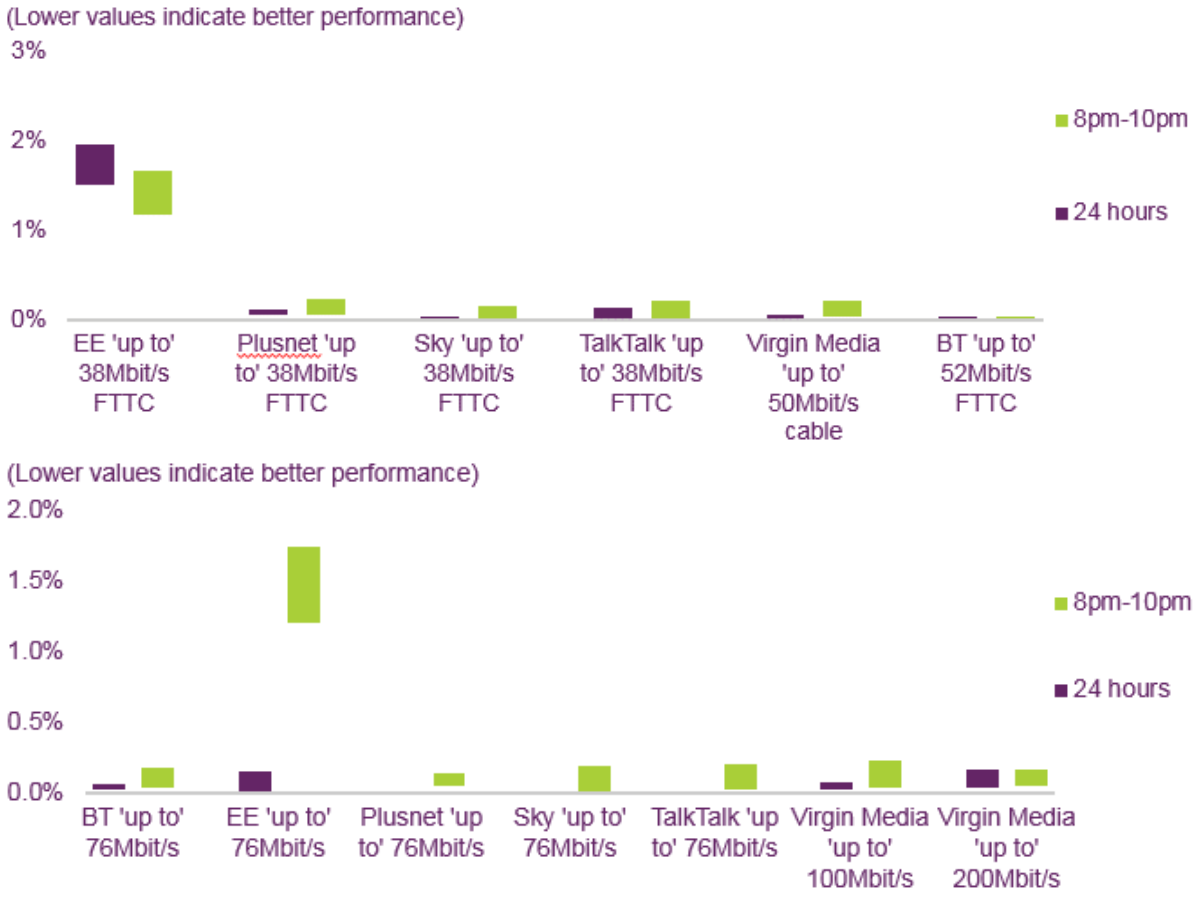
Figure 48: Average and peak-time DNS failure rates for ADSL2+ ISP packages and significant differences, to a 95% level of confidence: November 2016



	24-hour average	Peak time
ISP Package	**performed better than...**	**performed better than...**
BT	EE	EE
Sky	EE	EE
TalkTalk	EE	EE
KCOM	EE	EE
Plusnet	EE	EE

Source: Ofcom, using data provided by SamKnows; see note [36] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown.

Figure 49: Average and peak-time DNS failure rates for ISP packages 'up to' 30Mbit/s and above, and significant differences, to a 95% level of confidence: November 2016



	24-hour average	Peak time
ISP Package	**performed better than...**	**performed better than...**
BT "up to" 52Mbit/s FTTC	V200*, PN38, PN76, EE76, EE38	PN76*, V200*, V50*, PN38*, EE38, EE76
Sky "up to" 38Mbit/s FTTC	V200*, PN38, PN76, EE76, EE38	EE76, EE38
Virgin Media "up to" 50Mbit/s cable	PN76*, EE76, EE38	EE76, EE38
Sky "up to" 76Mbit/s FTTC	PN76*, EE76, EE38	EE76, EE38
BT "up to" 76Mbit/s FTTC	PN76*, EE76, EE38	EE76, EE38
Virgin Media "up to" 100Mbit/s cable	EE76, EE38	EE76, EE38
TalkTalk "up to" 38Mbit/s FTTC	EE76, EE38	EE76, EE38
Plusnet "up to" 38Mbit/s FTTC	EE76, EE38	EE76, EE38
Plusnet "up to" 76Mbit/s FTTC	EE76, EE38	EE76, EE38
Virgin Media "up to" 200Mbit/s cable	EE76, EE38	EE76, EE38
TalkTalk "up to" 76Mbit/s FTTC	EE76, EE38	EE76, EE38

Source: Ofcom, using data provided by SamKnows; see note [37] & [38] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; the table shows significant differences to a 95% confidence level; an asterisk (*) denotes that a difference is not significant to a (higher) 99% level of confidence.

Jitter

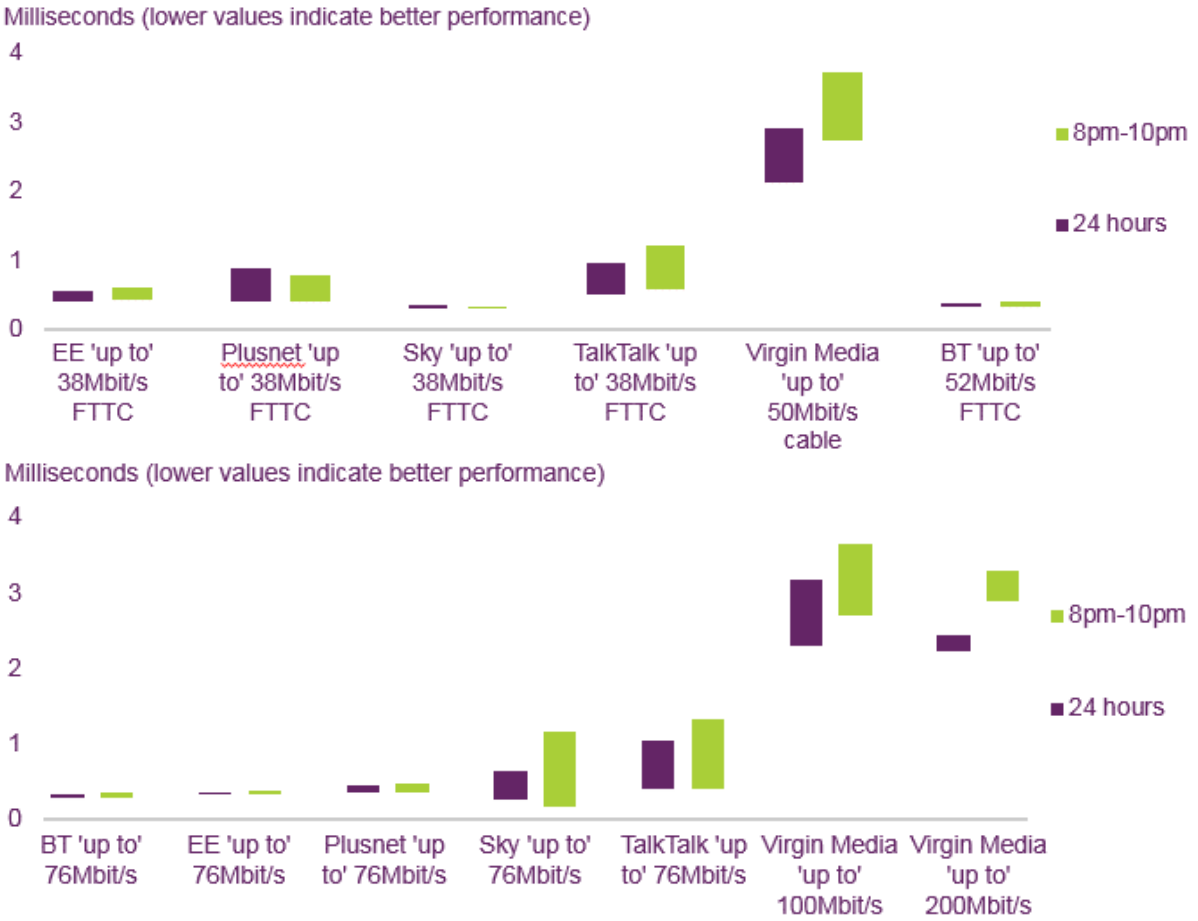
'Jitter' can be described as the rate of change of latency. The lower the measure of jitter, the more stable the connection. Jitter and packet loss are the two biggest contributors to the quality of a voice over internet protocol (VoIP) phone call. Online gamers will also desire low jitter (low latency is useless if the connection has a high jitter rate). Modern specialist VoIP devices will often include a 'jitter buffer' of around 20 milliseconds. This effectively allows for up to a 20-millisecond jitter, with no noticeable effect for the end-user. Better performance is indicated by lower bars.

Figure 50: Average and peak-time upstream jitter for ADSL2+ ISP packages and significant differences, to a 95% level of confidence: November 2016

	24-hour average	Peak time
ISP Package	**performed better than...**	**performed better than...**
BT	KCOM, Sky	No differences

Source: Ofcom, using data provided by SamKnows; see note [36] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown.

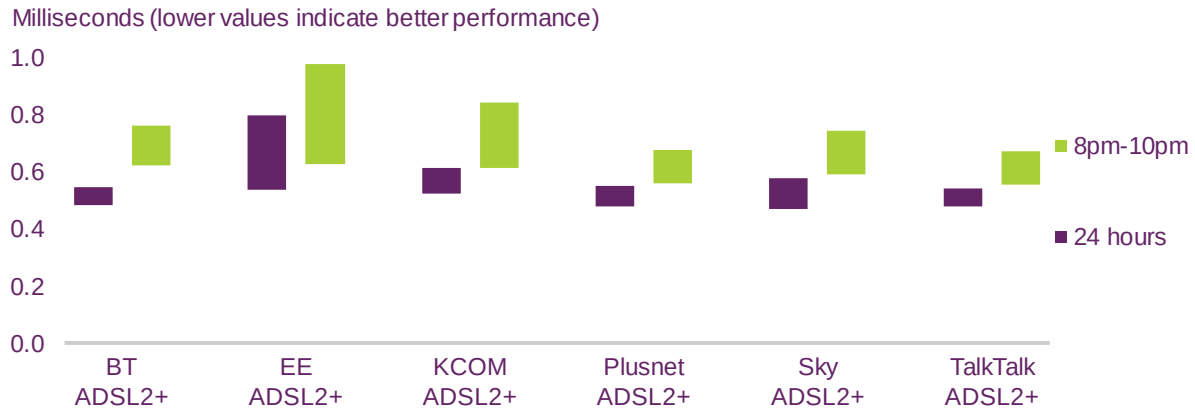
Figure 51: Average and peak-time upstream jitter for ISP packages 'up to 30Mbit/s and above, and significant differences, to a 95% level of confidence: November 2016



	24-hour average	Peak time
ISP Package	**performed better than...**	**performed better than...**
BT "up to" 76Mbit/s FTTC	PN76*, EE38, PN38*, TT76*, TT38, V100, V50, V200	PN76*, EE38, PN38*, TT76*, TT38, V200, V50, V100
Sky "up to" 38Mbit/s FTTC	PN76*, EE38, PN38*, TT76*, TT38, V100, V50, V200	EE76*, PN76, EE38, PN38*, TT76, TT38, V200, V50, V100
EE "up to" 76Mbit/s FTTC	V100, V50, V200	EE38, PN38*, TT76*, TT38, V200, V50, V100
BT "up to" 52Mbit/s FTTC	EE38*, TT38*, V100, V50, V200	EE38*, PN38*, TT76*, TT38, V200, V50, V100
Plusnet "up to" 76Mbit/s FTTC	TT38*, V100, V50, V200	TT38*, V200, V50, V100
EE "up to" 38Mbit/s FTTC	V100, V50, V200	V200, V50, V100
Plusnet "up to" 38Mbit/s FTTC	V100, V50, V200	V200, V50, V100
TalkTalk "up to" 76Mbit/s FTTC	V100, V50, V200	V200, V50, V100
TalkTalk "up to" 38Mbit/s FTTC	V100, V50, V200	V200, V50, V100
Sky "up to" 76Mbit/s FTTC	No differences	V200, V50, V100

