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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 2017.

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, which includes high-level summaries of some of the analysis in this report, and an interactive data visualisation tool.

We publish this report in accordance with Ofcom's duty to carry out and publish research on the experience of consumers.

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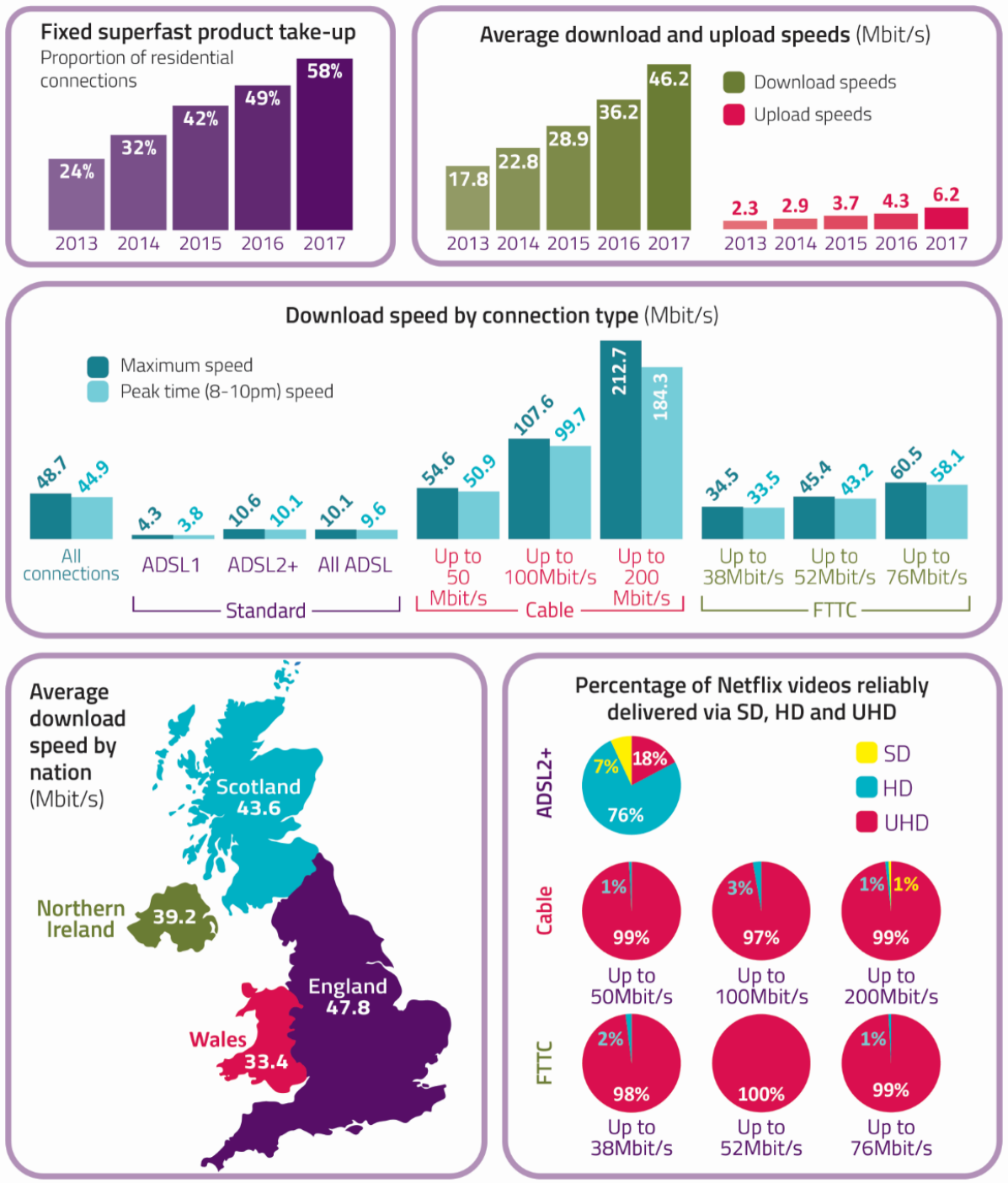
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SD
HD
UHD
ADSL2+
7%
18%
76%
Cable
1%
99%
3%
97%
1%
1%
99%
Up to 50Mbit/s
Up to 100Mbit/s
Up to 200Mbit/s
FTTC
2%
98%
100%
1%
99%
Up to 38Mbit/s
Up to 52Mbit/s
Up to 76Mbit/s

Executive summary

More than four in five UK households[1] have a fixed broadband service and they are putting ever-increasing demands on their connections, with mean monthly data use per residential fixed broadband connection increasing to 190GB, in the year to June 2017.[2] The main driver of this increase is growing take-up of over-the-top (OTT) video-on-demand TV services, including subscription services which are used in over ten million UK homes.[3]

The availability of higher-speed fixed broadband services continues to improve. In our *Connected Nations* Spring 2018 update,[4] we reported that superfast broadband services offering predicted download speeds of 30Mbit/s or higher were available to 93% of UK premises by January 2018. However, many consumers continue to receive a poor fixed broadband user experience, due to the technological limitations of the copper networks used to provide most fixed broadband services. This is particularly true for consumers in rural areas, where there is lower availability (and take-up) of superfast broadband than in urban areas.

We commission research to gain insight into the overall performance delivered by UK residential broadband providers, and how this varies by a range of factors including geography, time of day, technology and service provider.

This report is based on research undertaken in November 2017 in conjunction with our technical partner, SamKnows Ltd. Data are collected from monitoring units connected to panellists' routers and this enables us to make robust assessments of the performance delivered to UK households.

However, care is required when interpreting the results, and they may not be wholly reflective of the consumer experience, as performance is also determined by a number of factors that are not captured by our research. These include signal degradation over wifi, in-home contention when multiple devices are connected at the same time, device limitations and the performance of the servers delivering content consumed over the connection.

Average actual fixed broadband speeds continue to improve

The average actual fixed broadband download speed delivered to UK homes continued to improve and increased by 10.0Mbit/s (28%) to 46.2Mbit/s in the year to November 2017. Over the same period, average upload speeds increased from 4.3Mbit/s to 6.2Mbit/s. The main driver for both increases was the growing take-up of superfast fibre and cable broadband products, and the proportion of lines receiving an average peak-time speed of 30Mbit/s or more increased from 41% to 54% in the year to November 2017. Although superfast broadband is available to 93% of UK premises, around two in five UK broadband connections are delivered using ADSL (i.e. over the copper telephone wire between the telephone exchange and the end-user).

Differences in performance between urban and rural areas remain significant

Actual download speeds are typically lower than advertised speeds, and while only 3% of lines had an advertised speed of less than 10Mbit/s in November 2017, 21% of UK home broadband connections delivered an average download speed of less than 10Mbit/s. This is largely due to the limitations of the technologies that deliver last-mile connectivity over the copper local loop, such as

[1] https://www.ofcom.org.uk/__data/assets/pdf_file/0017/105443/uk-communications-market.pdf
[2] https://www.ofcom.org.uk/__data/assets/pdf_file/0017/108512/connected-nations-fixed-broadband-2017.pdf
[3] BARB Establishment Survey: Q4 2017
[4] https://www.ofcom.org.uk/research-and-data/multi-sector-research/infrastructure-research/connected-nations-update-spring-2018.

ADSL and superfast fibre-to-the-cabinet (FTTC), although network congestion can also reduce the speed of all connection types at busy times.

The proportion of lines receiving an average download speed of more than 30Mbit/s at peak times was significantly lower for connections in rural areas of the UK (23%) than in urban areas (59%) and while 17% of urban connections had an average peak-time speed of under 10Mbit/s, the proportion was much higher in rural areas (53%).

The primary reason for these differences is the lower availability and take-up of superfast cable and fibre services in rural areas, and our Connected Nations 2017 report shows that superfast broadband was available to 95% of urban premises in May 2017,[5] compared to 66% in rural areas. In addition, longer average copper line lengths in rural areas mean that the speed of ADSL broadband tends to be lower than in urban areas.

A download sync speed of at least 10Mbit/s and an upload sync speed of at least 1Mbit/s are the specification for the Government's proposed broadband universal service obligation (USO). Responsibility for implementing the USO has now passed from Government to Ofcom. Ofcom expects this implementation process to take two years.

Our research also shows differences in performance across the UK nations, with average actual download speeds ranging from 33.4Mbit/s in Wales to 47.8Mbit/s in England (in Northern Ireland the average was 39.2Mbit/s, while in Scotland it was 43.6Mbit/s).

Actual download speed varies by ISP services and technology

Our report also compares the performance of different ISP packages. We find that although consumers can receive better performance by switching to a different technology or upgrading to a service with a higher advertised speed, it is unlikely that they will experience a significant improvement by switching from one ADSL or FTTC package to another at the same advertised speed (as services will be provided over the same copper line).

Virgin Media's 'up to' 200Mbit/s cable service provided the fastest average download speed of the packages included in the report,[6] both over the whole day (193.6Mbit/s) and during the peak 8-10pm period (184.3Mbit/s). Our analysis also indicates that average 24-hour ADSL download speeds increased by 4% to 9.8Mbit/s in the year to November 2017, while 'up to' 38Mbit/s, 52Mbit/s and 76Mbit/s FTTC services had average speeds of 33.9Mbit/s, 44.3Mbit/s and 59.3Mbit/s respectively. The average download speed of 'up to' 50Mbit/s cable connections was 52.9Mbit/s, while for 'up to' 100Mbit/s cable services it was 102.5Mbit/s.

While cable connections had the highest downstream bandwidth, the highest average upload speeds over 24 hours and during the 8-10pm peak-time period were recorded for 'up to' 76Mbit/s FTTC services (both were over 16Mbit/s).

There was a notable improvement in cable connection performance at busy times

Average download speeds tend to fall during busy periods when broadband networks suffer the effects of contention (network congestion). Across all connections, average 8-10pm peak-time download speeds (44.9Mbit/s) were 92% of the average maximum speed (48.7Mbit/s). The proportion of the maximum speed delivered during peak times varied by connection type, ranging from 87% for 'up to' 200Mbit/s cable services (equivalent to 92% of the advertised speed) to 97% for 'up to' 38Mbit/s FTTC services.

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[5] https://www.ofcom.org.uk/__data/assets/pdf_file/0017/108512/connected-nations-fixed-broadband-2017.pdf

[6] We did not have sufficient panellists to include Virgin Media's 'up to' 300Mbit/s cable service, or any full-fibre FTTP ISP packages, in this report.

In last year's report, we highlighted that, despite average cable download speeds being higher than those of ADSL and FTTC connections, a significant minority of cable connections received severely degraded speeds at peak times. We attributed this to localised network congestion, as cable network topology means than contention occurs closer to the end-user, making it more difficult to add additional capacity. Our research shows an improvement in peak-time cable performance in 2017, suggesting that Virgin Media, the UK's largest cable provider, has been investing in additional network capacity.

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

The streaming of video content is one of the most bandwidth-hungry online activities for which home broadband users regularly use their connection, and we ran tests to investigate the capability of delivering Netflix video content. We found that more than 97% of single Netflix video streams delivered over superfast FTTC and cable products were reliably delivered in ultra-high definition (UHD) resolution during the 8pm-10pm peak-time period. For ADSL2+ services, 18% of streams were delivered at UHD, and over three-quarters (76%) were delivered in high-definition (HD). It should be noted that the streaming quality that can be reliably achieved may drop when multiple users are simultaneously using the same connection.

Ofcom is committed to improving the availability and quality of fixed broadband services

Ofcom recently published a package of measures to further increase investment in full-fibre broadband, following a range of recent commitments by broadband companies that could see up to six million premises covered by full-fibre by 2020.[7] According to these new rules, BT has a duty to make its telegraph poles and underground tunnels open to rival providers, making it quicker and easier for them to build their own full-fibre networks. In addition, Openreach, BT's infrastructure division, will have to repair faulty infrastructure and provide a 'digital map' of its duct and poles network, so that other providers can plan where to lay fibre.