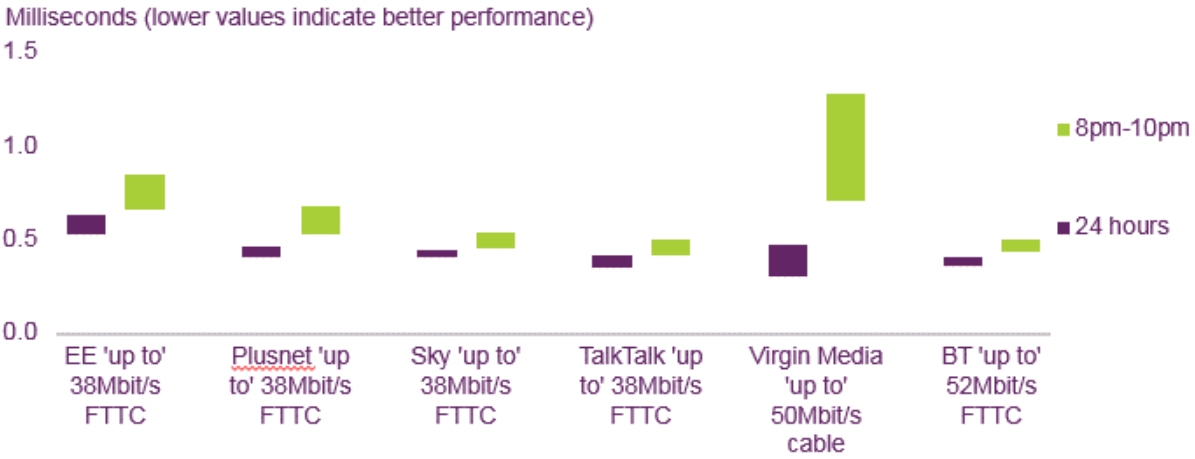
Source: Ofcom, using data provided by SamKnows; see note [37] & [38] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; the table shows significant differences to a 95% confidence level; an asterisk (*) denotes that a difference is not significant to a (higher) 99% level of confidence.

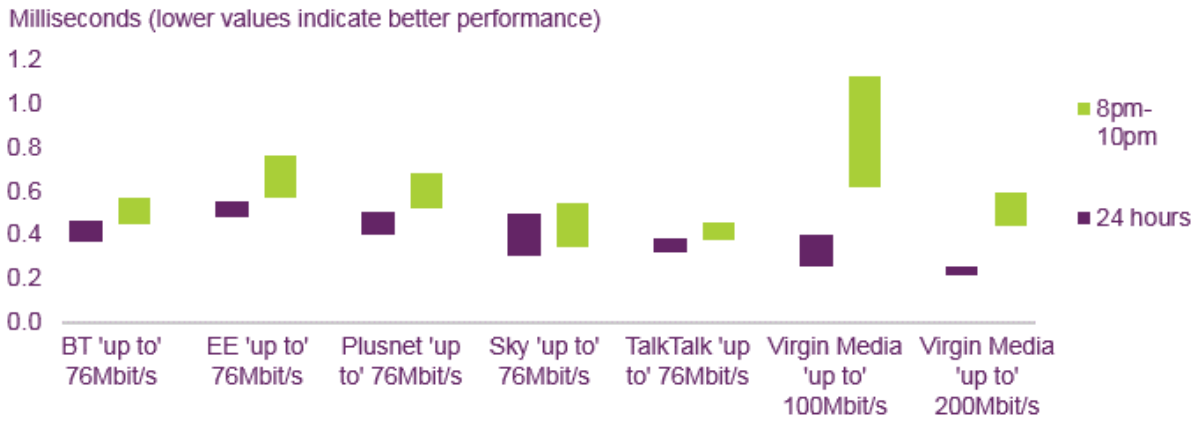
Figure 52: Average and peak-time downstream jitter for ADSL2+ ISP packages and significant differences, to a 95% level of confidence: November 2016



Source: Ofcom, using data provided by SamKnows; see note [36] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown.

Figure 53: Average and peak-time downstream jitter for ISP packages 'up to' 30Mbit/s and above and significant differences, to a 95% level of confidence: November 2016





	24-hour average	Peak time
ISP Package	**performed better than...**	**performed better than...**
Virgin Media “up to” 200Mbit/s cable	V100*, TT76, TT38, BT52, V50, Sky76, BT76, Sky38, PN38, PN76, EE76, EE38	EE76*, V100*, EE38, V50
Virgin Media “up to” 100Mbit/s cable	Sky38*, PN38*, PN76, EE76, EE38	No difference
TalkTalk “up to” 76Mbit/s FTTC	Sky28, PN38*, PN76*, EE76, EE38	BT76*, PN38, PN76, EE76, EE38, V100, V50
TalkTalk “up to” 38Mbit/s FTTC	EE76, EE38	EE76, V100, EE38, V50
BT “up to” 52Mbit/s FTTC	EE76, EE38	PN38*, PN76*, EE76, EE38, V100, V50
Virgin Media “up to” 50Mbit/s cable	EE76*, EE38	No difference
Sky “up to” 76Mbit/s FTTC	EE38*	EE76*, V100*, EE38, V50
BT “up to” 76Mbit/s FTTC	EE76*, EE38	V100*, EE38, V50
Sky “up to” 38Mbit/s FTTC	EE76*, EE38*	EE76*, V100*, EE38, V50
Plusnet “up to” 38Mbit/s FTTC	EE76, EE38	V50*
Plusnet “up to” 76Mbit/s FTTC	EE38*	V50*

Source: Ofcom, using data provided by SamKnows; see note [37] & [38] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; the table shows significant differences to a 95% confidence level; an asterisk (*) denotes that a difference is not significant to a (higher) 99% level of confidence.

Sources

[1] Source: SamKnows measurement data for all national panel members with a connection in November 2016. Panel base: 2023 (Above 'up to 2Mbit/s' and 'up to' and including 10Mbit/s – 130; Above 'up to 10Mbit/s and less than 'up to' 30Mbit/s - 643; 'Up to 30Mbit/s and higher – 1250)
Notes: (1) Data have been weighted by ISP package market share, rural/urban and geographic market classification, max attainable speed (FTTC) and distance from exchange (ADSL) to ensure that they are representative of the UK as a whole; (2) Data are collected from multi-thread download speed tests; (3) The above 'up to' 10Mbit/s and less than than 'up to' 30Mbit/s includes ADSL2+ connections which are not marketed using a connection speed.

[2] Source: Ofcom, based on data provided by the UK's largest ISPs by retail market share (representing over 90% of the total market), data as at November of each year
Notes: (1) The above 'up to' 10Mbit/s and less than 'up to' 30Mbit/s includes ADSL2+ connections which are not marketed using a connection speed.

[3] Source: SamKnows measurement data for all national panel members with a connection in November 2016. Panel base: 2023 (ADSL – 773; FTTC – 788 and cable 452)
Notes: (1) Data have been weighted by ISP package market share, rural/urban and geographic market classification, max attainable speed (FTTC) and distance from exchange (ADSL) to ensure that they are representative of the UK overall; (2) Data are collected from multi-thread download speed tests.

[4] Source: SamKnows measurement data for all national panel members with a connection in November 2016. Panel base: 2023 (urban ADSL – 457; rural ADSL - 316; urban FTTC – 662 and rural FTTC - 126)
Notes: (1) Data have been weighted by ISP package market share, rural/urban and geographic market classification, max attainable speed (FTTC) and distance from exchange (ADSL) to ensure that they are representative of the UK as a whole; (2) Data are collected from multi-thread download speed tests; (3) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

[5] Source: SamKnows measurement data for all national panel members with a connection in November 2016. Panel base: 2023 (urban - 1575; rural - 448)
Notes: (1) Data have been weighted by ISP package market share, rural/urban and geographic market classification, max attainable speed (FTTC) and distance from exchange (ADSL) to ensure that they are representative of the UK overall; (2) Data are collected from multi-thread download speed tests.

[6] Source: SamKnows measurement data for all panel members with a connection in November 2016 where density and nation data available. Panel base: 4367 (England 3458; Scotland 473; Wales 310 and Northern Ireland 126)
Notes: (1) Data have been weighted by rural/urban with nation and by the profile of lines by technology and speed as given in Ofcom's Connected Nations report of August 2016 to be representative with nation. (2) This weighting is different from that used in the national panel and cannot be compared (3) Data are collected from multi-thread download speed tests.

[7] Source: SamKnows measurement data for all national panel members with a connection in November 2016. Panel base: 2023 (ADSL1 – 130; ADSL2+ - 643; FTTC38 – 368; FTTC52 – 164; FTTC 76 – 256; cable 'up to' 50Mbit/s 68; cable 'up to' 100Mbit/s 88 and cable 'up to 200Mbit/s' 326)
Notes: (1) Data have been weighted by ISP package market share, rural/urban and geographic market classification, max attainable speed (FTTC) and distance from exchange (ADSL) to ensure that they are representative of the UK as a whole; (2) Data are collected from multi-thread download speed tests; (3) Due to the low representation of high-speed cable packages in the UK, ISP panel results are used for cable 'up to' 50Mbit/s, cable 'up to' 100Mbit/s and cable 'up to' 200Mbit/s (4) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

[8] Source: SamKnows measurement data for all national panel members with a connection in November 2016. Panel base: 2023 (ADSL1 – 130; ADSL2+ - 643; FTTC38 – 368; FTTC52 – 164; FTTC 76 – 256; cable 'up to' 50Mbit/s 68; cable 'up to' 100Mbit/s 88 and cable 'up to 200Mbit/s' 326)
Notes: (1) Data have been weighted by ISP package market share, rural/urban and geographic market classification, max attainable speed (FTTC) and distance from exchange (ADSL) to ensure that they are representative of the UK as a whole; (2) Data are collected from multi-thread download speed tests; (3) Due to the low representation of high-speed cable packages in the UK, ISP panel results are used for cable 'up to' 50Mbit/s, cable 'up to' 100Mbit/s and cable 'up to' 200Mbit/s (4) As some operators ensure that headline speeds are met by over-provisioning their networks, maximum is taken either as the maximum or headline speed for that line dependent on which is lowest. (5) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

[9] Source: SamKnows measurement data for all national panel members with a connection in November 2016. Panel base: 2023 (urban: ADSL1 – 19; ADSL2+ - 438; FTTC38 – 299; FTTC52 – 126; FTTC 76 – 237; cable 'up to' 50Mbit/s 66; cable 'up to' 100Mbit/s 88 and cable 'up to 200Mbit/s' 329; Rural: ADSL1 – 111; ADSL2+ - 205; FTTC38 – 69; FTTC52 – 38; FTTC 76 – 19)
Notes: (1) Data have been weighted by ISP package market share, rural/urban and geographic market classification, max attainable speed (FTTC) and distance from exchange (ADSL) to ensure that they are representative of the UK as a whole; (2) Data are collected from multi-thread download speed tests; (3) Due to the low representation of high-speed cable packages in the UK, ISP panel results are used for cable 'up to' 50Mbit/s, cable 'up to' 100Mbit/s and cable 'up to' 200Mbit/s; (4) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

[10] Source: SamKnows measurement data for all panel members with a connection in November 2016 where density and nation data available. Panel base: 4367 (England urban 2757; England rural 701; Scotland urban 308; Scotland rural 165; Wales urban 170; Wales rural 140; Northern Ireland Urban 84 and Northern Ireland rural 42)
Notes: (1) Data have been weighted by rural/urban with nation and by the profile of lines by technology and speed as given in Ofcom's Connected Nations report of August 2016 to be representative with nation. (2) This weighting is different from that used in the national panel and cannot be compared (3) Data are collected from multi-thread download speed tests; (4) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

[11] Source: SamKnows measurement data for all national panel members with a connection in November 2016. Panel base: 2023 (above 'up to 2Mbit/s' and 'up to' and including 10Mbit/s" – 130; above 'up to 10Mbit/s and less than 'up to' 30Mbit/s - 643; 'Up to 30Mbit/s and higher – 1250)
Notes: (1) Data have been weighted by ISP package market share, rural/urban and geographic market classification, max attainable speed (FTTC) and distance from exchange (ADSL) to ensure that they are representative of the UK as a whole; (2) The above 'up to' 10Mbit/s and less than than 'up to' 30Mbit/s includes ADSL2+ connections which are not marketed using a connection speed.

[12] Source: SamKnows measurement data for all national panel members with a connection in November 2016. Panel base: 2023 (ADSL1 – 130; ADSL2+ - 643; FTTC38 – 368; FTTC52 – 164; FTTC 76 – 256; cable 'up to' 50Mbit/s 68; cable 'up to' 100Mbit/s 88 and cable 'up to 200Mbit/s' 326)
Notes: (1) Data have been weighted by ISP package market share, rural/urban and geographic market classification, max attainable speed (FTTC) and distance from exchange (ADSL) to ensure that they are representative of the UK as a whole; (2) Due to the low representation of high-speed cable packages in the UK, ISP panel results are used for cable 'up to' 50Mbit/s, cable 'up to' 100Mbit/s and cable 'up to' 200Mbit/s; (3) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

[13] Source: SamKnows measurement data for all national panel members with a connection in November 2016. Panel base: ADSL2+ - 643
Notes: (1) Data have been weighted by ISP package market share, rural/urban and geographic market classification, and distance from exchange (ADSL) to ensure that they are representative of the UK as a whole; (2) Data are collected from multi-thread download speed tests.

[14] Source: SamKnows measurement data for all national panel members with a connection in November 2016. Panel base: Cable 'up to' 50Mbit/s 68
Notes: (1) Due to the low representation of high-speed cable packages in the UK, ISP panel results are used for cable 'up to' 50Mbit/s, cable 'up to' 100Mbit/s and cable 'up to' 200Mbit/s; (2) Data are collected from multi-thread download speed tests.

[15] Source: SamKnows measurement data for all national panel members with a connection in November 2016. Panel base: Cable 'up to' 100Mbit/s 88
Notes: (1) Due to the low representation of high-speed cable packages in the UK, ISP panel results are used for cable 'up to' 50Mbit/s, cable 'up to' 100Mbit/s and cable 'up to' 200Mbit/s; (2) Data are collected from multi-thread download speed tests.

[16] Source: SamKnows measurement data for all national panel members with a connection in November 2016. Panel base: Cable 'up to' 200Mbit/s 334
Notes: (1) Due to the low representation of high-speed cable packages in the UK, ISP panel results are used for cable 'up to' 50Mbit/s, cable 'up to' 100Mbit/s and cable 'up to' 200Mbit/s; (2) Data are collected from multi-thread download speed tests.

[17] Source: SamKnows measurement data for all national panel members with a connection in November 2016. Panel base: FTTC 'up to' 38Mbit/s 299
Notes: (1) Data have been weighted by ISP package market share, rural/urban and geographic market

classification, max attainable speed (FTTC) to ensure that they are representative of the UK as a whole; (2) Data are collected from multi-thread download speed tests.

[18] Source: SamKnows measurement data for all national panel members with a connection in November 2016.
Panel base: FTTC 'up to' 52Mbit/s 126
Notes: (1) Data have been weighted by ISP package market share, rural/urban and geographic market classification, max attainable speed (FTTC) to ensure that they are representative of the UK as a whole; (2) Data are collected from multi-thread download speed tests.

[19] Source: SamKnows measurement data for all national panel members with a connection in November 2016.
Panel base: FTTC 'up to' 52Mbit/s 237
Notes: (1) Data have been weighted by ISP package market share, rural/urban and geographic market classification, max attainable speed (FTTC) to ensure that they are representative of the UK as a whole; (2) Data are collected from multi-thread download speed tests.

[20] Source: SamKnows measurement data for all national panel members with a connection in November 2016.
Panel base: 2023 (ADSL1 – 130; ADSL2+ - 643; FTTC38 – 368; FTTC52 – 164; FTTC 76 – 256; cable 'up to' 50Mbit/s 68; cable 'up to' 100Mbit/s 88 and cable 'up to 200Mbit/s' 326)
Notes: (1) Data have been weighted by ISP package market share, rural/urban and geographic market classification, max attainable speed (FTTC) and distance from exchange (ADSL) to ensure that they are representative of the UK as a whole; (2) Due to the low representation of high-speed cable packages in the UK, ISP panel results are used for cable 'up to' 50Mbit/s, cable 'up to' 100Mbit/s and cable 'up to' 200Mbit/s.

[21] Source: SamKnows measurement data for all national panel members with a connection in November 2016.
Panel base: 2023 (ADSL1 – 130; ADSL2+ - 643; FTTC38 – 368; FTTC52 – 164; FTTC 76 – 256; cable 'up to' 50Mbit/s 68; cable 'up to' 100Mbit/s 88 and cable 'up to 200Mbit/s' 326)
Notes: (1) Data have been weighted by ISP package market share, rural/urban and geographic market classification, max attainable speed (FTTC) and distance from exchange (ADSL) to ensure that they are representative of the UK as a whole; (2) Due to the low representation of high-speed cable packages in the UK, ISP panel results are used for cable 'up to' 50Mbit/s, cable 'up to' 100Mbit/s and cable 'up to' 200Mbit/s (3) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

[22] Source: SamKnows measurement data for all ISP panel members with a connection in November 2016.
Panel base: BT ADSL2+ 143; EE ADSL2+ 72; KCOM ADSL2+ 80; Plusnet ADSL2+ 112; Sky ADSL2+ 190; TalkTalk ADSL2+ 161
Notes: (1) Data have been normalised to the UK profile by distance from exchange (ADSL) to ensure that operators can be compared on a like-for-like basis; (2) Data are collected from multi-thread download speed tests; (3) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

[23] Source: SamKnows measurement data for all ISP panel members with a connection in November 2016.
Panel base: BT ADSL2+ 143; EE ADSL2+ 72; KCOM ADSL2+ 80; Plusnet ADSL2+ 112; Sky ADSL2+ 190; TalkTalk ADSL2+ 161
Notes: (1) Data have been normalised to the UK profile by distance from exchange (ADSL) to ensure that operators can be compared on a like-for-like basis; (2) Data are collected from multi-thread download speed tests.

[24] Source: SamKnows measurement data for all ISP panel members with a connection in November 2016.
Panel base: BT 'up to' 52Mbit/s 282; EE 'up to' 38Mbit/s 104; Plusnet 'up to' 38Mbit/s 123; Sky 'up to' 38Mbit/s 199; TalkTalk 'up to' 38Mbit/s 158; Virgin 'up to' 50Mbit/s 68
Notes: (1) Data have been normalised to the UK profile by max attainable line speed (FTTC) to ensure that operators can be compared on a like-for-like basis; (2) Data are collected from multi-thread download speed tests; (3) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

[25] Source: SamKnows measurement data for all ISP panel members with a connection in November 2016.
Panel base: BT 'up to' 76Mbit/s 334; EE 'up to' 76Mbit/s 87; Plusnet 'up to' 76Mbit/s 326; Sky 'up to' 38Mbit/s 93; TalkTalk 'up to' 38Mbit/s 154; Virgin 'up to' 100Mbit/s 88; Virgin 'up to' 200Mbit/s 334
Notes: (1) Data have been normalised to the UK profile by max attainable line speed (FTTC) to ensure that operators can be compared on a like-for-like basis; (2) Data are collected from multi-thread download speed tests; (3) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

[26] Source: SamKnows measurement data for all ISP panel members with a connection in November 2016.
Panel base: BT 'up to' 52Mbit/s 282; EE 'up to' 38Mbit/s 104; Plusnet 'up to' 38Mbit/s 123; Sky 'up to' 38Mbit/s

199; TalkTalk 'up to' 38Mbit/s 158; Virgin 'up to' 50Mbit/s 68
Notes: (1) Data have been normalised to the UK profile by max attainable line speed (FTTC) to ensure that operators can be compared on a like-for-like basis; (2) Maximum speed is calculated as the average of the daily maximum speeds achieved throughout the month or the headline package speed dependent on which is lowest; (3) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

[27] Source: SamKnows measurement data for all ISP panel members with a connection in November 2016. Panel base: BT 'up to' 76Mbit/s 334; EE 'up to' 76Mbit/s 87; Plusnet 'up to' 76Mbit/s 326; Sky 'up to' 38Mbit/s 93; TalkTalk 'up to' 38Mbit/s 154; Virgin 'up to' 100Mbit/s 88; Virgin 'up to' 200Mbit/s 334.
Notes: (1) Data have been normalised to the UK profile by max attainable line speed (FTTC) to ensure that operators can be compared on a like-for-like basis; (2) Maximum speed is calculated as the average of the daily maximum speeds achieved throughout the month or the headline package speed dependent on which is lowest; (3) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

[28] Source: SamKnows measurement data for all ISP panel members with a connection in November 2016. Panel base: BT 'up to' 52Mbit/s 282; EE 'up to' 38Mbit/s 104; Plusnet 'up to' 38Mbit/s 123; Sky 'up to' 38Mbit/s 199; TalkTalk 'up to' 38Mbit/s 158; Virgin 'up to' 50Mbit/s 68.
Notes: (1) Data have been normalised to the UK profile by max attainable line speed (FTTC) to ensure that operators can be compared on a like-for-like basis; (2) Maximum speed is calculated as the average of the daily maximum speeds achieved throughout the month or the headline package speed, dependent on which is lowest.

[29] Source: SamKnows measurement data for all ISP panel members with a connection in November 2016. Panel base: BT 'up to' 76Mbit/s 334; EE 'up to' 76Mbit/s 87; Plusnet 'up to' 76Mbit/s 326; Sky 'up to' 38Mbit/s 93; TalkTalk 'up to' 38Mbit/s 154; Virgin 'up to' 100Mbit/s 88; Virgin 'up to' 200Mbit/s 334.
Notes: (1) Data have been normalised to the UK profile by max attainable line speed (FTTC) to ensure that operators can be compared on a like-for-like basis; (2) Maximum speed is calculated as the average of the daily maximum speeds achieved throughout the month or the headline package speed, dependent on which is lowest.

[30] Source: SamKnows measurement data for all ISP panel members with a connection in November 2016. Panel base: BT ADSL2+ 143; EE ADSL2+ 72; KCOM ADSL2+ 20; Plusnet ADSL2+ 112; Sky ADSL2+ 190; TalkTalk ADSL2+ 161.
Notes: (1) Data have been normalised to the UK profile by distance from exchange (ADSL) to ensure that operators can be compared on a like-for-like basis; (2) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

[31] Source: SamKnows measurement data for all ISP panel members with a connection in November 2016. Panel base: BT 'up to' 52Mbit/s 282; EE 'up to' 38Mbit/s 104; Plusnet 'up to' 38Mbit/s 123; Sky 'up to' 38Mbit/s 199; TalkTalk 'up to' 38Mbit/s 158; Virgin 'up to' 50Mbit/s 68
Notes: (1) Data have been normalised to the UK profile by max attainable line speed (FTTC) to ensure that operators can be compared on a like-for-like basis; (2) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

[32] Source: SamKnows measurement data for all ISP panel members with a connection in November 2016. Panel base: BT 'up to' 76Mbit/s 334; EE 'up to' 76Mbit/s 87; Plusnet 'up to' 76Mbit/s 326; Sky 'up to' 38Mbit/s 93; TalkTalk 'up to' 38Mbit/s 154; Virgin 'up to' 100Mbit/s 88; Virgin 'up to' 200Mbit/s 334
Notes: (1) Data have been normalised to the UK profile by max attainable line speed (FTTC) to ensure that operators can be compared on a like-for-like basis; (2) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

[33] Source: SamKnows measurement data for all ISP panel members with a connection in November 2016. Panel base: BT ADSL2+ 143; EE ADSL2+ 72; KCOM ADSL2+ 80; Plusnet ADSL2+ 112; Sky ADSL2+ 190; TalkTalk ADSL2+ 161
Notes: (1) Data have been normalised to the UK profile by distance from exchange (ADSL) to ensure that operators can be compared on a like-for-like basis.

[34] Source: SamKnows measurement data for all ISP panel members with a connection in November 2016. Panel base: BT 'up to' 52Mbit/s 282; EE 'up to' 38Mbit/s 104; Plusnet 'up to' 38Mbit/s 123; Sky 'up to' 38Mbit/s 199; TalkTalk 'up to' 38Mbit/s 158; Virgin 'up to' 50Mbit/s 68
Notes: (1) Data have been normalised to the UK profile by max attainable line speed (FTTC) to ensure that operators can be compared on a like-for-like basis.

[35] Source: SamKnows measurement data for all ISP panel members with a connection in November 2016. Panel base: BT 'up to' 76Mbit/s 334; EE 'up to' 76Mbit/s 87; Plusnet 'up to' 76Mbit/s 326; Sky 'up to' 38Mbit/s 93; TalkTalk 'up to' 38Mbit/s 154; Virgin 'up to' 100Mbit/s 88; Virgin 'up to' 200Mbit/s 334

Notes: (1) Data have been normalised to the UK profile by max attainable line speed (FTTC) to ensure that operators can be compared on a like-for-like basis.