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. A new version of the code was approved in March 2018, including changes such as the provision of a minimum guaranteed download speed at the point of sale, and improving the process of the right to exit.[8]

[7] https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2018/new-rules-boost-full-fibre
[8] The codes of practice can be accessed at https://www.ofcom.org.uk/phones-telecoms-and-internet/information-for-industry/codes-of-practice

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, where appropriate by promoting competition. 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. Ofcom has undertaken this research since 2008, using data collected by our research partner SamKnows Limited (SamKnows) from a volunteer panel of UK residential broadband users. 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, however, there are other ways in which broadband performance can be measured.

For example, our *Connected Nations* reports, include 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 approach 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.

There are a number of limitations to the research that we present here. While our research accurately represents the performance delivered to our panellists' routers, it does not capture certain important factors other than broadband network performance that can affect the end user's experience, such as wifi router performance. Similarly, there may be steps that consumers can take to improve their user experience, such as replacing in-home wiring and moving their router to a more suitable location.

BT free speed upgrades

From September to October 2017, BT rolled out speed upgrades to some of its 'up to' 38Mbit/s and 52Mbit/s BT Infinity 1 fibre-to-the-cabinet (FTTC) customers. Under the upgrade programme, existing Infinity 1 customers whose lines were capable of supporting sync speeds greater than 55Mbit/s had their upload and download speeds upgraded to those offered by BT's Infinity 2 'up to' 76Mbit/s service, free of charge. More than a million BT customers benefitted from this upgrade.

In this report, BT Infinity 1 panellists whose speeds were upgraded under the programme are included in the "BT 'up to' 76Mbit/s FTTC" category. While the upgrades are positive for those who received them, they are likely to have a number of knock-on effects on the reported results:

- As BT Infinity 1 panellists with higher-quality lines are likely to have been upgraded to its 'up to' 76Mbit/s service, the remaining panellists on these packages are likely to have lower-than-average-quality lines. As a result, the data in this report are likely to slightly understate the performance that we would expect new customers signing up to BT's 'up to' 52Mbit/s FTTC service to receive.
- The upgrades also mean that BT 'up to' 76Mbit/s FTTC panellists are likely to have higher-than-average-quality lines, resulting in an overstatement of the performance that we would expect new customers buying this service would receive.

Likewise, upgraded customers may have experienced performance fluctuations and/or outages following their upgrade as their router adjusted to optimise performance. For some BT 'up to' 76Mbit/s panellists, this period of stabilisation will have occurred during the measurement period, meaning that they may have experienced more variation in performance than usual. The metrics that are likely to be affected by this stabilisation are:

- upload and download speeds;
- packet loss;
- disconnections; and
- minimum speed as a proportion of maximum speed.

Analysis undertaken by SamKnows shows that the results for upgraded BT 'up to' 76Mbit/s FTTC panellists were consistent through the month, suggesting that any stabilisation period following the upgrade has not had a material effect on our results.

Having undertaken comparisons of the average upload and download speeds of BT's 'up to' 52Mbit/s and 'up to' 76Mbit/s FTTC packages in November 2016 and November 2017, we have found that:

- the average download and upload speeds of BT's 'up to' 52Mbit/s FTTC service were lower in November 2017 than in November 2016;
- the average download and upload speeds of BT's 'up to' 76Mbit/s FTTC service were higher in November 2017 than in November 2016; and

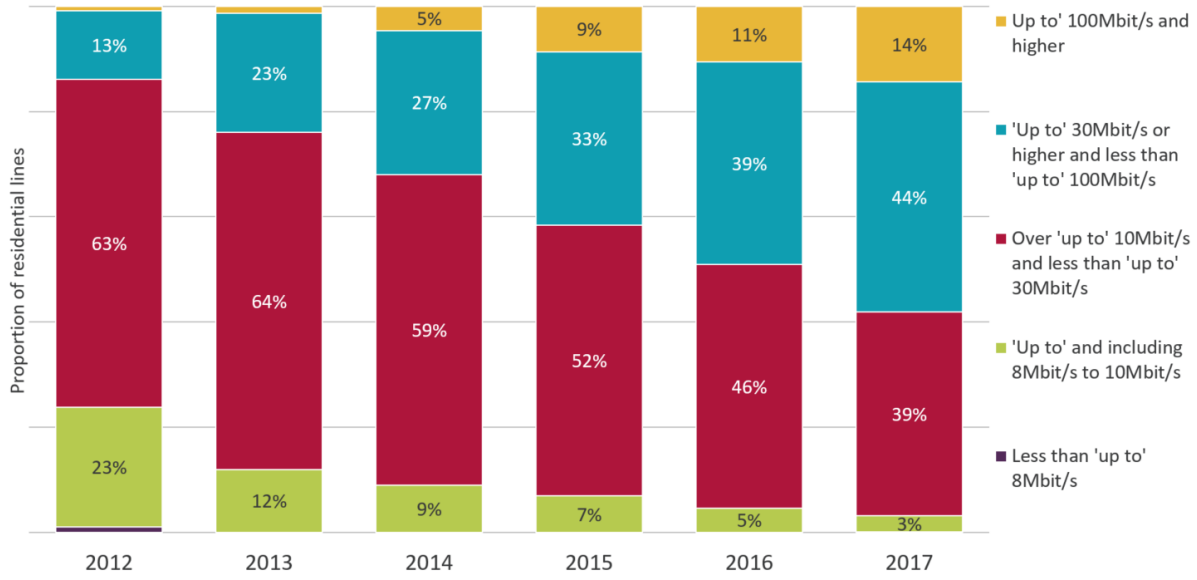
While these changes are in line with those that we might expect to result from changes in the mixes in line quality for these services, following the recent upgrades, we are unable to conclude that they are due to the upgrades rather than other service provision factors.

Overview of fixed broadband speeds

More than half of UK home broadband connections were superfast products, or higher, in November 2017

- Continuing the trend from previous years, customers are upgrading (or being upgraded) to higher-speed broadband packages, including cable and fibre superfast products.
- In November 2017, 58% of UK home broadband connections were superfast products with an advertised speed of 'up to' 30Mbit/s or higher, a 9pp increase since 2016
- Similarly, the proportion of home broadband connections with that had an advertised speed of 'up to' 100Mbit/s or higher increased by 4pp to 14% during the year.

Figure 1: UK residential broadband lines, by advertised speed

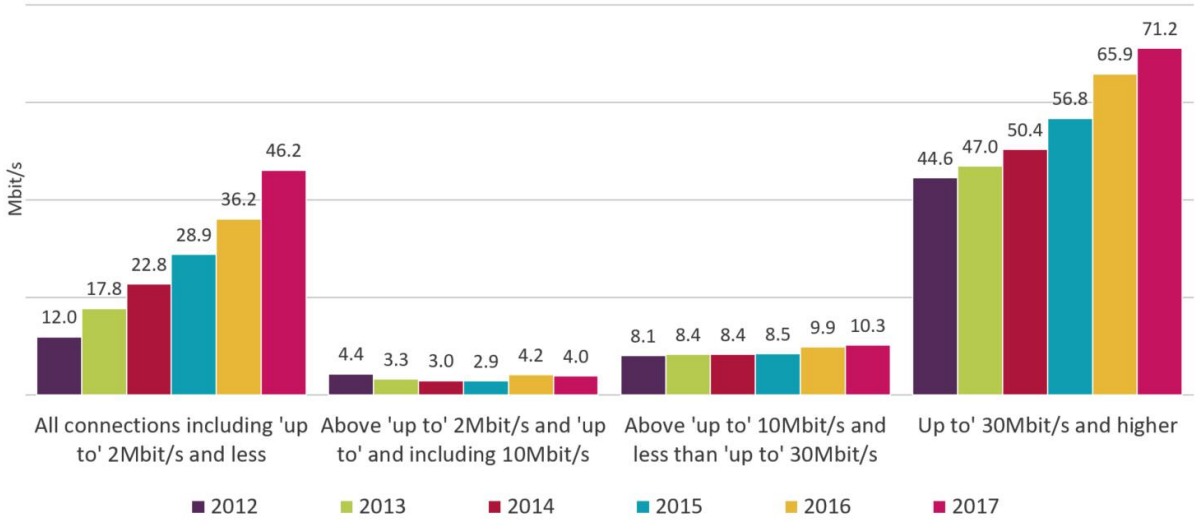


Source: Ofcom / operators; see note [2] in the sources section

Growing take-up of higher-bandwidth services resulted in a 28% increase in average download speeds during the year

- The average actual speed of UK residential fixed broadband services recorded over the 24-hour period increased by 28% to 46.2Mbit/s in the year to November 2017.
- This was a similar rate of increase to that recorded in the year to November 2016 (25%), but this rate of increase may not be sustainable, as migration to superfast services may slow if some households decide that standard broadband services are sufficient for their needs.

Figure 2: Average actual broadband speeds: November 2012 to November 2017

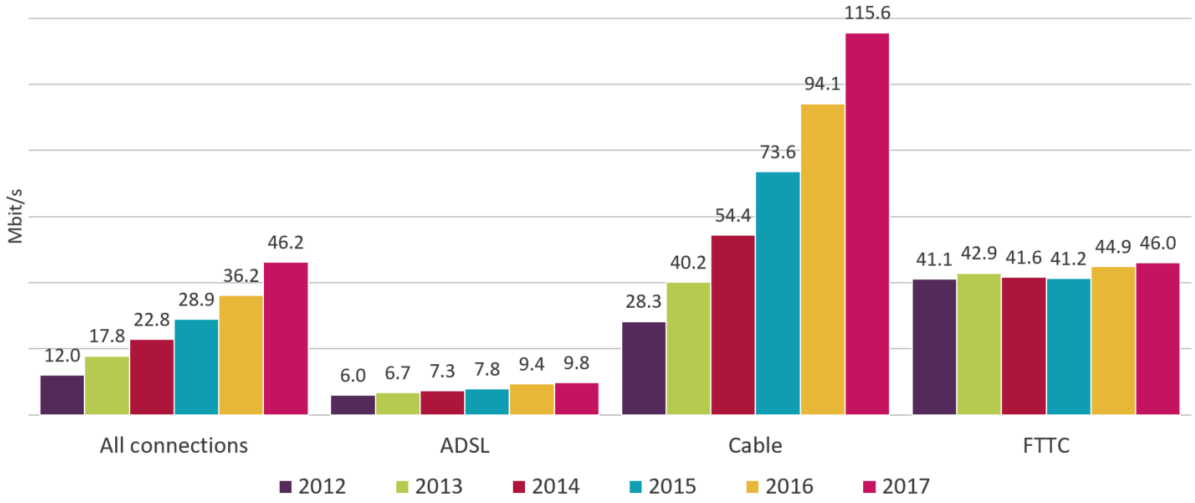


Source: Ofcom, using data provided by SamKnows; see note [1] in the sources section

Cable connections had the fastest average download speeds in November 2017

- Our analysis indicates that the average download speeds of ADSL, cable and FTTC connections all increased in the year to November 2017.
- The increase in the average download speeds delivered by FTTC connections (up 1.1Mbit/s to 46.0Mbit/s) was partly due to an increase during the year in the proportion of connections that were higher-tier 'up to' 76Mbit/s products.
- Cable services experienced the largest proportional increase during the year, up 23% to 115.6Mbit/s, partly due to the introduction of a new 'up to' 300Mbit/s service, the UK's first widely available ultrafast product, in early 2017.
- The average speed of an ADSL connection increased by 0.4Mbit/s (4%) to 9.8Mbit/s during the year.

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

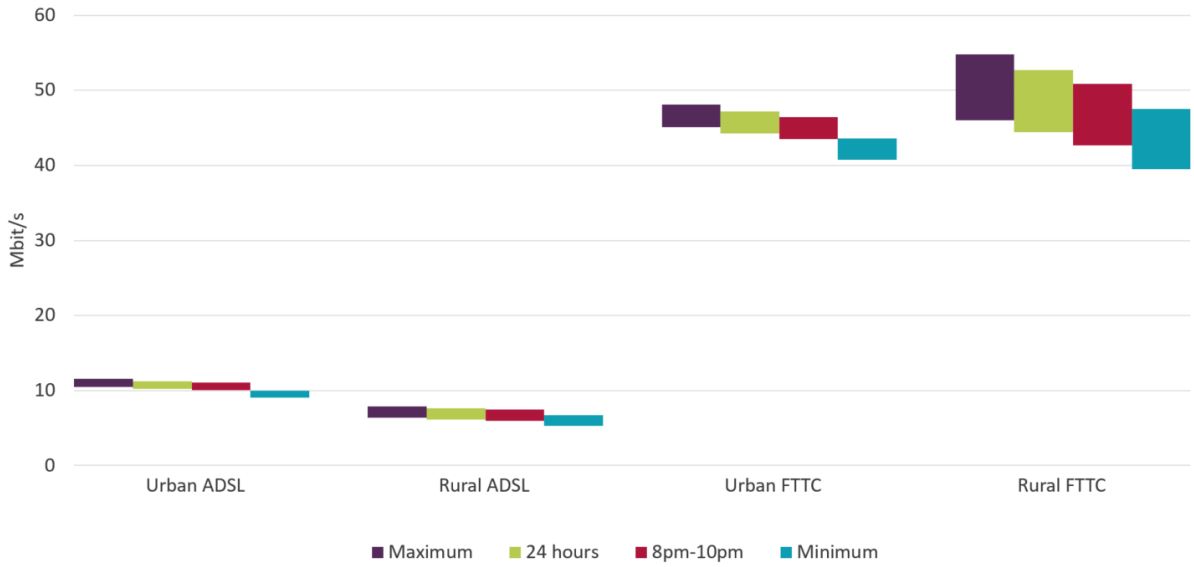


Source: Ofcom, using data provided by SamKnows; see note [3] in the sources section

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

- The copper-based technologies used to deliver ADSL and FTTC connections suffer from speed degradation as the length of copper over which data is transmitted increases, and due to issues with the quality of some copper lines.
- In ADSL deployments, data travels over copper which runs all the way from the local exchange to the end user's premises, whereas in FTTC, copper is only used from the street cabinet to the end-user.
- As a result, ADSL copper line lengths tend to be significantly longer in rural areas, where population density is lower, than in urban areas. These variations are not as evident for FTTC.
- The effects of these differences are evident when comparing ADSL performance in urban and rural areas of the UK. For ADSL connections, the average 24-hour download speed in urban areas (10.7Mbit/s) was 56% higher than the 6.9Mbit/s average in rural areas.
- There were no differences between average urban and rural FTTC download speeds.
- Most rural ADSL customers who are able to upgrade to FTTC will experience a significant increase in performance when doing so (FTTC, on average, is more than six times as fast as ADSL).

Figure 4: Average ADSL and fibre download speeds, by rurality: November 2017 (Mbit/s)



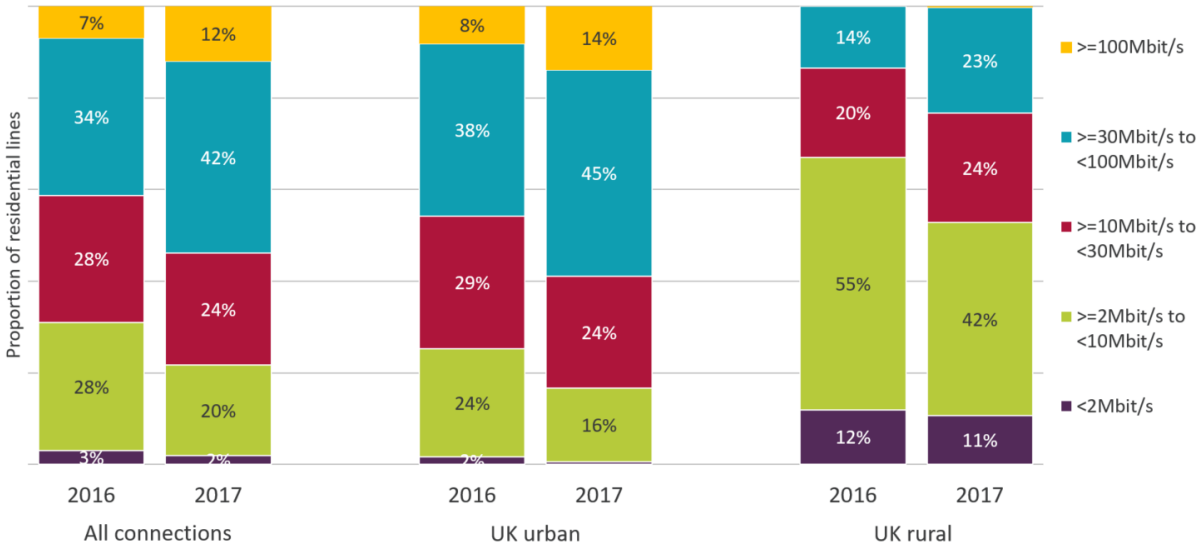
Source: Ofcom, using data provided by SamKnows; see note [4] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists within our sample) falls within the ranges shown

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

- Our research shows that over half (54%) of UK home broadband connections had an 8-10pm peak-time average actual download speed of 30Mbit/s or higher in November 2017, up from 41% in November 2016.
- Similarly, 22% of home broadband connections had a peak-time average actual speed of less than 10Mbit/s in November 2017.
- However, lower download speeds over copper broadband technologies and lower superfast broadband availability in rural areas[9] resulted in significant variations in performance between urban and rural areas of the UK.
- Fifty-nine per cent of panellists in urban areas received an average 8-10pm peak-time speed of 30Mbit/s or higher in November 2017, compared to 23% in rural areas, while 17% received peak-time speeds of less than 10Mbit/s, compared to 53% in rural areas (down from 67% in 2016).

[9] Our Connected Nations 2017 report (https://www.ofcom.org.uk/__data/assets/pdf_file/0017/108512/connected-nations-fixed-broadband-2017.pdf) shows that superfast broadband was available to 95% of urban premises in May 2017, compared to 66% in rural areas

Figure 5: Distribution of average peak-time, 8-10pm, fixed broadband download speeds, by rurality: November 2016 and 2017



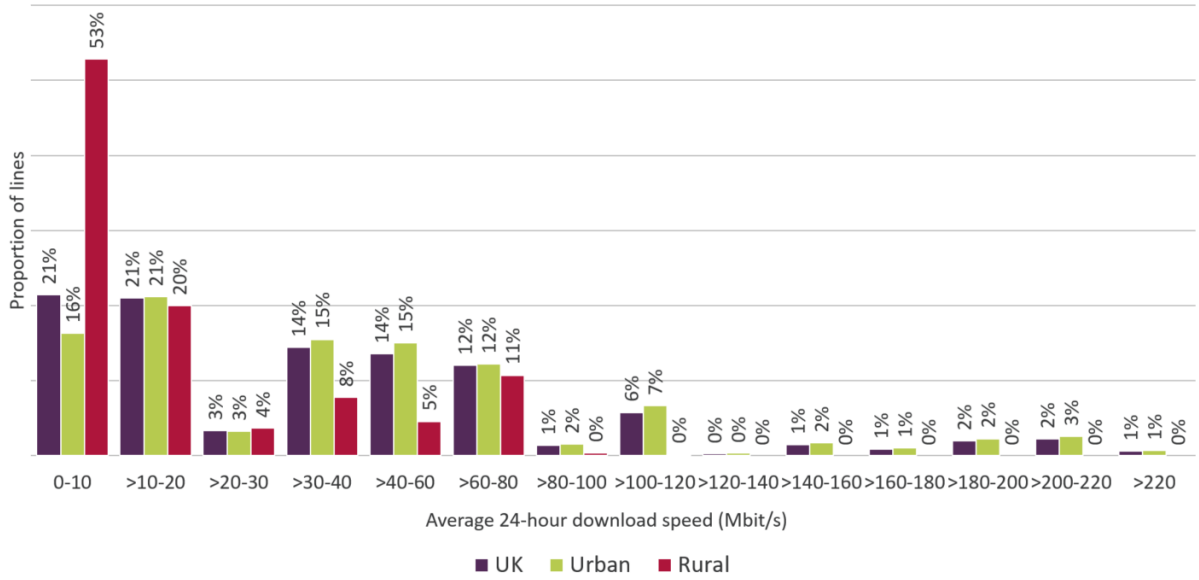
Source: Ofcom, using data provided by SamKnows; see note [5] in the sources section

Many rural consumers do not receive download speeds of 10Mbit/s or higher

- Our research shows that, in November 2017, over half (53%) of panellists in rural areas of the UK received an average 24-hour download speed of less than 10Mbit/s, which we consider to be the speed which enables full participation in a digital society.
- This proportion was much higher than for the UK as a whole (21%) and the proportion in urban areas (16%).
- However, many rural and urban consumers would be able to achieve higher speeds by switching to fibre or cable services.
- In our *Connected Nations Spring 2018* update,[10] we reported that, by January 2018, superfast broadband services offering predicted download speeds of 30Mbit/s or higher were available to 93% of UK premises.

[10] https://www.ofcom.org.uk/__data/assets/pdf_file/0017/113543/Connected-Nations-update-Spring-2018.pdf

Figure 6: Distribution of average fixed broadband download speeds, by rurality, November 2017

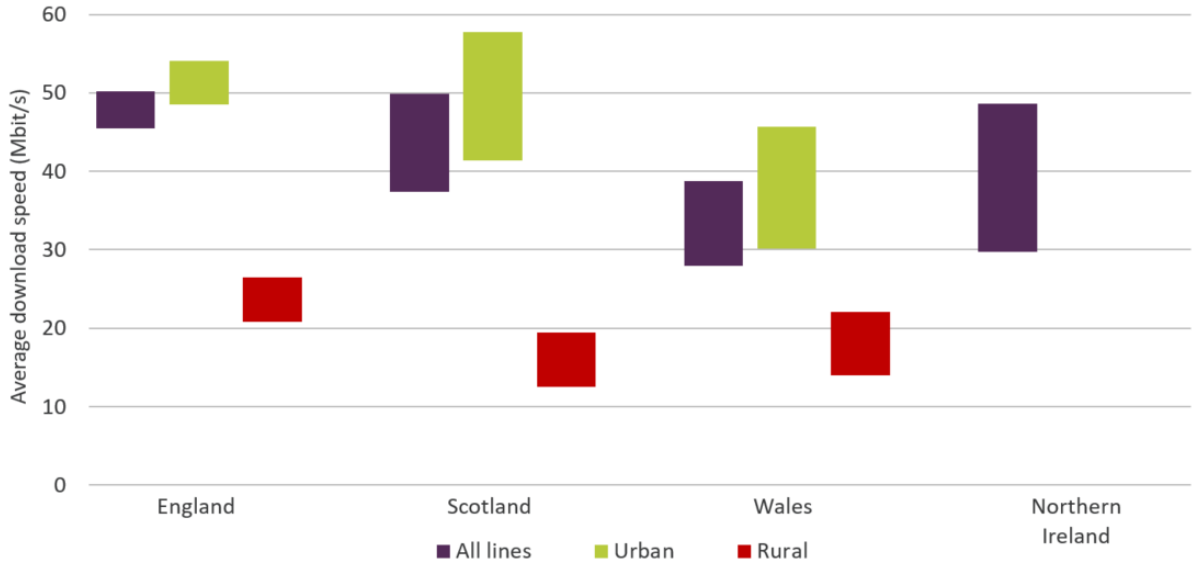


Source: Ofcom, using data provided by SamKnows; see note [5] in the sources section

Broadband performance varies across the UK nations

- Our research also compared average actual download speeds in England, Scotland and Wales in November 2017 (rural and urban performance in Northern Ireland is not included in this analysis as we were unable to recruit sufficient panellists to enable us to report robustly on these areas).
- Our research showed that across England, Scotland and Wales overall, England had the highest average fixed broadband download speed in November 2017, at 47.8Mbit/s.
- England also had the highest average urban and rural download speeds, at 51.3Mbit/s and 23.7Mbit/s respectively.
- Wales had the lowest overall and average urban download speeds in November 2017, at 33.4Mbit/s and 37.9Mbit/s respectively.
- The overall average download speed was 43.6Mbit/s in Scotland, while in urban and rural Scotland it was 49.6Mbit/s and 16.0Mbit/s, respectively. This was the lowest average rural download speed recorded among the nations).
- The overall average download speed in Northern Ireland was 39.2Mbit/s.