[36] Source: SamKnows measurement data for all ISP panel members with a connection in November 2016. Panel base: BT ADSL2+ 143; EE ADSL2+ 72; KCOM ADSL2+ 20; Plusnet ADSL2+ 112; Sky ADSL2+ 190; TalkTalk ADSL2+ 161
Notes: (1) Data have been normalised to the UK profile by distance from exchange (ADSL) to ensure that operators can be compared on a like-for-like basis; (2) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

[37] Source: SamKnows measurement data for all ISP panel members with a connection in November 2016. Panel base: BT 'up to' 52Mbit/s 282; EE 'up to' 38Mbit/s 104; Plusnet 'up to' 38Mbit/s 123; Sky 'up to' 38Mbit/s 199; TalkTalk 'up to' 38Mbit/s 158; Virgin 'up to' 50Mbit/s 68
Notes: (1) Data have been normalised to the UK profile by max attainable line speed (FTTC) to ensure that operators can be compared on a like-for-like basis; (2) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

[38] Source: SamKnows measurement data for all ISP panel members with a connection in November 2016. Panel base: BT 'up to' 76Mbit/s 334; EE 'up to' 76Mbit/s 87; Plusnet 'up to' 76Mbit/s 326; Sky 'up to' 38Mbit/s 93; TalkTalk 'up to' 38Mbit/s 154; Virgin 'up to' 100Mbit/s 88; Virgin 'up to' 200Mbit/s 334
Notes: (1) Data have been normalised to the UK profile by max attainable line speed (FTTC) to ensure that operators can be compared on a like-for-like basis; (2) The bars indicate that there is a 95% probability that the actual average speed for all corresponding consumers fall within the given range.

Annex 1

Technical and research methodologies

Technical methodology

This report is Ofcom's thirteenth fixed-line residential broadband speeds report and the tenth in which we have published ISP package-specific data and comparisons between ISPs. The technical methodology chosen is the same as that used in Ofcom's previous reports and is based on that created by broadband performance company SamKnows Limited, Ofcom's technical partner in this research project.

SamKnows recruited a panel of UK residential broadband users and supplied monitoring units to each panellist. SamKnows also managed the collection and aggregation of the performance data and made a major contribution in assisting Ofcom in the analysis of the data.

All panellists were sent a hardware monitoring unit which they were instructed to connect to their router. The monitoring unit sits between the panellist's router and the rest of their network, thereby allowing the unit to determine when the network is free to run tests (the device operates in a bridging mode, rather than routing).

The measurement units are connected to panellists' routers using an Ethernet cable in order that the test results accurately reflect the performance of their connections. Where consumers use Wi-Fi (or other technologies such as powerline) to connect devices to their router, it is possible that the actual speeds received will be lower than those delivered over an Ethernet connection as a result of the limitations of these technologies (although recent mass market Wi-Fi technologies can theoretically support speeds in excess of 300Mbit/s). The potential for this difference is greater for higher-speed broadband connections, where the speeds delivered may be higher than the maximum bandwidth that the in-home network technology is capable of supporting.

SamKnows developed a customised OpenWRT firmware image which is installed on the units. At the point of delivery to the panellists, this is all that is present on the device; the physical unit contains no additional software, apart from a single script that checks for the availability of the software component at boot-up. This is beneficial both from a security perspective (everything is destroyed when the power is lost) and from a support perspective (any problems with a unit's configuration can be undone simply by power-cycling it). New versions of the software can be delivered remotely without requiring a reboot.

Software within the unit then performed a range of tests to a set schedule, running over 14,000 separate tests from each panellist over the course of a day. The software was configured to identify other network activity and not to run tests when such activity was detected. This avoided compromising results by running tests at a time when bandwidth was being used by other internet-connected devices in the household (including those using a wireless connection).

The software uses a combination of standard UNIX tools and customer code developed in the C programming language.

All monitoring units maintain accurate time using ntp.

We believe that this technical methodology is robust as it does not rely on monitoring solutions that do not account for the impact on speed of PC set-up, or for having more than one computer using a broadband connection.

Speed tests

The project uses speed tests with multiple concurrent TCP connections, to assess the capacity of the user's broadband connection.

Speed tests run for a fixed duration of 10 seconds if the user's broadband connection is not subject to a data cap or has had it lifted for the purposes of this project. Fixed-duration speed tests ensure comparability across broadband connections regardless of their access speed.

On connections with data caps still in place, units download 3 x 2MB files using separate TCP sessions (in parallel). Connections faster than 30Mbit/s will transfer an increased amount during the downstream throughput test. This amount is up to 12MB (3 x 4MB files) or 10 seconds (whichever is reached first). Connections of 50Mbit/s or faster are all without data caps and therefore employ the full 10-second speed test.

The nature of the protocols used on the internet means that during a file download the speed at which data is sent is gradually increased until a stable speed is achieved. To measure this stable speed, our tests exclude the period of the speed ramp-up. The exact way the speed ramp-up occurs on different networks may lead to slight variations in the accuracy with which the stable speed can be measured.

An initial lead-in period is used to ensure that TCP window sizes are increased before measurements are made. Multi-thread tests were run nine times per day, once every six hours in off-peak periods and once every hour at peak times. We found that, typically, the download speeds achieved using the multi-thread tests in the early hours of the day determine the maximum speed the line can support.

Additionally, it is understood that some ISPs operate transparent HTTP proxy servers on their networks. To overcome this, the web servers are configured to respond with the following headers, which should disable caching in standards-compliant proxy servers:

Cache-Control: "private, pre-check=0, post-check=0, max-age=0"

Expires: 0

Pragma: no-cache

Upload tests are performed for a fixed duration of 10 seconds for connections without data caps or those with an upload speed of 20Mbit/s or faster. For those with data caps, upload tests were performed using 3 x 1MB files with a similar initial lead-in period to that used for download tests. Connections with upload speeds faster than 10Mbit/s will transfer an increased amount during the upstream throughput test. This amount is up to 6MB. Six speed-test servers are deployed in a range of different data centres in and immediately around London to handle the traffic. 12Gbit/s of capacity is shared between these servers. Each server is monitored for excessive network load and for CPU, disk and memory load. The test results gathered by each server are compared against one another daily, to ensure that there is no significant variation in the speed attainable per server. Units cycle through the speed-test servers in a round-robin fashion when testing.

Testing web page loading times

The test downloaded the HTML and media assets of a simple web page hosted on a SamKnows-managed server. This makes use of up to eight concurrent TCP connections to fetch the assets. Both tests make use of libcurl.

The time in milliseconds to receive the complete response from the web server is recorded, as well as any failed attempts. A failed attempt is deemed to be one where the web server cannot be reached, or where a HTTP status code of something other than 200 is encountered.

Tests were run every hour.

Testing latency, packet loss and jitter

A bespoke application was used to test latency, packet loss and jitter. The application was designed to run continuously to get a statistically robust set of data. The test used UDP rather than ICMP and sent approximately 2000 packets every hour.

The test also records instances of contiguous packet loss events. These are termed 'disconnections'. The duration of the disconnection event will vary by its cause – a minor routing issue may only cause a few seconds' disconnection, whereas a modem losing synchronisation with the telephone exchange may result in a 30 second disconnection.

Testing recursive DNS resolver responsiveness and failures

Testing an ISP's recursive DNS resolution can be accomplished using many tools, such as nslookup, dnsip and dig. For the purposes of the research, dig was chosen for the flexibility it offers.

Typically, an ISP will have two or more recursive DNS resolvers. Rather than using the DNS servers provided by the DHCP leases to the testing units, the software on the units tests the ISP DNS resolvers directly. This allows us to determine failure of a single DNS server. It also overcomes another issue – that of people changing the DNS servers being returned in DHCP leases from their router (this proved quite common with customers of some ISPs).

The tests record the number of milliseconds for a successful result to be returned. A successful result is deemed to be one when an IP address is returned (the validity of the IP address is not checked). A failure is recorded whenever the DNS server could not be reached or an IP address was not returned. The hostnames of four popular websites were queried every hour.

Testing Netflix video streaming performance

The Netflix test is an application-specific test, supporting the streaming of binary data from Netflix's servers using the same CDN selection logic as their real client uses. The test has been developed in direct cooperation with Netflix.

The test begins by calling a Netflix hosted web-based API. This API examines the client's source IP address and uses the existing proprietary internal Netflix logic to determine from which Netflix server this user's IP address would normally be served content. This logic will take into account the ISP and geographic location of the requesting IP address. Where the ISP participates in Netflix's Open Connect programme, it is likely that one of these servers will be used. The API will return to the client a HTTP 302 redirect to a 25MB binary file hosted on the applicable content server.

The test then establishes a HTTP connection to the returned server and attempts to fetch the 25MB binary file. This runs for a fixed 10 seconds of realtime. HTTP pipelining is used to request multiple copies of the 25MB binary, ensuring that if the payload is exhausted before the 10 seconds are complete, we can continue receiving more data. The client downloads data at full rate throughout; there is no client-side throttling taking place.

It is important to note that this 25MB binary content does not contain video or audio; it is just random binary data. However, with knowledge of the bitrates that Netflix streams content at, we can treat the binary as if it were video/audio content operating at a fixed rate. This allows us to determine the amount of data consumed for each frame of video (at a set bitrate) and the duration that it represents. Using this, we can then infer when a stall occurred (by examining when our simulated video stream has fallen behind realtime). The test currently simulates videos at bitrates of 235Kbps, 375Kbps, 560Kbps, 750Kbps, 1050Kbps, 1750Kbps, 2350Kbps, 3000Kbps, 4500Kbps, 6000Kbps and 15600Kbps.

This approach also allows the derivation of 'bitrate reliably streamed', using the same methodology as the YouTube test described above. A small difference here is that download at a lower bitrate does not need to be restarted if a stall is encountered; because the incoming stream of binary data is decoded at a simulated bitrate, the playback characteristics of the same network stream are simply computed at a different bitrate entirely on the client side. This simply means that the test uses a predictable amount of bandwidth, even in cases where stalls occur.

The test captures the 'bitrate reliably streamed' (the highest quality video that can be streamed without rebuffering events), the download speed from the Netflix Open Connect Appliance and the video startup delay.

Connections with usage caps

Some of the test units were deployed on broadband connections with relatively low usage caps. To avoid using a significant proportion of the available download limit each month, the test schedule for the test units on these connections was reduced.

Research methodology

The performance data in this report are taken from a base of 4,824 (including 1505 panelists leased from Samknows) panellists who had a broadband monitoring unit connected to their routers in November 2016. 0 sets out Ofcom's definitions of geographic broadband markets (based on the definitions for the wholesale broadband access (WBA) market13). These were an important consideration in recruiting our panel and applying statistical analysis, because they enabled us to ensure that our panel was representative of the UK residential broadband market overall, and facilitated like-for-like comparison between ISP packages:

- Each panellist was assigned to one of the geographic markets, and we weighted the analysis accordingly to ensure that our overall findings were representative of UK residential broadband performance overall (for example, as Market 1 represents 11.7% of UK premises, we ensured that performance data from panellists in Market 1

[13] The WBA market relates to the wholesale broadband products that CPs provide for themselves and sell to each other. See *Review of the wholesale broadband access markets: Statement on market definition, market power determinations and remedies*, 3 December 2010: (http://stakeholders.ofcom.org.uk/binaries/consultations/wba/statement/wbastatement.pdf).

contributed 11.7% towards the overall computation of UK residential broadband performance).

- For comparisons of ISP package performance we used only panellists who live within geographic markets 2 and 3. This means that all panellists used for the ISP package comparisons live in areas served by a local telephone exchange in which at least one operator other than BT is present, i.e. there is at least one local loop unbundling (LLU) operator. This avoids any potential distortions of the data by ISPs using BT wholesale services (BT Retail, EE and Plusnet), caused by the inclusion of panellists who live in (typically less densely populated) Market 1 areas, and to whom LLU services are not available.

Figure 1.1: Ofcom definitions of geographic broadband markets

Market	Description	Exchanges	Proportion of premises
The Kingston-upon-Hull area	Those geographic areas covered by exchanges where Kingston Communications is the only operator	14	0.7%
Market 1	Those geographic areas covered by exchanges where BT is the only operator	3,388	11.7%
Market 2	Those geographic areas covered exchanges where two Principal Operators are present or forecast AND exchanges where three Principal Operators are present or forecast but where BT's share is greater than or equal to 50 per cent	660	10.0%
Market 3	Those geographic areas covered by exchanges where four or more Principal Operators are present or forecast AND exchanges where three Principal Operators are present or forecast but where BT's share is less than 50 per cent	1,539	77.6%

Source: Ofcom, including Review of the wholesale broadband access markets: Statement on market definition, market power determinations and remedies*, December 2010 (http://stakeholders.ofcom.org.uk/binaries/consultations/wba/statement/wbastatement.pdf)*
Note: The operators classed as Principal Operators were BT, Cable & Wireless Worldwide, O2, EE, Sky, TalkTalk and, in local exchange areas where cable coverage exceeded 65% of premises, Virgin Media

We have used statistical techniques to adjust our results to ensure that they are representative of the overall UK broadband population. This includes weighting the results from our panel by rural/urban, distance from exchange, geographic market definition and ISP. For the provider-specific comparisons we have also 'normalised' the data for ADSL operators by distance from exchange (using the straight-line distance from the panellist's location to the exchange), which we believe is necessary in order to provide like-for-like comparisons of ISPs which have different customer profiles.