Figure 7: Average download speeds, by UK nation, and significant differences to a 95% level of confidence: November 2017



	All lines	Urban	Rural
Country	**Was faster than**	**Was faster than**	**Was faster than**
England	Wales	Wales	Scotland*
Scotland	Wales*	-	-

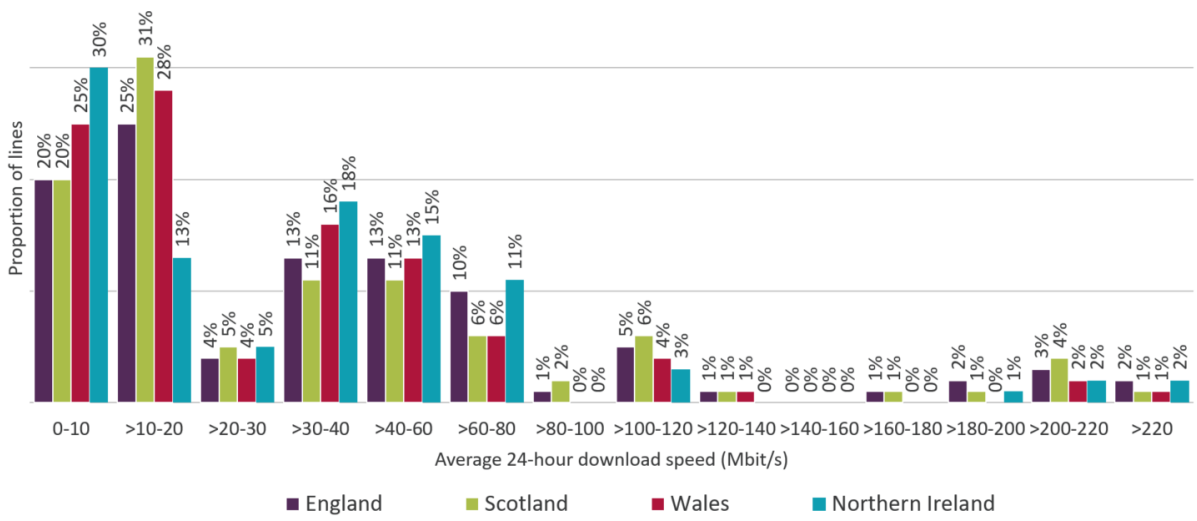
Source: Ofcom, using data provided by SamKnows; see note [6] in the sources section
Note: The additional weights used to calculate these figures means that they are not directly comparable to the UK average figures included elsewhere in this report; the chart bars show that there is a 95% probability 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.

Three-in-ten connections in Wales had an average speed of less than 10Mbit/s

- Northern Ireland had the highest proportion of connections receiving an average speed of 30Mbit/s or higher in November 2017 (52%), compared to 51% in England, 44% in Scotland and 43% in Wales.

- Northern Ireland also had the highest proportion of connections receiving an average download speed of less than 10Mbit/s in November 2017, at 30%, compared to 25% of connections in Wales and 20% in England and Scotland.

Figure 8: Distribution of average fixed broadband download speeds, by nation: November 2017

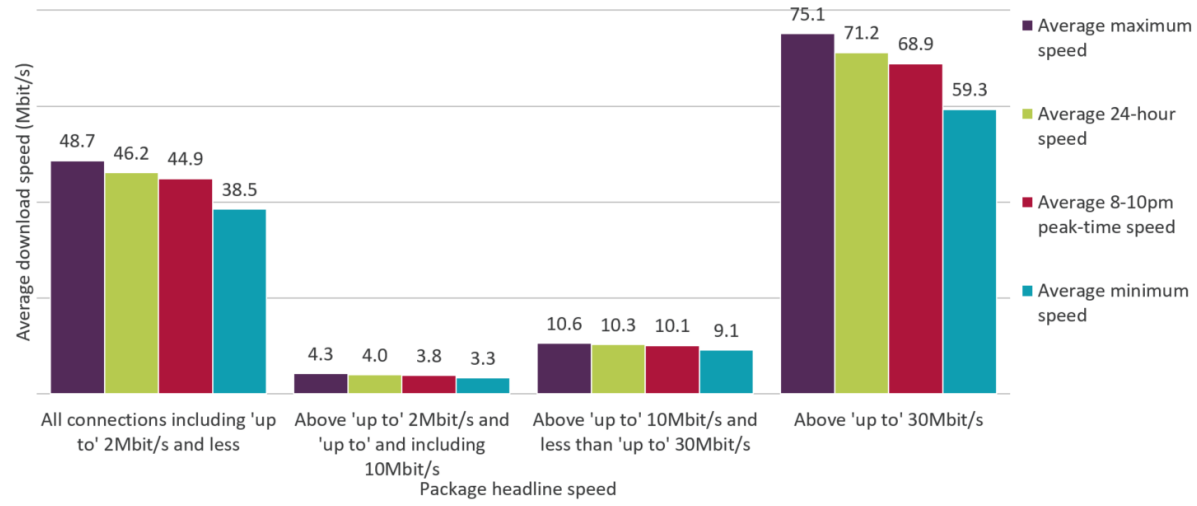


Source: Ofcom, using data provided by SamKnows; see note [6] in the sources section
Note: The additional weights used to calculate these figures means that they are not directly comparable to the UK average figures included elsewhere in this report.

Actual download speeds vary significantly throughout the day

- The performance of broadband services varies by time of day, with speeds slowing down during busy periods when traffic volumes are highest.
- Across all connections, the average minimum speed (38.5Mbit/s) was 79% of the average maximum speed (48.7Mbit/s).
- The average download speed recorded during the 8-10pm peak-time period was 44.9Mbit/s, 92% of the average maximum speed.

Figure 9: Average UK broadband speeds, by time of day: November 2017 (Mbit/s)

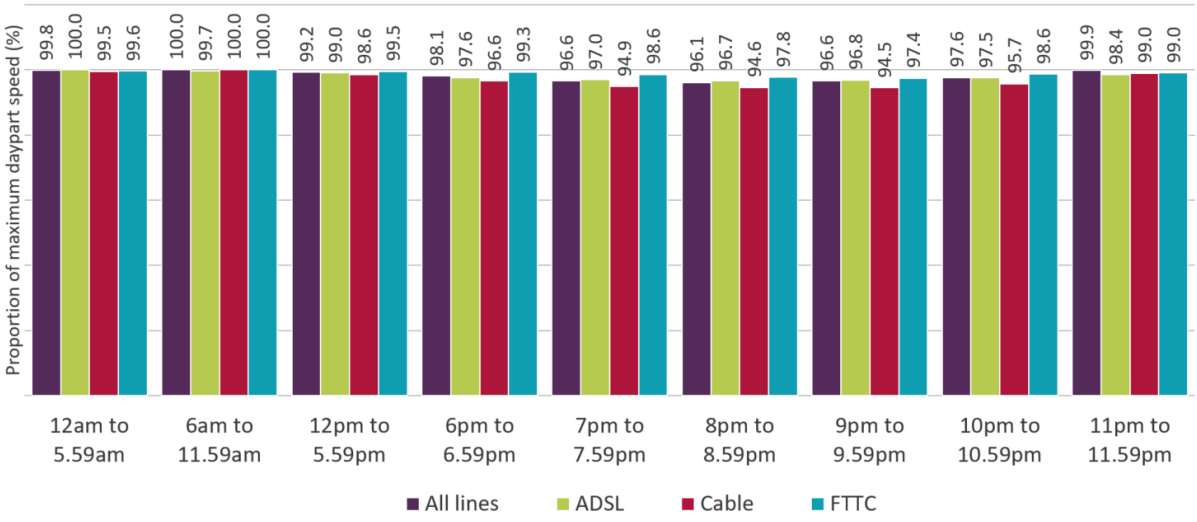


Source: Ofcom, using data provided by SamKnows; see note [1] in the sources section

Network slowdown affects all connection types

- Our research shows that all connection types recorded their lowest average speeds between 8pm and 10pm in the evening.
- The average across all connections was lowest between 8pm and 8.59pm, at 96.1% of the highest speed, which was recorded between 6am and 11.59am.
- The lowest speed over ADSL connections also occurred between 8pm and 8.59pm, at 96.7% of the highest speed, which was recorded between 12am and 5.59am.
- For cable and FTTC lines, the effects of contention were most pronounced between 9pm and 9.59pm, and the highest speeds occurred between 6am and 11.59am.
- For cable, the 9pm and 9.59pm average was 94.5% of the 6am to 11.59am average, whereas for FTTC it was 97.4% of the 6am to 11.59am average.

Figure 10: Proportion of maximum speed delivered through the day: November 2017 (Mbit/s)



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

Cable connection performance during busy times has improved

There are two main reasons why the majority of home broadband connections do not provide their headline (advertised) speed throughout the day:

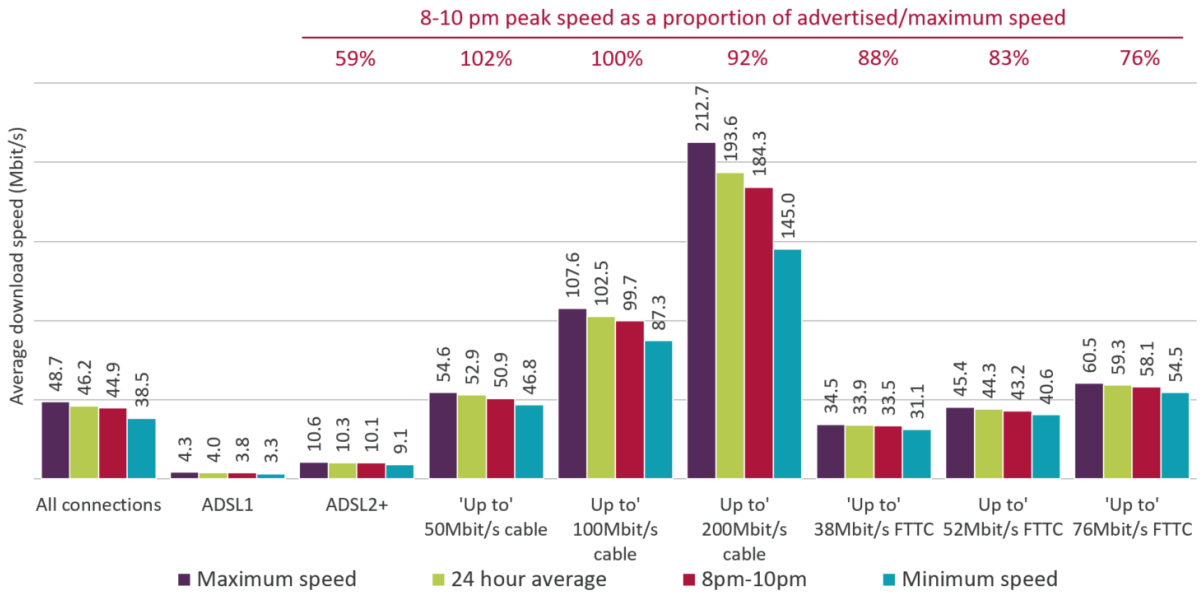
- For copper-based technologies such as ADSL and FTTC, the maximum speed that a line can support is dependent on the length and quality of the line from the end-user's home to the local exchange (for ADSL) or street cabinet (for FTTC). Current Advertising Standards Authority (ASA) guidelines require that the advertised speed is the maximum speed available to at least 10% of the customer base for a broadband service. 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 never be able to receive it.

- New ASA broadband advertising guidelines, which take effect on 23 May 2018, say that any speed claims used in advertising should be based on the download speed available to at least 50% of customers at peak times.
- 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 closer 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 ADSL2+ and FTTC connections in November 2017. There was more variation for the cable connections, with the 24-hour download speeds higher than the advertised speeds for the 'up to' 50Mbit/s and 100Mbit/s cable services.