David Saville of Saville Rossiter-Base has made an assessment of the research methodology and panel and helped ensure its suitability for purpose. Checks were also applied to ensure that straight-line distance was an appropriate metric to carry out normalisation, including comparing this distance with the line attenuation. Details of the statistical methodology used are provided in Annex 2. The methods of analysis for the

provider-specific comparison are based on those used in the July 2009 report which had expert review by econometrician Professor Andrew Chesher of University College London[14].

[14] The July 2009 report set out our findings over the six-month period from November 2008 to April 2009 and is available at http://stakeholders.ofcom.org.uk/market-data-research/telecoms-research/broadband-speeds/broadband_speeds/

Annex 2

Statistical methodology

Key statistical concepts used in this report

This report presents the findings from research which has involved the collection and interpretation of 1.66 million data points. It has been a complex process, both technically and statistically.

The glossary in Annex 3 provides definitions of the technical terms we use throughout the report. However, knowledge of the following is important in order to understand how we have analysed the performance data collected.

- We present data in the report only in cases where there are sufficient data points to deliver a statistically sound result. This means that we report performance only when statistical analysis indicates that our findings are accurate enough to be useful. Accuracy is determined by the number of measurement tests undertaken, the size of the sample (number of panellists) and the variation (spread or range of results) between panellists.

- In order to acknowledge the limited accuracy of the estimates, and to ensure that we highlight only those differences that are statistically significant, for many charts we do not show a value but instead show a range around the mean value which indicates the statistical confidence we have in our results. The range we use is called a 95% confidence interval, which is a statistically-derived range calculated from the standard error (which is itself calculated from the sample size and the variation within the sample). A 95% confidence interval means that if we repeated the research with a different sample, assembled in the same way, there would be a 95% probability that the mean value would be in the range shown. Where we have large samples and/or little variation within the sample, the confidence interval is much narrower than where we have smaller samples and/or large variation within the sample. Differences are reported as significant if they are significantly different as judged by a two-tailed 5% test of statistical significance. In the tables where we present differences which are statistically significant we present differences which are significant to a 95% level of confidence, but also highlight those which are not significantly different to a 99% level of confidence.

- In order to ensure that the national data we present are representative of UK residential broadband users as a whole, we have weighted the data by ISP package, rural/urban split, market classification, distance from the exchange for ADSL packages and max attainable speed for FTTC packages.

- We have similarly weighted the data where we are comparing the performance of individual ISPs' packages, in order to ensure that the analysis provides a fair comparison of actual performance rather than reflecting random differences in the ISP package customer profiles in the sample.

- A difficulty in comparing ADSL and FTTC broadband providers is that with this technology, speed varies by the length and quality of the specific consumer's telephone line. Therefore, providers which have a higher proportion of customers in rural areas, where line lengths are typically longer, may be expected to deliver lower speeds on average than those which focus on towns and cities, simply because they have a different customer profile. For FTTC customers, the critical part of the line is that

between the customer's house and the cabinet – this section of the line is copper and subject to line degradation.

- To address this issue, we have taken the following steps:
    - For all ISP comparisons, we have included only consumers who live in an area where the exchange has been 'unbundled' by at least one LLU operator. This means that ISPs using wholesale services (such as BT Wholesale's IPstream or Wholesale Broadband Connect products) can be compared on a like-for-like basis with LLU operators.
    - We have excluded all ADSL customers where the straight-line distance from their home to the local telephone exchange is more than 5km, in order to limit the impact of outliers when weighting, and normalised data to straight-line distance distributions.
    - Straight-line distance weighting was applied only to ADSL operators in this report and not to cable or FTTC services, where performance is less influenced by distance from the exchange.
    - For FTTC customers, we do not have adequate information on distance between cabinet and customer premises. We therefore approximate this distance by normalising data using the max. attainable speed. The max. attainable speed is the best speed which a line can carry and is therefore a suitable proxy for measuring quality of the line.
    - For this report, in the light of the proposed change of methodology in relation to FTTC services, Virgin Media cable services have been compared to tier 1 and tier 2 FTTC services, which are weighted by market share, market and rural/urban split. In practice, as most FTTC services are in market 3 and urban areas, the main impact from the weighting comes from combining different ISPs by market share.
    - No weights are applied to Virgin cable packages, as these circuits are not affected by distance from the exchange or supplier cabinets.

Sample size

A panel of UK residential broadband users was drawn from a pool of over 40,000 volunteers following a recruitment campaign by SamKnows in March and April 2010. The objective was to obtain a representative panel, in order to monitor the performance of residential fixed-line broadband in the UK over a two-year period of research. In addition to obtaining a panel sufficient for monitoring changes in overall performance, the panel was recruited to enable specific analysis of the performance of the most common ISP packages in the UK, in particular higher-speed packages (with advertised 'up to' speeds of above 10Mbit/s).

A third round of recruitment took place between January and April 2011 to maintain and increase the panel and to enable reporting of the following ISP packages which had not previously been included: KCOM 'up to' 24Mbit/s, EE 'up to' 20Mbit/s, Plusnet 'up to' 20Mbit/s and Virgin Media 'up to' 30Mbit/s. A further 234 monitoring units were sent out to ensure a minimum sample of 50 panellists for each of these.

A fourth round of recruitment occurred between May 2012 and November 2012, to maintain the existing panel (in particular KC ADSL2+ and Plusnet ADSL2+) and to enable reporting of additional high-speed packages (BT's 'up to' 76Mbit/s FTTC service and Virgin Media's 'up

to' 60Mbit/s and 100Mbit/s services). In total 333 additional monitoring units were sent out. A fifth round of recruitment took place between November 2012 and May 2013 to maintain the existing panel and to enable reporting of additional high-speed services – Plusnet's 'up to' 38Mbit/s and 'up to' 78Mbit/s packages, and Virgin Media 'up to' 120Mbit/s service.

Between May 2013 and November 2013, further recruitment was undertaken to maintain the existing panel and enable reporting of two additional high-speed services – Everything Everywhere's 'up to 38Mbit/s' and Sky 'up to 38Mbit/s' services. Restrictions were placed allowing no more than two respondents per ISP by technology allowed on any exchange. Between May and November 2014, a further 182 boxes were issued to new panellists.

Between November 2014 and November 2015, a further 1,109 boxes were sent out. The purpose of this recruitment was to rebalance the panel and allow better reporting of national rural and urban data. In order to allow more robust rural and nation reporting, a further 2,411 boxes were sent out between November 2015 and October 2016 – these included boxes sent to ADSL1 and ADSL2 respondents in rural areas.

The current active panel also excludes customers with packages with headline speeds of 'up to' 2Mbit/s and less, because of the current low share of these connections (less than 0.1% of the total in November 2013). In our first round of research, conducted between October 2008 and April 2009, we found that the speeds delivered by 'up to' 2Mbit/s and less packages were consistent over time and between providers. In this report we have excluded data from 'up to' 2Mbit/s and less packages, due to their low market share

Prior to despatch of the monitoring units, volunteers were screened and preliminary speed measurements and checks on IP addresses were undertaken, in order to reduce the impact of respondent misconceptions regarding which package they were using on the sampling.

In total, 4,736 measurement units have been despatched since October 2008. Of the 1,453 which are not providing data, 600 were phased out, as not capable of reporting packages with speeds over 20Mbit/s. 4,344 of these were connected by panellists between 1 November and 30 November 2016. Of these, 2,023 supplied data to the UK average, and 3,126 to the named ISP package comparisons. This includes 1,505 panellists leased from SamKnows to ensure robust national, nations' and ISP coverage.

Figure 2.1: Panellist numbers

Sample set		Number
Total number of boxes dispatched		**3,250 (600 phased out)**
Total number of boxes connected – including 1,505 panellists leased from SamKnows (valid panellists- those who achieved 5 or more tests within the month for all metrics).		**4,344**
	Excluded because of missing data, (i.e. measurements, packages, distance)	224
	Used for nations analysis only	250
	Other Exclusions to improve UK sample weighting (i.e. distance, market classification, region, ISP)	78
Total participants included in UK Analysis		**2,023**
Total participants included in ISP Package Analysis		**3,126**

Source: Ofcom

All measurement data were collated and stored for analysis purposes as a monthly trimmed average of the measurements obtained for each respondent for the relevant time interval (e.g. 24 hours, 8 to 10pm weekday, 9am to 5pm Monday to Friday). Only panellists who provided a minimum of five valid measurements across all the download speeds tests for each time interval were included in the monthly analysis. A trimmed mean was used because, for a small proportion of respondents, the occasional test result was far in excess of what was achievable on the line. The top 0.5% of results per respondents did not count towards the average.

The average number of measurements per respondent for the 24-hour multi-thread download speed tests in November 2016 was 288, from a theoretical maximum of 360 per respondent (i.e. if all panellists had their monitoring unit connected on 1 May and all scheduled tests were run - tests were not run when the monitoring unit detected concurrent use of the bandwidth).

Average download speeds are generally very accurately measured, so the main factors limiting the accuracy of the analysis reported here are the number of panellists and the average number of measurements.

Quotas were set before the exact package market shares for operators were available, but results were weighted to be representative at national level. To recruit ISP packages to match the specific quota criteria above, and to achieve 100-150 panellists per package, only those ISP packages with more than 250,000 subscribers in total were targeted, although we do include ISP packages with less than 250,000 subscribers where we can recruit sufficient panellists, and where we believe a package is important enough to the future development of the market to warrant inclusion in the report.

Due to issues beyond our control, there were difficulties in recruiting specific geographies and packages for this report. Therefore, in enable to allow robust reporting, we leased 1,505 panellists from SamKnow's wider UK panels. Their data will be used for this report, but Ofcom seeks to recruit panellists unique to the Ofcom panel to fill these gaps.

The results and analysis of the 4,344 panellists' measurement results were divided into two separate datasets, each weighted to targets.

- **National panel** (over 'up to' 2Mbit/s packages): 2,023 panellists. All with at least five valid test measurements across all download tests, with a validated IP address, single measurement speed check, and distance and geographic market classification data.

- **ISP package panel**: 3,126 panellists. A subset of the national panel, consisting of panellists from geographic markets 2 and 3 only. Panellists from LLU operators Sky and TalkTalk and cable provider Virgin Media were on-net only. There was a target of 100 valid panellists for each ISP package, but the criterion for inclusion in the reporting was an effective sample minimum of 50 valid panellists (those with a base of fewer than 75 should be treated with caution).

Additional validation for the ISP package panel included a review of measured speed against straight-line distance from the exchange to the panellist's premises, and a review of outliers. Any package reassignment identified was made to both the ISP package panel and the national panel datasets.

Sample weighting

Two weighting classifications wereapplied to the data:

- **National panel**. Weighting by ISP market and package shares by LLU/ non-LLU connections supplied by ISPs as at November 2016, urban/rural, geographic market classification, xDSL distance to exchange (fitted to UK representative exchange line distribution provided by BT Openreach) and max attainable normalisation for FTTC lines.

- **ISP package panel.** Weighting to distance from exchange (those panellists with an unrecorded or straight-line distance to the exchange of more than 5km were excluded):

    - **ADSL2+ packages** were normalised by distance from exchange, to the aggregated distribution of straight-line distance between premises and exchanges of all panellists on those headline packages

    - **FTTC packages** were normalised to the appropriate max attainable speed curve that matched the headline package speed (38Mbit/s or 76Mbit/s) and to the installation method – self or engineer install. BT Openreach provided four curves – 38Mbit/s self and engineer install, and 76Mbit/s self and engineer install

    - **Cable packages** are not weighted, as speed of services is not directly related to distance from the exchange

- As mentioned previously, our measurement approach does not take account of respondent-specific issues, such as wiring, which may influence the speed of connection. Such variations have most impact on high-speed services where a respondent has a short line length. We assessed several methods of accommodating this issue and asked Saville Rossiter-Base for guidance.