- During the 8pm-10pm peak-time period, 'up to' 38Mbit/s FTTC lines delivered an average of 97% of their maximum speed in November 2017, while for 'up to' 76Mbit/s FTTC lines this proportion was 96% and for 'up to' 52Mbit/s FTTC connections it was 95%.
- This compared to 93% for 'up to' 50Mbit/s and 100Mbit/s cable connections and 87% for 'up to' 200Mbit/s cable services, equivalent to 102%, 100% and 92% of their respective advertised speeds.
- All three cable services included in the report have shown an improvement in peak-time download speeds since November 2016. For 'up to' 50Mbit/s cable services, the average peak-time download speed increased by 22% to 50.9Mbit/s in the year to November 2017, while for 'up to' 100Mbit/s and 200Mbit/s services the increases were 26% and 23% respectively.
- ADSL2+ services, on average, achieved 96% of the maximum speed during peak times, equivalent to 59% of their advertised speeds.

Figure 11: Variations in download speeds, by time of day: November 2017 (Mbit/s)

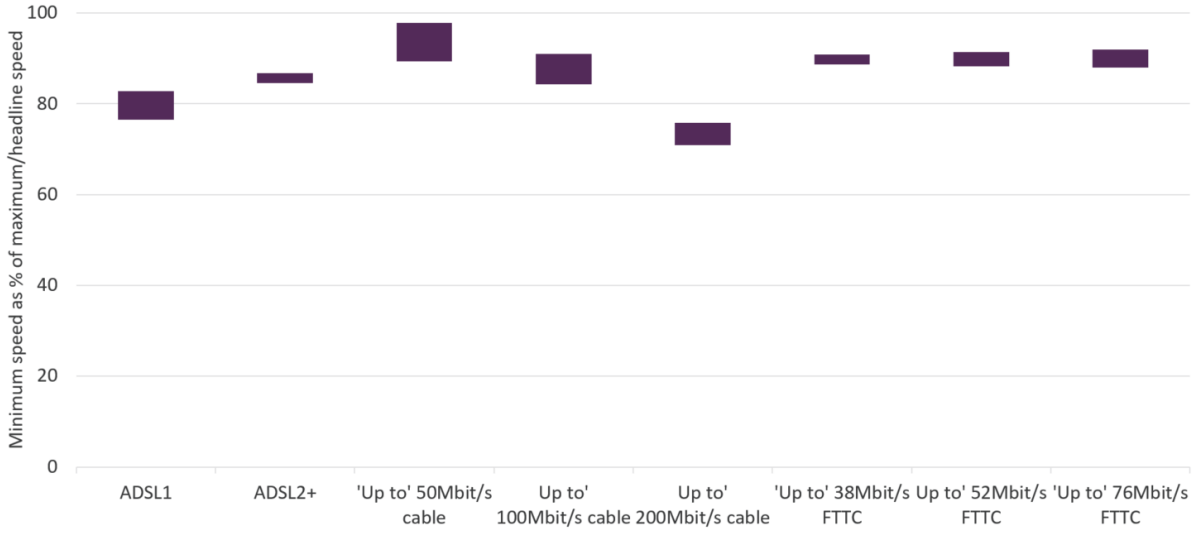


Source: Ofcom, using data provided by SamKnows; see note [7] in the sources section.
Note: Where a service's average maximum speed is higher than the advertised speed of their service, the advertised speed has been used to calculate the figures above the chart.

Contention varies by network technology

- We measure network slowdown during busy periods (contention) by comparing ISP packages' average minimum and maximum speeds, our assumption being that the primary reason for any differences between the two is network congestion.
- For 'up to' 50Mbit/s, 100Mbit/s and 200Mbit/s cable services, minimum download speeds represented 94%, 87% and 72% of their respective advertised speeds.
- For 'up to' 38Mbit/s and 76Mbit/s FTTC services, minimum download speeds were 90% of their maximum download speeds respectively, while for 'up to' 52Mbit/s FTTC and ADSL2+ services these proportions were slightly lower, at 89% and 86% respectively.

Figure 12: Minimum speed as proportion of maximum speed (%): November 2017

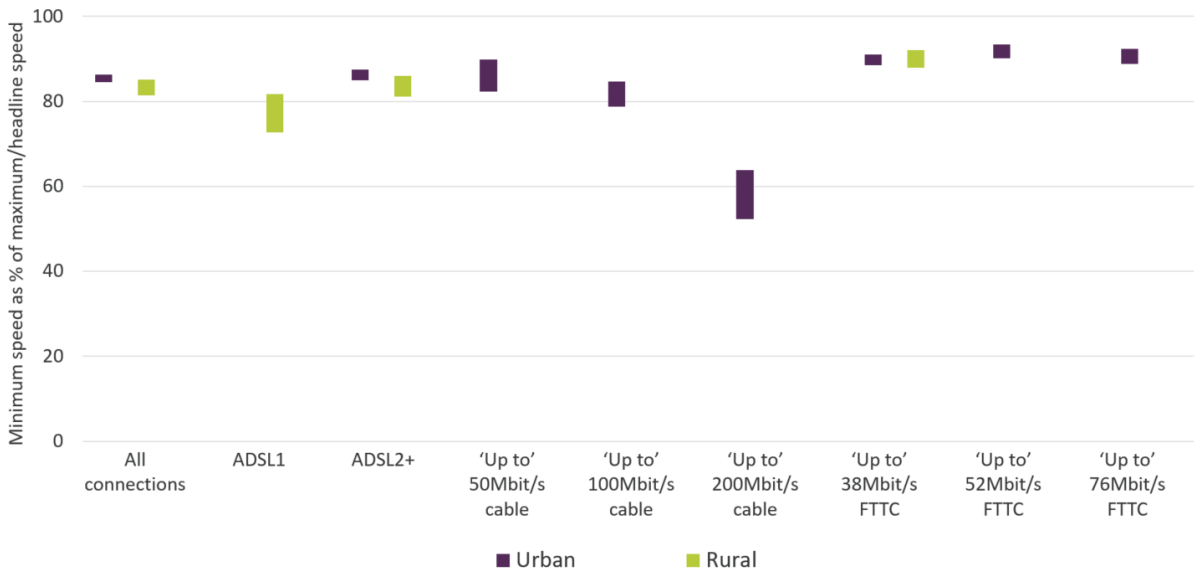


Source: Ofcom, using data provided by SamKnows; see note [8] in the sources section
Notes: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; where a panellist's maximum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

There is no variation between urban and rural connection in slowdown during busy periods

- Across all UK residential fixed broadband connections, we found that there were no statistically significant differences in contention between urban and rural areas of the UK in November 2017.
- There were no differences between contention in urban and rural areas of the UK for ADSL2+ and 'up to' 38Mbit/s FTTC connections: we did not have sufficient panellists to allow us to compare urban and rural cable contention for the other package types.

Figure 13: Minimum speeds as a proportion of maximum speed, by rurality (%): November 2017

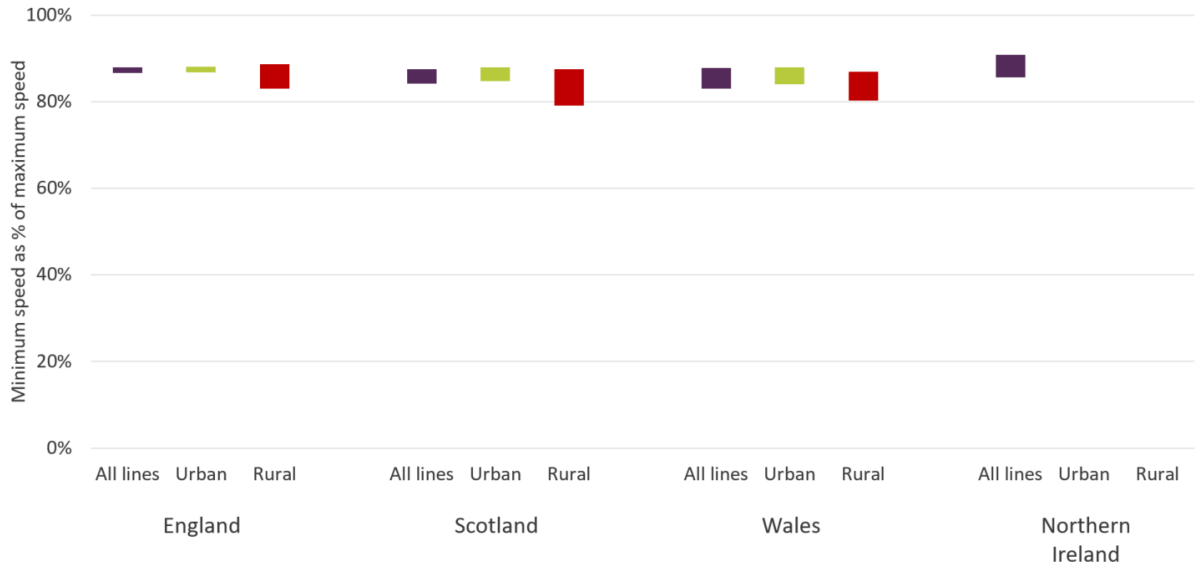


Source: Ofcom, using data provided by SamKnows; see note [9] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; where a panellist's maximum 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 England, Scotland and Wales

- Our analysis finds that there were no statistically significant differences in the levels of contention between the UK nations in November 2017.
- This was the case overall, and when comparing contention in urban and rural areas in each nation.

Figure 14: Minimum speeds as a proportion of maximum speed, by UK nation: November 2017



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.

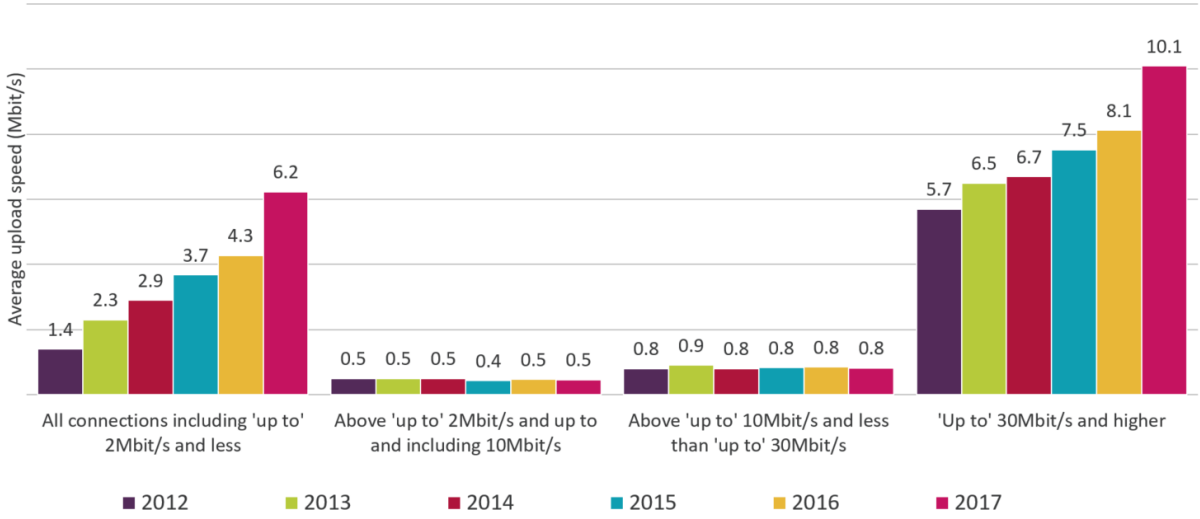
Upload speeds

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 21% in the year to November 2017

- The average upload speed of UK residential fixed broadband services increased by 2.0Mbit/s to 6.2Mbit/s in the year to November 2017.
- The main drivers of this increase were growing superfast take-up and a 24% increase in the average superfast product upload speed, from 8.1Mbit/s to 10.1Mbit/s.
- This was due to a higher proportion of FTTC lines being 'up to' 76Mbit/s connections, which have a headline upload speed of 19.5Mbit/s, rather than the 9.5Mbit/s for lower-tier services; the 2Mbit/s upload speeds of some legacy FTTC lines being upgraded to 9.5Mbit/s; and growing take-up of Virgin Media's 20Mbit/s upload 'gamer' services.
- The average upload speeds for 'above 'up to' 2Mbit/s and up to and including 10Mbit/s' and 'above 'up to' 10Mbit/s and up to and less than 30Mbit/s' were unchanged during the year, at 0.5Mbit/s and 0.8Mbit/s respectively.

Figure 15: Average UK fixed broadband upload speeds

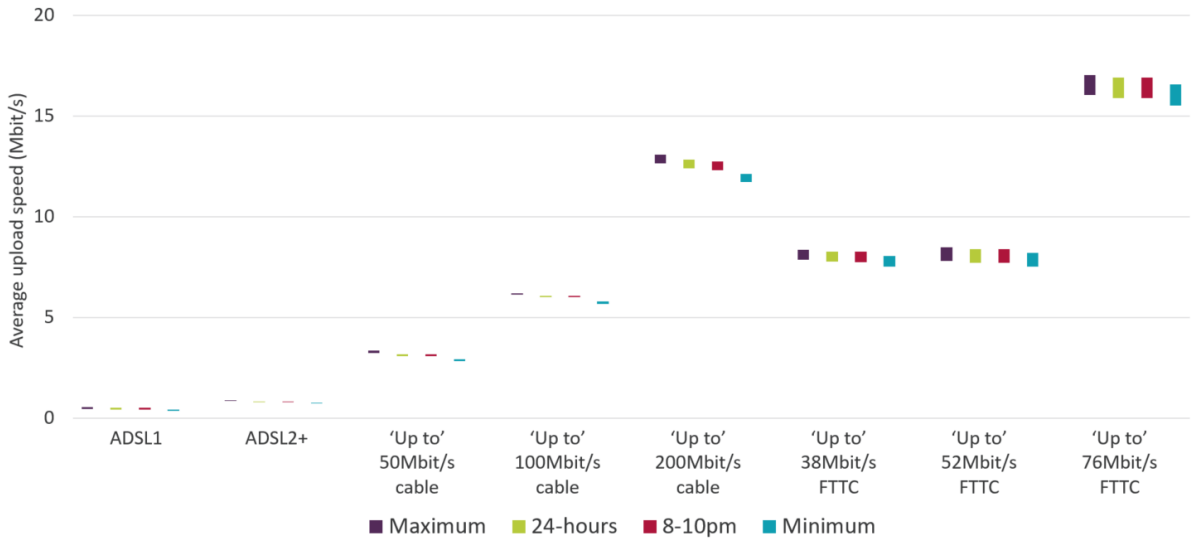


Source: Ofcom, using data provided by SamKnows; see note [11] in the sources section

Upload speeds vary widely by technology and speed tier

- There is significant variation in upload speeds between technology and service tiers.
- 'Up to' 76Mbit/s FTTC services recorded the highest average upload speeds in both the 24-hour and 8-10pm peak-time periods (both 16.4Mbit/s), followed by 'up to' 200Mbit/s cable services, at 12.6Mbit/s over 24 hours and 12.5Mbit/s in the 8-10pm peak-time period.
- The 24-hour and 8-10pm peak-time average upload speeds of 'up to' 38Mbit/s FTTC services were both 8.0Mbit/s, while for 'up to' 52Mbit/s FTTC connections they were both 8.3Mbit/s.
- The 24-hour and peak-time averages for ADSL2+services were both 0.8Mbit/s.

Figure 16: Maximum, average, peak-time and minimum upload speeds by technology and service tier: November 2017



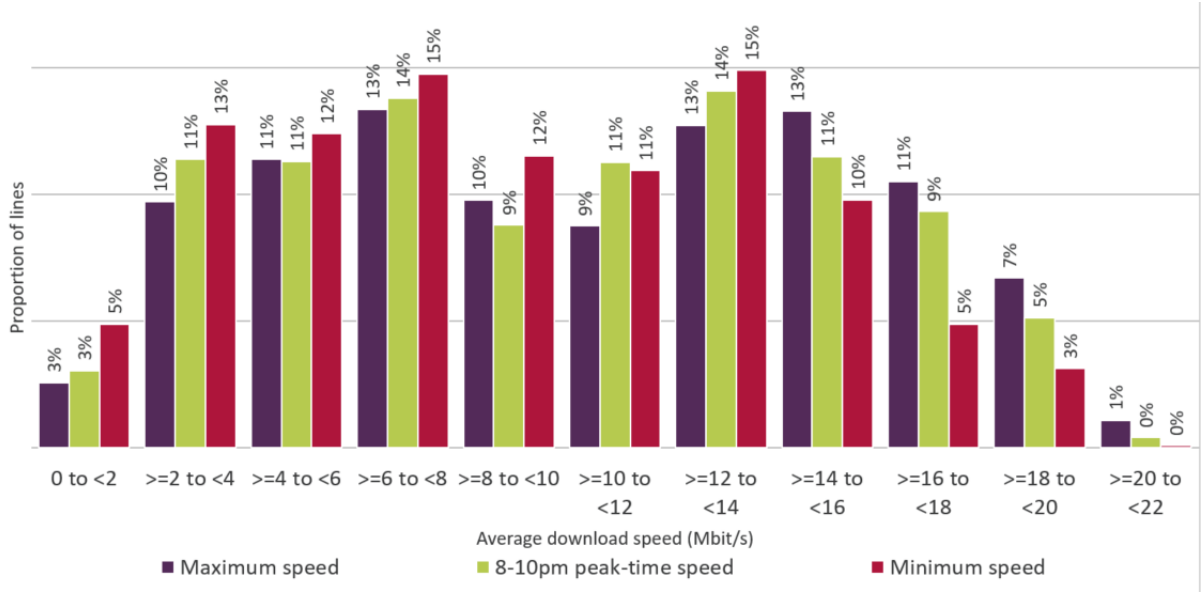
Source: Ofcom, using data provided by SamKnows; see note [12] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown.

Distribution of download speeds

The broadband speed received is determined by the underlying technology of the service

- For ADSL2+ packages, just under half of the panellists (47%) received an average maximum speed of less than 10Mbit/s in November 2017.
- Fifty-six per cent of ADSL2+ panellists received a minimum download speed below 10Mbit/s, while 48% had an average 8pm-10pm peak-time download speed of less than 10Mbit/s.

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

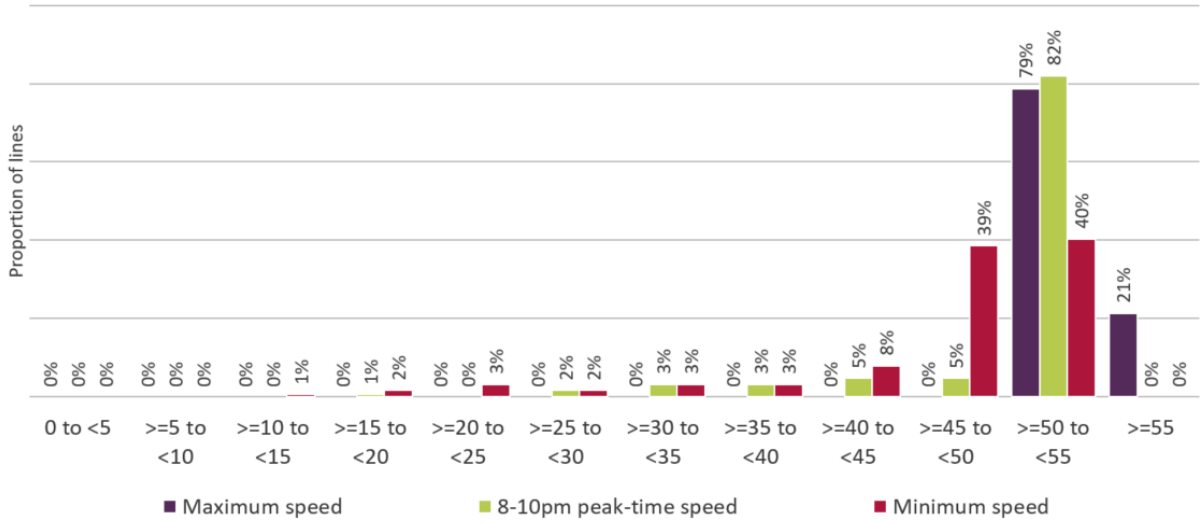


Source: Ofcom, using data provided by SamKnows; see note [13] in the sources section

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

- For 'up to' 50Mbit/s cable connections, all panellists achieved a maximum speed of 45Mbit/s or higher, and 79% received a similar minimum speed.
- No 'up to' 50Mbit/s cable lines received an average minimum speed of less than 10Mbit/s - an improvement since November 2016, when 11% of lines did.

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

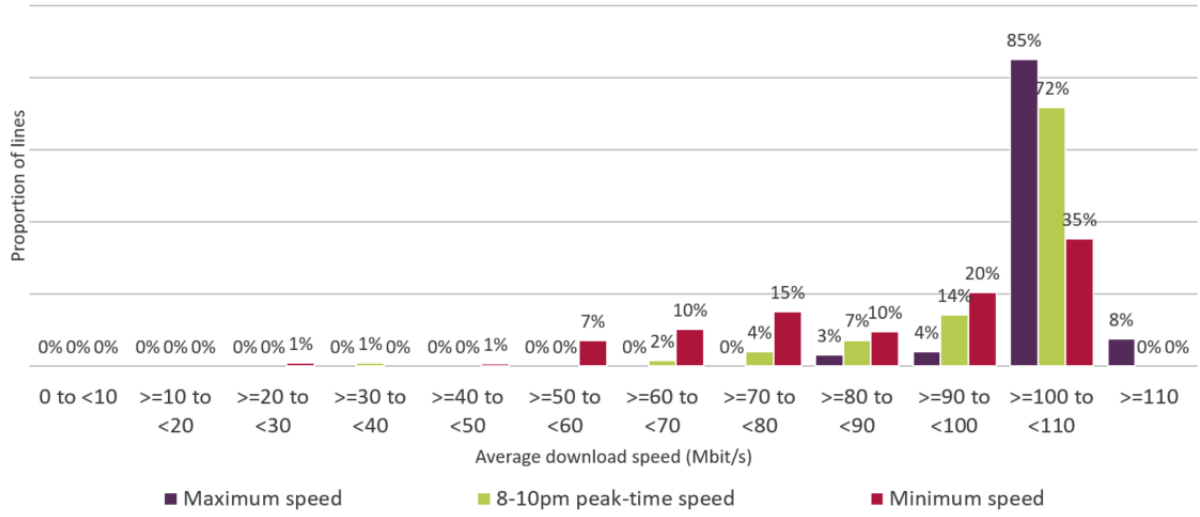


Source: Ofcom, using data provided by SamKnows; see note [14] in the sources section

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

- For 'up to' 100Mbit/s cable connections, 97% of the panellists achieved maximum speed of 90Mbit/s or higher.
- None of the 'up to' 100Mbit/s cable panellists received a minimum or average 8-10pm peak-time speed of less than 10Mbit/s, down from 7% in November 2016.
- Fifty-six per cent of 'up to' 100Mbit/s cable panellists received a minimum speed of 90Mbit/s or higher.