- The conclusion was that allowing for variance across the sample, based on line length, would not necessarily lead to the widening of confidence intervals to build in this element of respondent variability. This is because the calculation of confidence intervals requires a constant mean and standard error across the sample or sub-sample under review. If we allow variance to differ by band, we would also need to allow the mean to differ by distance band. Leaving aside the increased complexity of the calculation, allowing the mean to differ by distance band to reflect respondent difference would reduce the variance in each band and reduce the confidence intervals for pooled estimate of the mean across the whole sample. The following calculation, based on all non-cable ‘up to’ 20Mbit/s packages in May 2012, shows this to be the case.

Figure 2.2: Variation of mean and variance, by distance band

Distance band	Sample	Mean	Variance	Standard Deviation
1	62	12.91482	13.95910	3.73619
2	68	11.60854	9.42604	3.07019
3	74	8.73505	10.31055	3.21101
4	78	5.87748	9.55572	3.09123
5	67	2.90284	5.73256	2.39428

Source: Ofcom

The average variance across the five cells is 9.8, giving a standard deviation of 3.1, giving a confidence interval of 8.48 +/- 0.3Mbit/s. But the overall standard deviation, if mean is held constant, is 4.7, which would give a confidence interval of 8.48 +/- 0.5Mbit/s. The current

methodology therefore overestimates the variance in the sample and hence the confidence intervals.

Assigning panellists to ISP and broadband package

The following process was applied, to select panellists and assign them to the correct ISP package:

- Volunteer panellists (who registered at www.samknows.com/broadband/signup/ofcom) were required to provide their ISP, package name, headline speed and download limit from drop-down menus and/or text boxes provided in an online form. This was used as initial categorisation of potential candidates against the target quotas.
    - The stated package name and headline speed (where they allowed identification of the correct ISP package) were used to assign panellists to an ISP package.
- Volunteers who matched the sample criteria were screened by ISP package, and an average speed reading estimate was obtained to screen actual versus stated package. Those who were successfully screened were sent monitoring units.
    - The stated ISP allocation was validated against IP address. When an IP address and stated ISP were inconsistent or missing, the volunteer was rejected. When an average speed measurement was outside the feasible range, the volunteer was flagged, and a monitoring unit box dispatched if sample required for the assessed package.
- Once the volunteer correctly connected the monitoring unit and test measurements were received, straight-line distance from home to exchange and geographic market classification were added to the measurement data.
- A further stage of ensuring that respondents were assigned to the correct ISP package took place before the analysis stage. Four steps were undertaken:
    - The initial assumption was that the package assignment, recorded in the panel data file, was correct. However, the ISPs were asked to verify that respondents were on the correct package.
    - However, those participants whose stated and measured package assignments or ISP were not consistent, and could not be definitively reconciled, were excluded from the comparison data. Only those panellists with an ADSL connection, who were connected to an ADSL2+ enabled exchange, were considered for the ‘up to’ 20Mbit/s and 24Mbit/s package allocation. The above modification (upload speed assignment) was necessary to identify those customers using ADSLMax on an ADSL2+ exchange.

Weighting to distance from exchange

As performance of ADSL broadband is significantly affected by the length of the line between a consumer’s premises and the local exchange, any comparison between ISPs or technology could be affected by the distribution of distance among the sample.

It was therefore necessary to weight the data by distance from exchange in order to provide like-for-like comparison between the previously published data, ISPs' packages and technology, to ensure that any differences identified were due to differing performance and not due to a differing distribution of line lengths.

Distance from premises to local exchange was captured as the straight-line ('as the crow flies') distance, measured from the full postcodes of premises to the local exchange. Different weights by distance were applied to each of the UK national, 'up to' 8Mbit/s and 'up to' 10Mbit/s and 'up to' 20Mbit/s and 'up to' 24Mbit/s datasets.

Weighting fibre packages

Although fibre technologies show little speed degradation between the local exchange and the final point where fibre is present, most respondents with fibre have FTTC only. This means that the length of the co-axial cable between the cabinet and the consumer premises can have a significant impact on speed. As the FTTC network is being rolled out into more rural areas, the distribution of distance from the cabinet becomes important, as rural lines tend to be longer than urban.

In a similar manner as weighting to distance from exchange for ADSL, Ofcom has decided to normalise for distance from cabinet for FTTC products, to ensure a like-for-like comparison. An identical model to ADSL, based on straight-line distances from the cabinet, is not possible, as the relevant cabinet for many premises will be in the same postcode. Therefore, a proxy for distance from cabinet was used – this is maximum attainable speed. This is a network metric which assesses the line and determines the maximum speed it can carry. BT Openreach provided the maximum attainable speed for each panellist, and also the profile of fibre lines in the UK. Each ISP's respondent profile is adjusted to match the national profile and weighted accordingly to ensure like-for-like comparisons.

Ofcom uses a single curve for each speed, which does not discriminate between respondents with self and engineer installed lines

National panel

The national sample was weighted to match the line length distribution of the UK xDSL population, as provided by BT Openreach.

ISP package panel

The ISP package comparisons were made for subscribers in geographic markets 2 and 3, and, where appropriate, for LLU/on-net connections only. The line lengths in geographic markets 2 and 3 are typically much shorter than the UK average, and it was not appropriate to weight to the national average, as previously.

BT Openreach provided an estimated distribution of line lengths. There were statistically distinct differences between the distribution of line lengths for panellists on ADSL1 packages and for those on ADSL2+ packages; the same target distribution could not be used for both. The higher-speed ISP packages had lower numbers that were more than 2km from the exchange, and to avoid missing out weighting categories, the same distance bands could not be used.

Instead, the ADSL2+ packages were normalised by weighting each to the aggregate distribution of line length among all ADSL2+ panellists.

Nation comparison

For this analysis, an alternative weighting was used. All ADSL and FTTC data were normalised to the UK distance from exchange and max attainable speed profile of lines, as applicable. The data were further weighted to the urban/ rural split by technology within nation. However, as the data used to derive the profile of each nation (Ofcom's *Connected Nations*) do not differentiate between ADSL and FTTC types, these products were profiled according to the proportion falling into each of these speed categories – 'up to' 10 Mbit/s (ADSL), over 10 but under 20 Mbit/s (ADSL), under 40 Mbit/s (FTTC), over 40 Mbit/s but under 55 Mbit/s (FTTC), and over 55 Mbit/s (FTTC). Cable speeds were given. Due to this speed-based rather than pure technology weighting, it is not expected that the nations' data should be compared to the national sample.

Weighting methodology

Straight-line distance from premises to exchange was coded into two sets of distance bands, one for national and ISP ADSL1 packages, and one for ISP ADSL2+ packages. The size of each distance band was set to achieve approximately ten observations in each band in the sample, given the number of connected panellists.

For all respondents in a given distance band, the average measurement value was weighted (up or down) in proportion to the ratio of respondents in that band in the target distribution, and that observed in the relevant panel dataset.

Weighting efficiency

Overall, against the entire weighting framework, the national panel achieved a weighting efficiency of 75%. The under-0.5s are primarily driven by the over-representation (against current market shares) both of higher speed packages and shorter line lengths in the panel. The over-2s are driven by the interaction between market shortfall and distance from exchange.

Figure 2.3: National panel range of weights

Range	Count	Column N%
Less than 0.5	58	4%
0.5 to 1	601	42%
1 to 1.5	723	50%
1.5 to 2	17	1%
2 to 3	50	3%

Source: Ofcom

Overall, against the entire weight frame, the ISP package panel achieved a weighting efficiency of 89%. This is because Virgin Media cable packages are not weighted, as distance from exchange does not impair download speeds.

Figure 2.4: ISP package panel range of weights

Weights	Count	Column N %
Less than 0.5	121	4%
0.5 to 1	1517	48%
1 to 1.5	1294	41%
1.5 to 2	80	3%
2+	114	4%

Source: Ofcom

Figure 2.5: Weighting efficiency, by ISP package

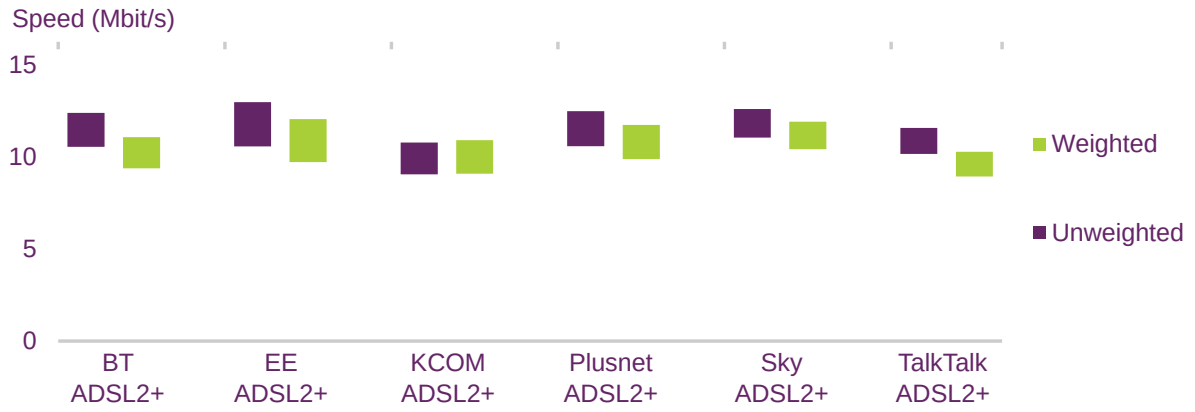
ISP package	Weighting efficiency
BT ADSL2+	68%
KC ADSL2+	82%
EE ADSL2+	89%
Plusnet ADSL2+	91%
Sky ADSL2+	93%
TalkTalk ADSL2+	75%
BT 'up to' 52Mbit/s	100%
EE 'up to' 38Mbit/s	93%
Plusnet 'up to' 38Mbit/s	81%
Sky 'up to' 38Mbit/s	94%
TalkTalk ‘up to’ 38 Mbit/s	96%
Virgin Media 'up to' 50Mbit/s	100%
BT 'up to' 76Mbit/s	83%
EE ‘up to’ 76 Mbit/s	70%
Plusnet 'up to' 76Mbit/s	100%
Sky ‘ up to’ 76 Mbit/s	91%
Talk Talk ‘up to’ 76 Mbit/s	87%
Virgin Media 'up to' 120Mbit/s	100%
Virgin Media 'up to' 152Mbit/s	100%

Source: Ofcom

Weighted and unweighted measurement data for ADSL2+ ISP packages

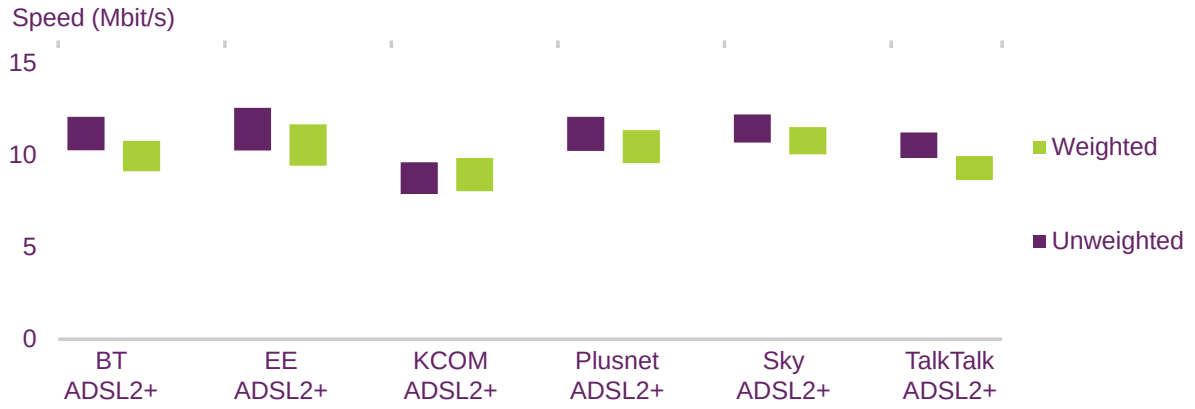
The effect of the combined overall ISP panel weighting on ADSL2+ ISP package performance is shown in the following tables.