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

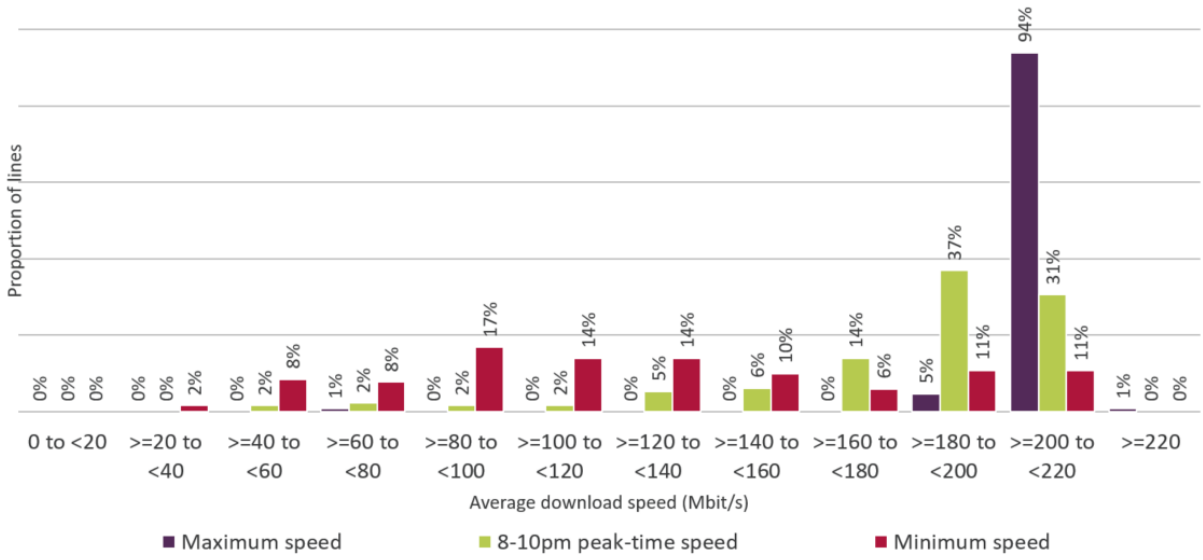


Source: Ofcom, using data provided by SamKnows; see note [15] in the sources section

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

- For 'up to' 200Mbit/s cable connections, 99% of panellists achieved an average maximum speed of 180Mbit/s or higher.
- Twenty-two per cent of 'up to' 200Mbit/s cable panellists received minimum speeds of 180Mbit/s or higher, and no panellists had an average minimum speed of less than 10Mbit/s.

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

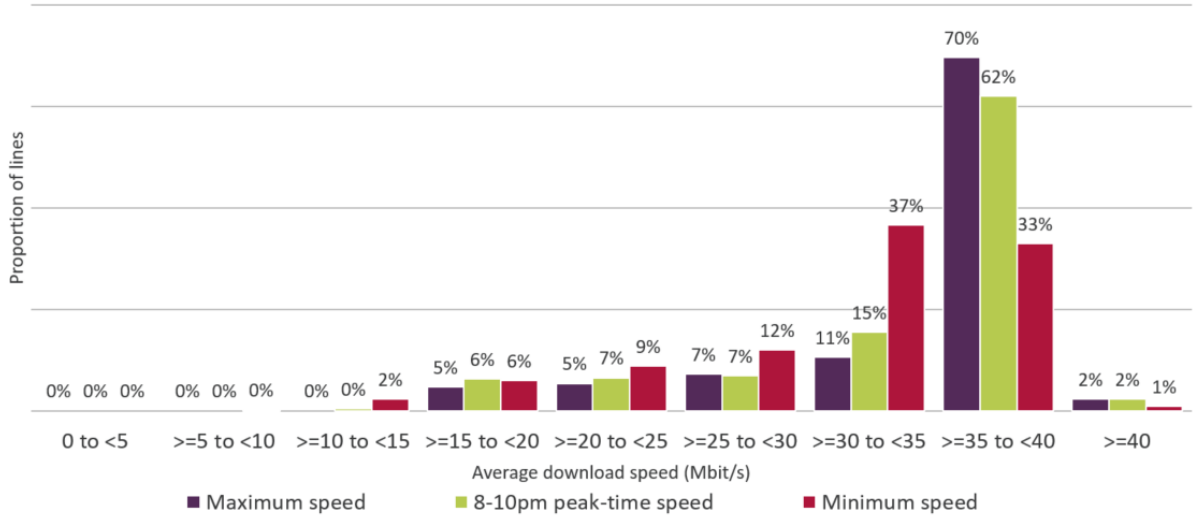


Source: Ofcom, using data provided by SamKnows; see note [16] in the sources section

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

- For 'up to' 38Mbit/s FTTC connections, 72% of panellists achieved a maximum speed of more than 35Mbit/s.
- No 'up to' 38Mbit/s FTTC panellists received a minimum speed of less than 10Mbit/s, and 34% received a minimum speed higher than 35Mbit/s.

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

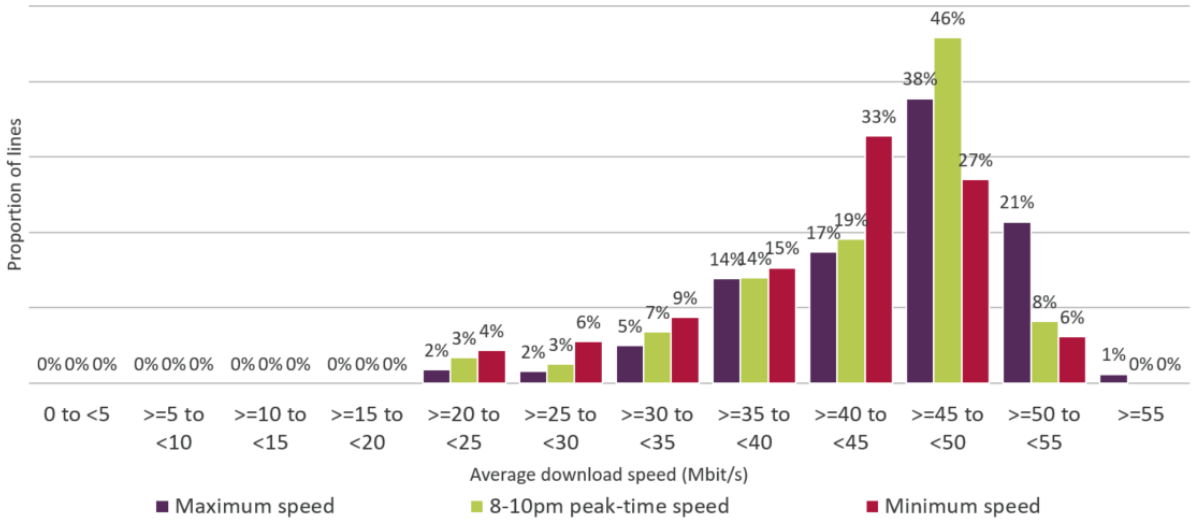


Source: Ofcom, using data provided by SamKnows; see note [17] in the sources section

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

- For 'up to' 52Mbit/s FTTC connections, 23% of panellists achieved a maximum speed of more than 50Mbit/s.
- No panellists received a minimum speed of less than 10Mbit/s, and 6% received a minimum speed greater than 50Mbit/s.

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

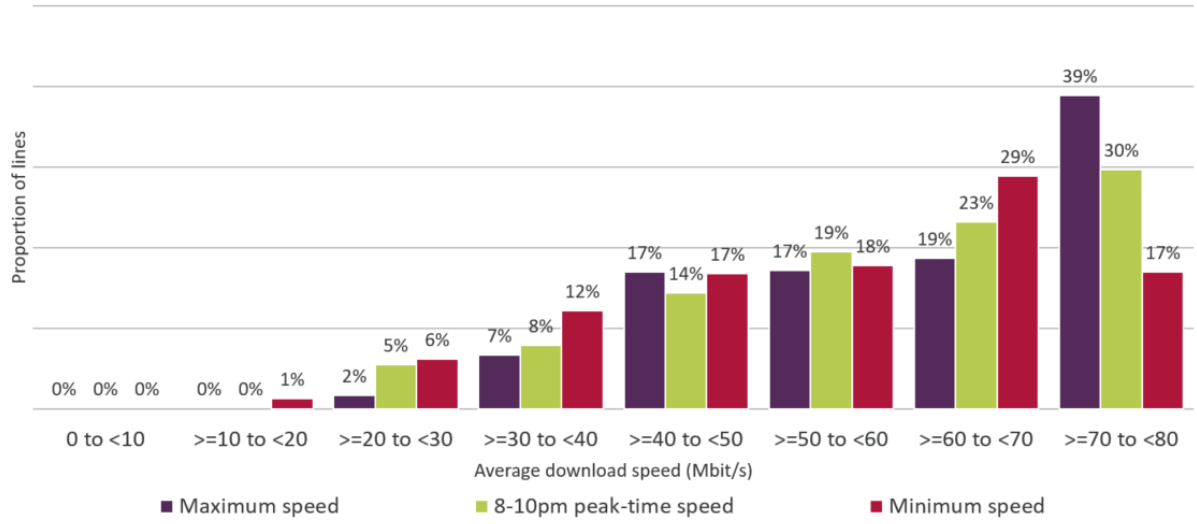


Source: Ofcom, using data provided by SamKnows; see note [18] in the sources section

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

- For 'up to' 76Mbit/s FTTC connections, 39% of panellists achieved a maximum speed more than 70Mbit/s.
- No panellists received a minimum speed of less than 10Mbit/s, and 17% of the panellists received a minimum speed greater than 70Mbit/s.

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

Single-stream 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 for which consumers use their broadband connection. To understand how well various fixed broadband connections handle the streaming of video content, we measure the streaming performance of broadband connections when accessing content from Netflix.

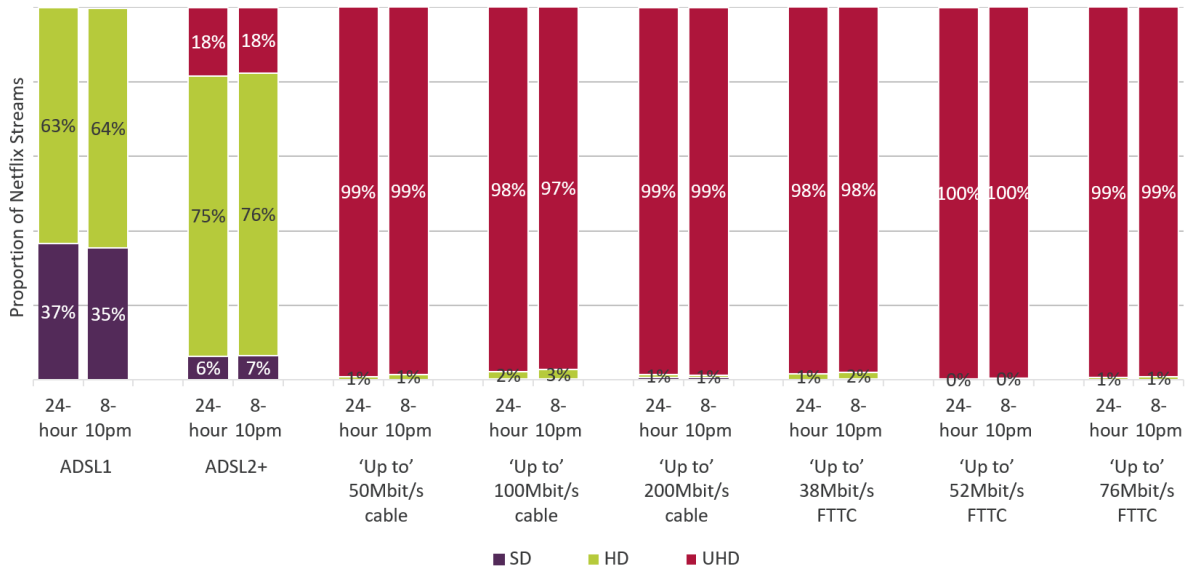
The charts below show the proportion of Netflix video streams that were delivered in the most commonly available resolutions: standard definition (SD), high definition (HD) and ultra-high definition (UHD) for each connection type.

It should be noted that these results represent the 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 UHD resolution

- More than 97% per cent of FTTC and cable Netflix video streams were delivered at UHD resolution during the 8pm-10pm peak-time period.
- For ADSL2+ services, around three-quarters of Netflix videos were streamed at HD resolution during the 24-hour and 8-10pm peak-time period, while 18% of streams were delivered in UHD (ADSL1 is not capable of supporting the speeds required for UHD).
- This suggests that ADSL2+ may currently be sufficient to meet the current broadband requirements of some smaller households, as video streaming is one of the most data-hungry uses of a broadband connection.