Figure 2.6: Maximum download speeds for ADSL2+ ISP packages, weighted and unweighted figures: November 2016



Source: Ofcom, using data provided by SamKnows measurement data for all panel members with a connection in November 2016.
Panel base: BT ADSL2+ 143; EE ADSL2+ 72; KCOM ADSL2+ 80; Plusnet ADSL2+ 112; Sky ADSL2+ 190; TalkTalk ADSL2+ 161
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 2.7: Average download speeds for ADSL2+ ISP packages, 24 hours, weighted and unweighted figures: November 2016

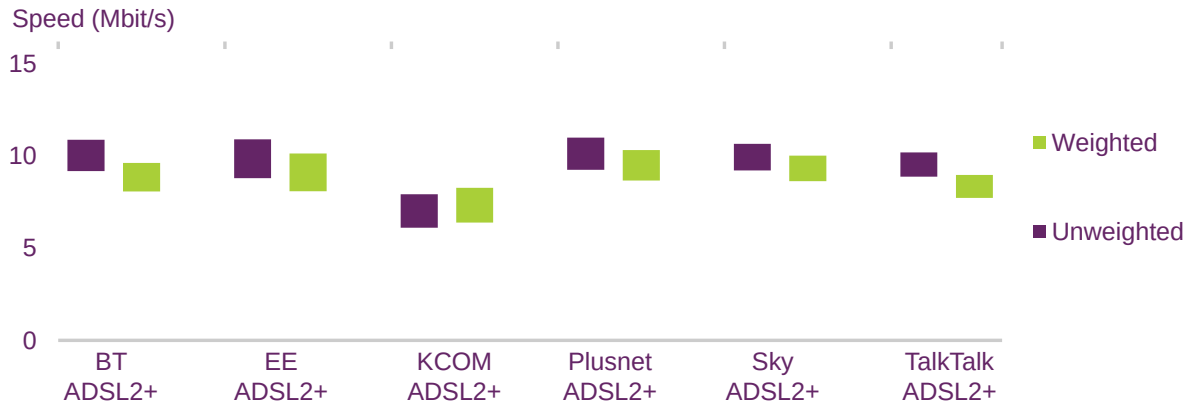


Source: Ofcom, using data provided by SamKnows measurement data for all panel members with a connection in November 2016.
Panel base: BT ADSL2+ 143; EE ADSL2+ 72; KCOM ADSL2+ 80; Plusnet ADSL2+ 112; Sky ADSL2+ 190; TalkTalk ADSL2+ 161
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 2.8: Peak-time download speeds for ADSL2+ ISP packages, 8pm to 10pm weekdays, weighted and unweighted figures: November 2016

Source: Ofcom, using data provided by SamKnows measurement data for all panel members with a connection in November 2016.
Panel base: BT ADSL2+ 143; EE ADSL2+ 72; KCOM ADSL2+ 80; Plusnet ADSL2+ 112; Sky ADSL2+ 190; TalkTalk ADSL2+ 161
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

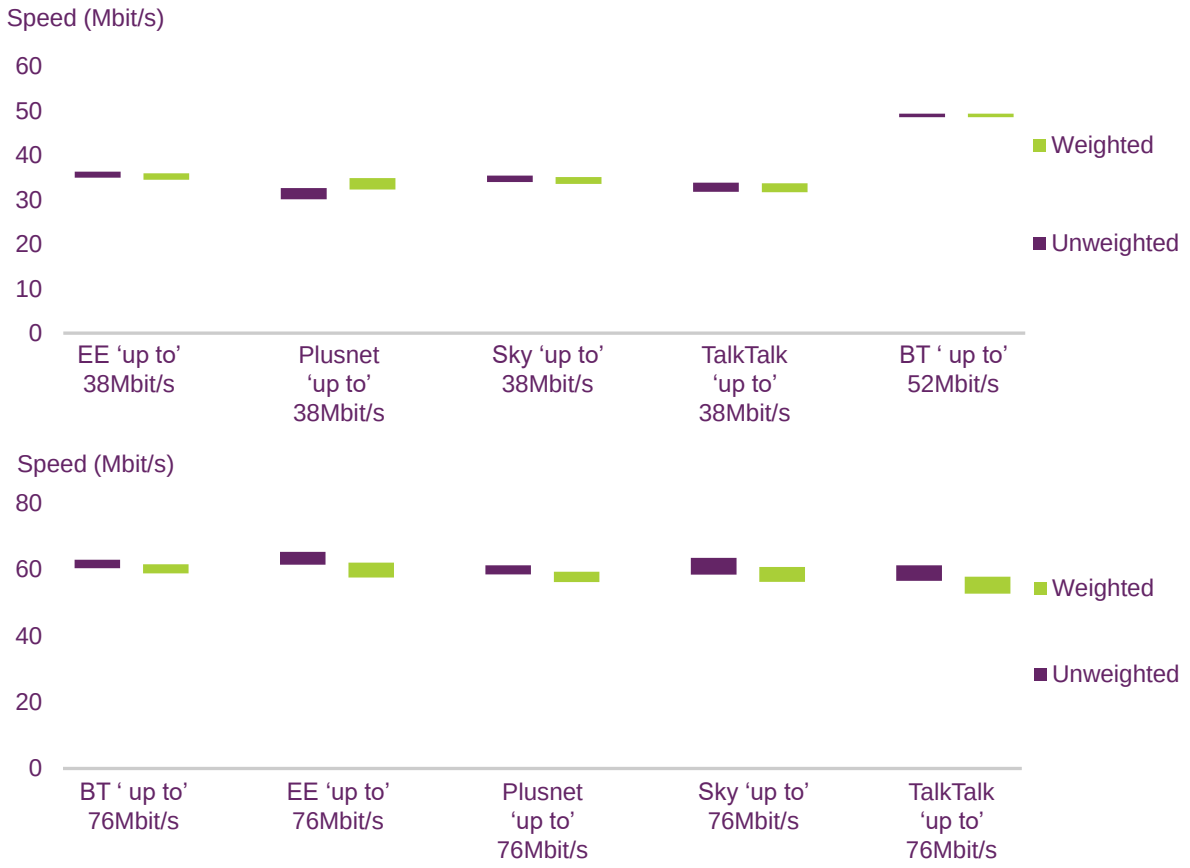
Figure 2.9: Minimum download speeds for ADSL2+ ISP packages, weighted and unweighted figures: November 2016



Source: Ofcom, using data provided by SamKnows measurement data for all panel members with a connection in November 2016.
Panel base: BT ADSL2+ 143; EE ADSL2+ 72; KCOM ADSL2+ 80; Plusnet ADSL2+ 112; Sky ADSL2+ 190; TalkTalk ADSL2+ 161
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange to ensure

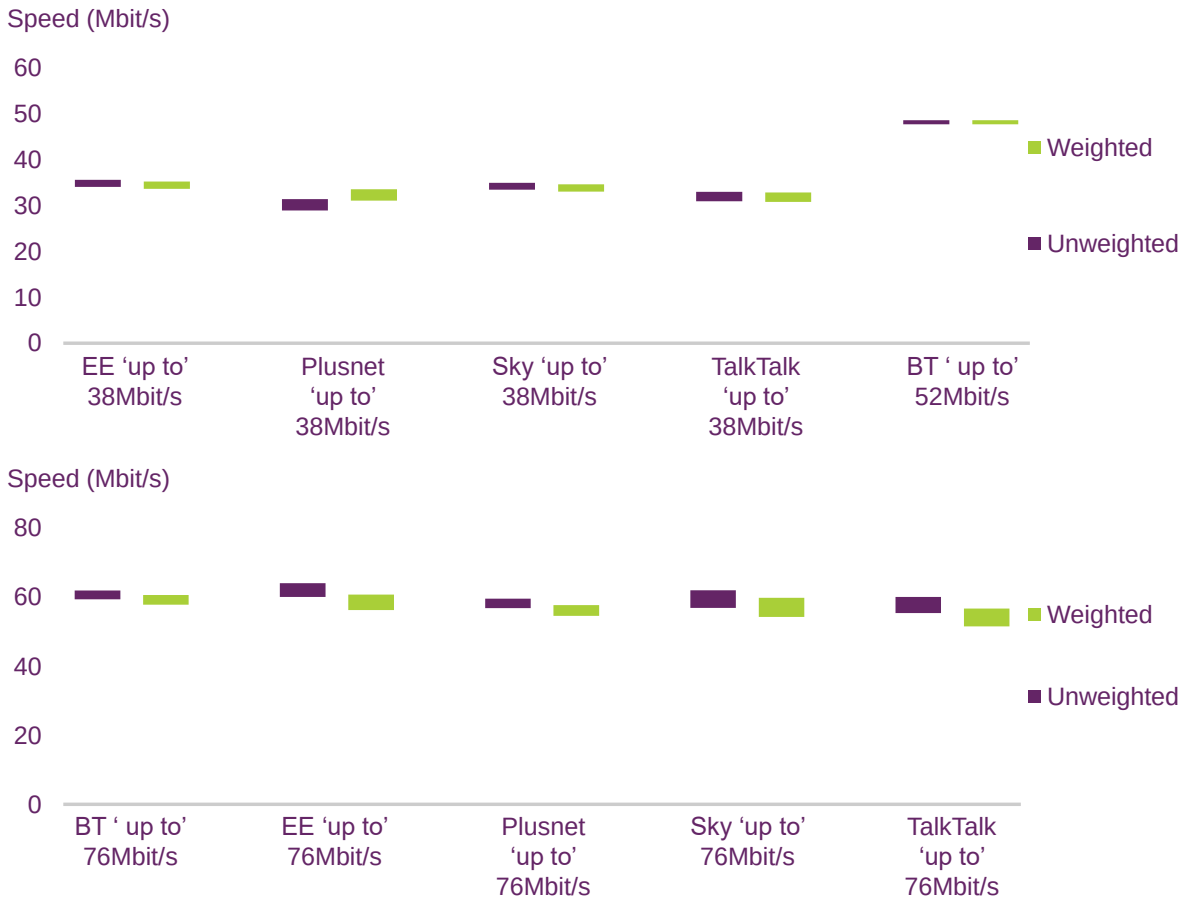
that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 2.10: Maximum download speeds for FTTC ISP packages, weighted and unweighted figures: November 2016



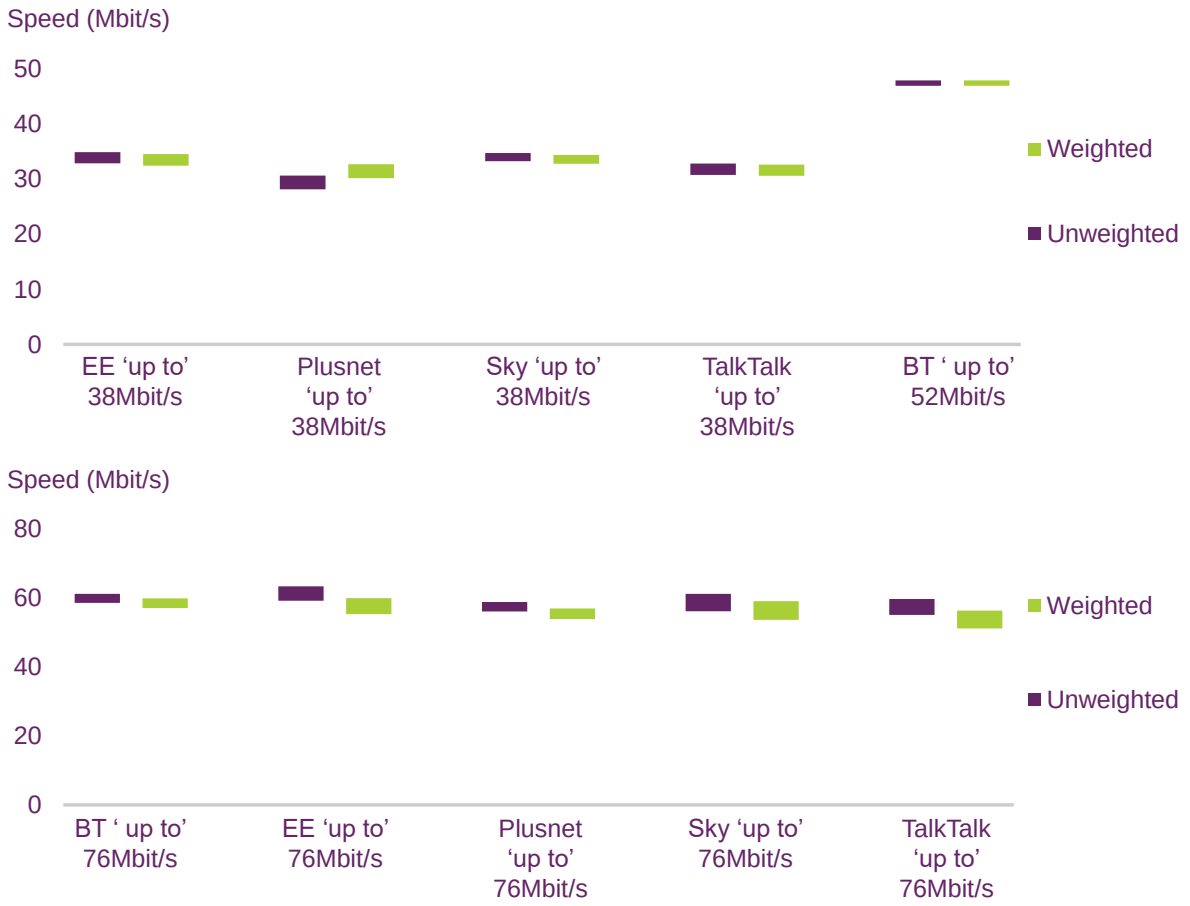
Source: SamKnows measurement data for all ISP panel members with a connection in November 2016.
Panel base: BT 'up to' 52Mbit/s 282; EE 'up to' 38Mbit/s 104; Plusnet 'up to' 38Mbit/s 123; Sky 'up to' 38Mbit/s 199; TalkTalk 'up to' 38Mbit/s 158; Virgin 'up to' 50Mbit/s 68, BT 'up to' 76Mbit/s 334; EE 'up to' 76Mbit/s 87; Plusnet 'up to' 76Mbit/s 326; Sky 'up to' 38Mbit/s 93; TalkTalk 'up to' 38Mbit/s 154; Virgin 'up to' 100Mbit/s 88; Virgin 'up to' 200Mbit/s 334
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 2.11: Average download speeds for FTTC ISP packages, weighted and unweighted figures: November 2016



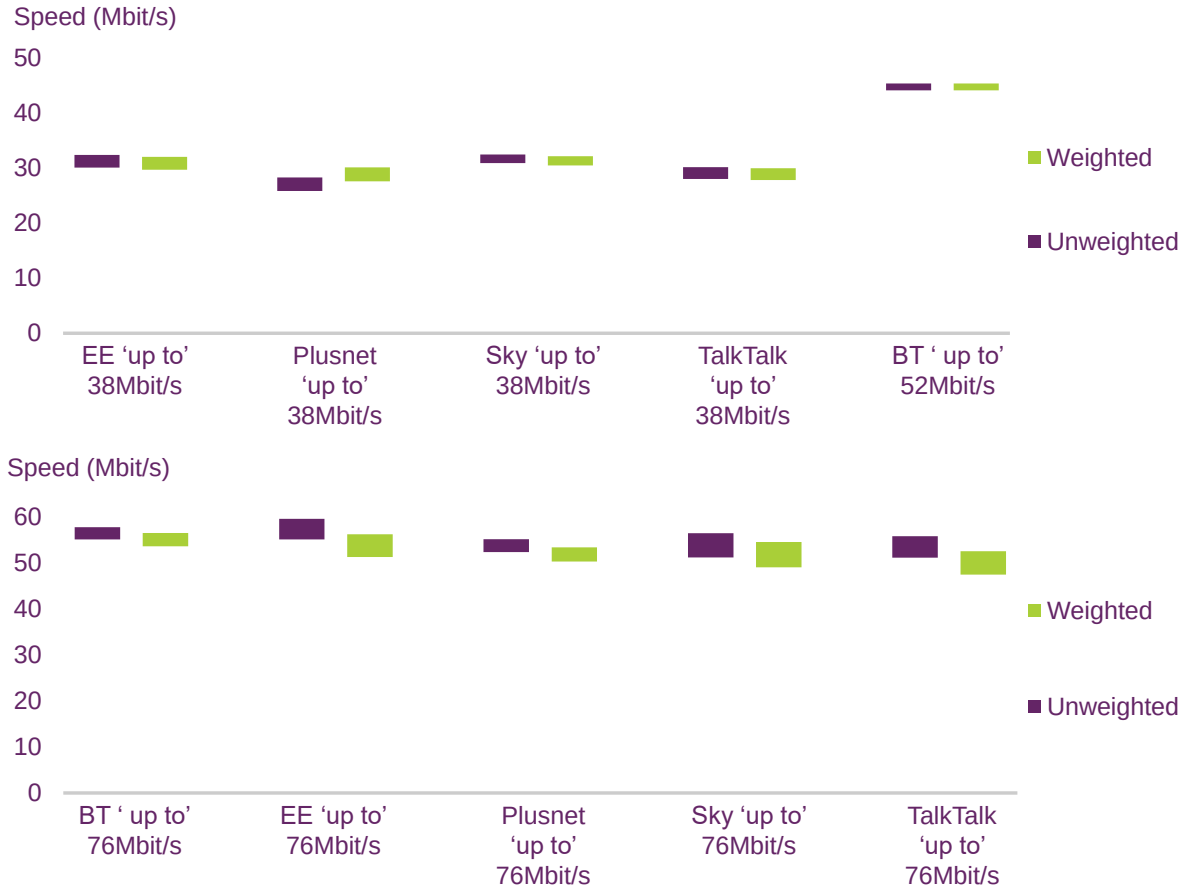
Source: SamKnows measurement data for all ISP panel members with a connection in November 2016.
Panel base: BT 'up to' 52Mbit/s 282; EE 'up to' 38Mbit/s 104; Plusnet 'up to' 38Mbit/s 123; Sky 'up to' 38Mbit/s 199; TalkTalk 'up to' 38Mbit/s 158; Virgin 'up to' 50Mbit/s 68, BT 'up to' 76Mbit/s 334; EE 'up to' 76Mbit/s 87; Plusnet 'up to' 76Mbit/s 326; Sky 'up to' 38Mbit/s 93; TalkTalk 'up to' 38Mbit/s 154; Virgin 'up to' 100Mbit/s 88; Virgin 'up to' 200Mbit/s 334
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 2.12: Peak-time (8pm to 10pm) download speeds for FTTC ISP packages, weighted and unweighted figures: November 2016



Source: SamKnows measurement data for all ISP panel members with a connection in November 2016.
Panel base: BT 'up to' 52Mbit/s 282; EE 'up to' 38Mbit/s 104; Plusnet 'up to' 38Mbit/s 123; Sky 'up to' 38Mbit/s 199; TalkTalk 'up to' 38Mbit/s 158; Virgin 'up to' 50Mbit/s 68, BT 'up to' 76Mbit/s 334; EE 'up to' 76Mbit/s 87; Plusnet 'up to' 76Mbit/s 326; Sky 'up to' 38Mbit/s 93; TalkTalk 'up to' 38Mbit/s 154; Virgin 'up to' 100Mbit/s 88; Virgin 'up to' 200Mbit/s 334
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 2.13: Minimum download speeds for FTTC ISP packages, weighted and unweighted figures: November 2016



Source: SamKnows measurement data for all ISP panel members with a connection in November 2016.
Panel base: BT 'up to' 52Mbit/s 282; EE 'up to' 38Mbit/s 104; Plusnet 'up to' 38Mbit/s 123; Sky 'up to' 38Mbit/s 199; TalkTalk 'up to' 38Mbit/s 158; Virgin 'up to' 50Mbit/s 68, BT 'up to' 76Mbit/s 334; EE 'up to' 76Mbit/s 87; Plusnet 'up to' 76Mbit/s 326; Sky 'up to' 38Mbit/s 93; TalkTalk 'up to' 38Mbit/s 154; Virgin 'up to' 100Mbit/s 88; Virgin 'up to' 200Mbit/s 334
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

Comparison of urban and rural speeds over time

Using Bluewave Geographic's Locale dataset, it is possible to segment all UK postcodes into one of seven urban-rural groupings. This dataset, widely used in market research design and sampling, allocates postcodes to a category based on their population density and how close the settlement they live within is to a larger one. The seven groupings range from A (large cities such as London and Birmingham), to G (isolated rural areas such as the Western Isles and Dartmoor).

To simplify the analysis, the groupings have been banded together into two broad groups: urban and rural (population less than 2.5k and in open countryside). This grouping enables us to compare rural and urban areas over time.

Annex 3

Glossary

Access line speed The maximum broadband download speed that a line is capable of supporting. See also Maximum line speed.

ADSL Asymmetric digital subscriber line. A digital technology that allows the use of a standard telephone line to provide high speed data communications. Allows higher speeds in one direction (towards the customer) than the other.

ADSL1 The first generation of ADSL, capable of theoretical data speeds of up to 8Mbit/s towards the customer and up to 640kbit/s from the customer.

ADSL2+ An improved version of ADSL, offering high speeds, especially on shorter telephone lines. In the case of ADSL2+, theoretical speeds of up to 24Mbit/s can be delivered towards the customer.

Advertised speed The speed at which broadband services are typically marketed, usually expressed as 'up to' xMbit/s (megabits per second).

Backhaul The links by which data are transmitted from a local telephone exchange back to the core or backbone of the operator's network.

Bandwidth The maximum amount of data that can be transmitted along a channel.

Broadband A service or connection generally defined as being 'always on', providing a bandwidth greater than narrowband.

Broadband speed The speed at which data are transmitted over a broadband connection, usually measured in megabits per second (Mbit/s).

Cable Sometimes referred to as Hybrid Fibre Coaxial (HFC) networks, cable networks combine optical fibre and coaxial cable (a cable made up of a conductor and a tubular insulating layer) to carry TV and broadband signals to end users. DOCSIS (Data Over Cable Service Interface Specification) is the technology standard used to deliver high speed broadband over HFC networks.

Contention A slowdown in performance caused when multiple users share the same bandwidth within a network and the bandwidth available is less than the aggregate demand.

Download speed Also downlink or downstream speed. Rate of data transmission from a network operator's access node to a customer, typically measured in Megabits per second (Mbit/s).

DNS The domain name service (or system) provides a crucial role in the internet. This protocol translates domain names (such as google.com) into the IP addresses that are actually used to route traffic (e.g. 80.77.246.42). Every ISP maintains its own DNS servers through which customers' computers issue queries to translate names into IP addresses. When these servers fail or operate slowly, web browsing and other online activities suffer.

DSL Digital subscriber line. A family of technologies generally referred to as DSL, or xDSL, capable of transforming ordinary phone lines (also known as 'twisted copper pairs') into high-speed digital lines, capable of supporting advanced services such as fast internet access

and video on demand. ADSL, HDSL (high data rate digital subscriber line) and FTTC (very high data rate digital subscriber line) are all variants of xDSL).

Exchange The local telephone exchange is the building where all consumers' copper telephone lines are connected to enable telephone calls to be switched, and where network equipment is installed which enables consumers' data traffic to be routed via an operator's core network to its destination.

FTTC (fibre to the cabinet) An access network consisting of optical fibre extending from the access node to the street cabinet. The street cabinet is usually located only a few hundred metres from the subscriber premises. The remaining segment of the access network from the cabinet to the customer is usually a copper pair, but another technology such as wireless could be used.

FTTx A term used to refer to any broadband network architecture using optical fibre to provide all or part of the connection between the local exchange and the end-user's premises.

Headline speed The speed at which a broadband service is marketed, usually expressed as 'up to'

ISP Internet service provider. A company that provides access to the internet.

Jitter The variation in latency. A measure of the stability of an internet connection.

Latency The time it takes a single packet of data to travel from a user's PC to a third-party server and back again. The figure is most commonly measured in milliseconds, and a connection with low latency will feel more responsive for simple tasks like web browsing.

LLU (local loop unbundling) LLU is the process whereby incumbent operators (in the UK these are BT and Kingston Communications) make their local network (the lines that run from customer's premises to the telephone exchange) available to other communications providers. The process requires the competitor to deploy its own equipment in the incumbent's local exchange and to establish a backhaul connection between this equipment and its core network.

Local loop The access network connection between the customer's premises and the local telephone exchange, usually a loop comprising two copper wires.

Maximum line speed The highest download speed that a broadband connection is capable of delivering. Also known as the access line speed. As it is a characteristic of ADSL broadband that speeds degrade with distance from exchange, the maximum line speed varies, and only those users who have a line length of less than 1km typically achieve maximum speeds of close to a services' headline speed.

Mbit/s Megabits per second. A unit measuring the bit-rate.1Mbit/s is the equivalent of 1,000kbit/s.

Modem synchronisation speed The maximum download speed that a line is capable of supporting according to the way the line is configured by a customer's ISP.

Multi-thread test A test involving the download of two or more data files simultaneously - in the case of our research, three files (see Technical Methodology – Annex 1). Multi-thread tests typically record faster speeds than single-thread tests, in particular for higher-speed connections.

Packet loss The loss of data packages during transmission over an internet connection.

Single-thread test A test involving the download of a single file. Single-thread tests typically record faster speeds than multi-thread tests, in particular for higher-speed connections.

Streaming content Audio or video files sent in compressed form over the internet and consumed by the user as they arrive. Streaming is different to downloading, where content is saved on the user's hard disk before the user accesses it.

Upload speed Also uplink or upstream speed. Rate of data transmission from a customer's connection to a network operator's access node, typically measured in Megabits per second (Mbit/s).

VDSL Very high data rate digital subscriber line. A digital technology that allows the use of a standard telephone line to provide very high speed data communications, which is used in fibre-to-the-cabinet deployments.