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

Disconnections

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

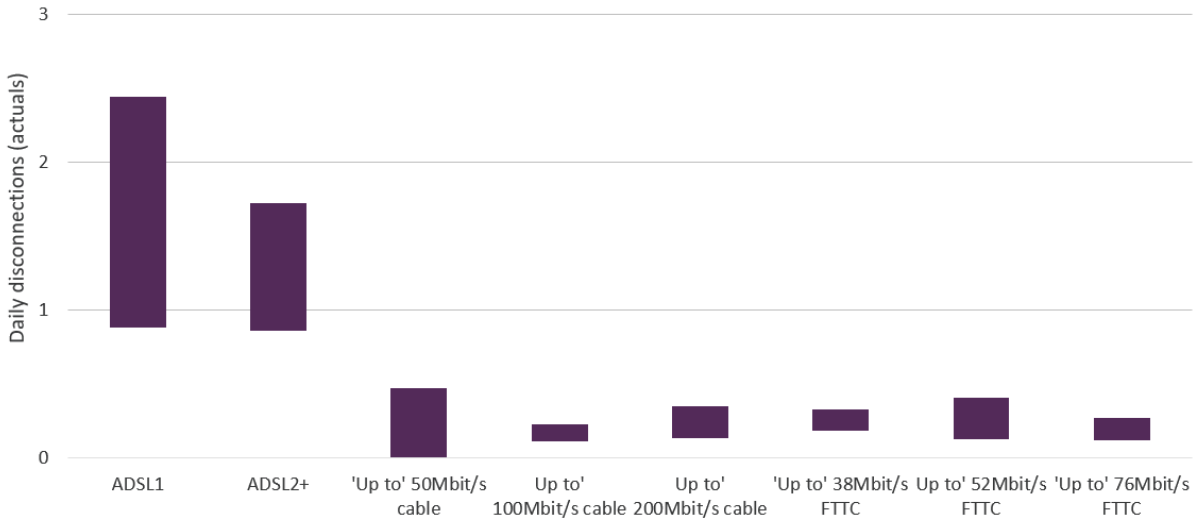
Users cannot undertake any online activities when their service loses internet connectivity, and interruptions to the fixed broadband service can be inconvenient and frustrating for users.

It should be noted that that all not all disconnections are due to network performance: for example, a panellist rebooting their router would be classified as a disconnection event by our test.

Superfast products tend to suffer from fewer disconnections than standard services

- Our research shows that ADSL services tend to suffer from disconnections of 30 seconds or longer more frequently than cable and FTTC services.
- In November 2017, ADSL connections had an average of 1.3 disconnections of 30 seconds or longer per day (1.7 for ADSL1 and 1.3 for ADSL2+).
- This compared to averages of 0.2 or 0.3 across all of the cable and FTTC connection types 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.

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.

Panellist recruitment

We undertook additional panellist recruitment prior to the November 2017 measurement period; one of the main purposes of this was to enable us to include one or more FTTP packages in the ISP package comparisons in this section of the report. Unfortunately, we were unable to recruit sufficient panellists to enable us to do this, including for KCOM, which has deployed FTTP to many of its customers in Kingston-upon-Hull and the surrounding areas.

As such, the only KCOM package where we had sufficient panellist size to report was its ADSL2+ service, and the performance of these connections should not be taken as representative for KCOM customers as a whole. FTTP services are available to over 75% of premises in the Hull area with the highest speed residential packages advertised at 'up to' 400Mbit/s. Around half of KCOM's customers take fibre-based services.

We are also unable to include Virgin Media's 'up to' 300Mbit/s cable service, the UK's first widely available ultrafast broadband service, in this report, due to not having enough panellists in November 2017.

Other than connections provided by KCOM, the incumbent provider in Kingston-upon-Hull, all of the ADSL2+ and fibre broadband packages included in the report are provided over the Openreach 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 an ADSL or FTTC package to another with the same advertised speed, unless the performance 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. This is because any such services will be provided over the same copper line, whose characteristics will be a key determining factor of the performance of any ADSL or FTTC broadband service delivered over it.

As mentioned previously, there are a number of limitations to our research, and it does not capture certain important factors that help determine the end-user's experience, such as wifi router performance, and there may be steps that consumers can take to improve their user experience, such as replacing in-home wiring and moving their router to a more suitable location.

Presentation of results

We present our findings 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.

We have designed the sampling and statistical methodologies 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.

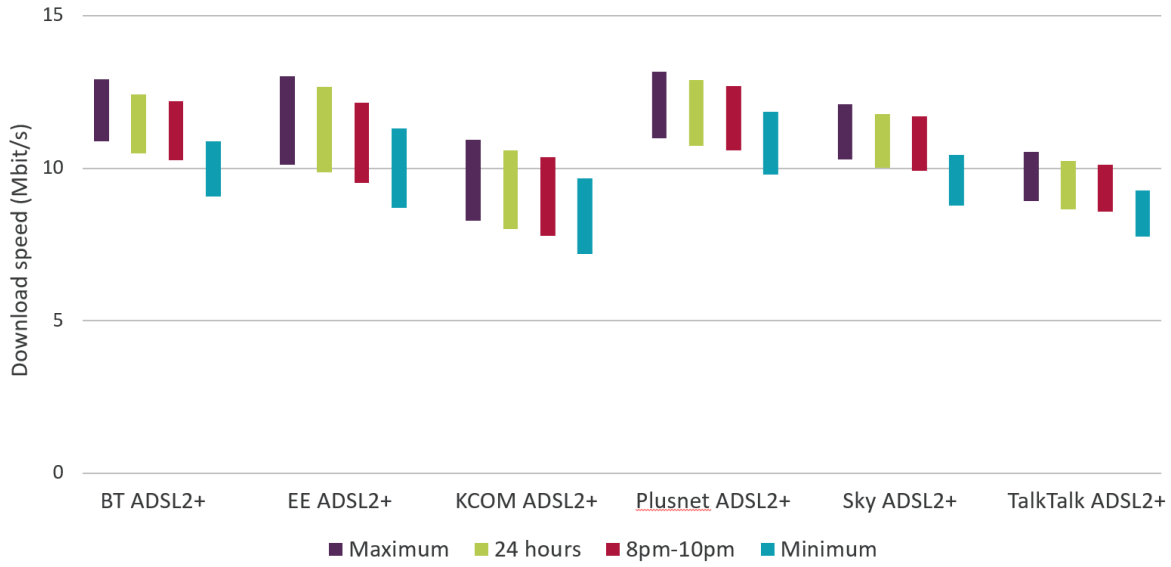
ADSL2+ connections: download speeds

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 is in Annex 2 of this report.

Variation in performance of ADSL2+ packages

- The average actual 24-hour download speeds of the ADSL2+ ISP packages included in our report ranged from 9.3Mbit/s for KCOM's service to 11.8Mbit/s for Plusnet's.
- The largest drops in the 8-10pm peak-time speed were observed for BT, EE and KCOM's ADSL2+ services, for which the average 8-10pm peak-time speeds were 94% of the average maximum speed.
- Sky's ADSL2+ service had the highest average 8-10pm peak-time speed as proportion of the maximum speed, at 97%.

Figure 26: Maximum, average, peak-time and minimum download speeds for ADSL2+ ISP packages



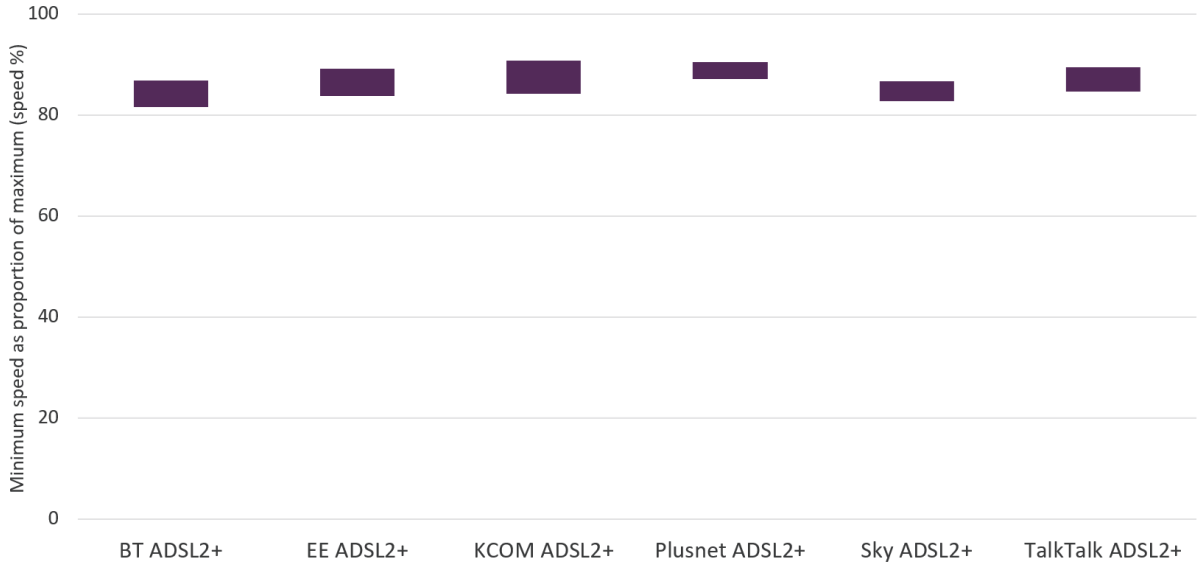
	Maximum	24-hour average	8pm-10pm	Minimum
ISP	**Was faster than**	**Was faster than**	**Was faster than**	**Was faster than**
Plusnet	KCOM* & TalkTalk*	KCOM* & TalkTalk*	KCOM* & TalkTalk*	KCOM* & TalkTalk*
BT	TalkTalk*	TalkTalk*	TalkTalk*	KCOM* & TalkTalk

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, our assumption being that any difference between the two is due to network slowdown at busy times.
- Plusnet's ADSL2+ service had the lowest level of contention; average minimum speeds were 90% of the average maximum speed.
- The highest level of contention was for BT's ADSL+ service, for which minimum speeds averaged 84% of the maximum speed.

Figure 27: Minimum speed as a proportion of maximum speed for ADSL+ ISP packages, and significant differences, to a 95% level of confidence: November 2017



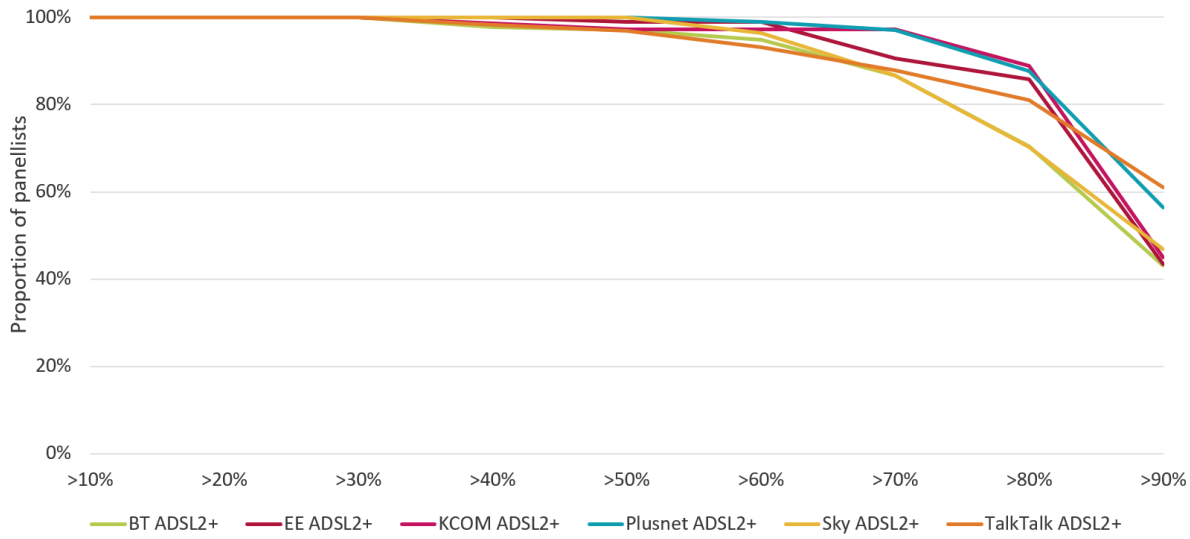
ISP	Was better than
Plusnet	Sky* & BT*

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 greater than 90% of its maximum speed ranged from 43% for BT's service to 61% for TalkTalk's.
- The proportion of panellists whose connection had a minimum speed less than half its maximum speed ranged from 0% for Plusnet and Sky's ADSL2+ services to 3% for BT, KCOM and TalkTalk.

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

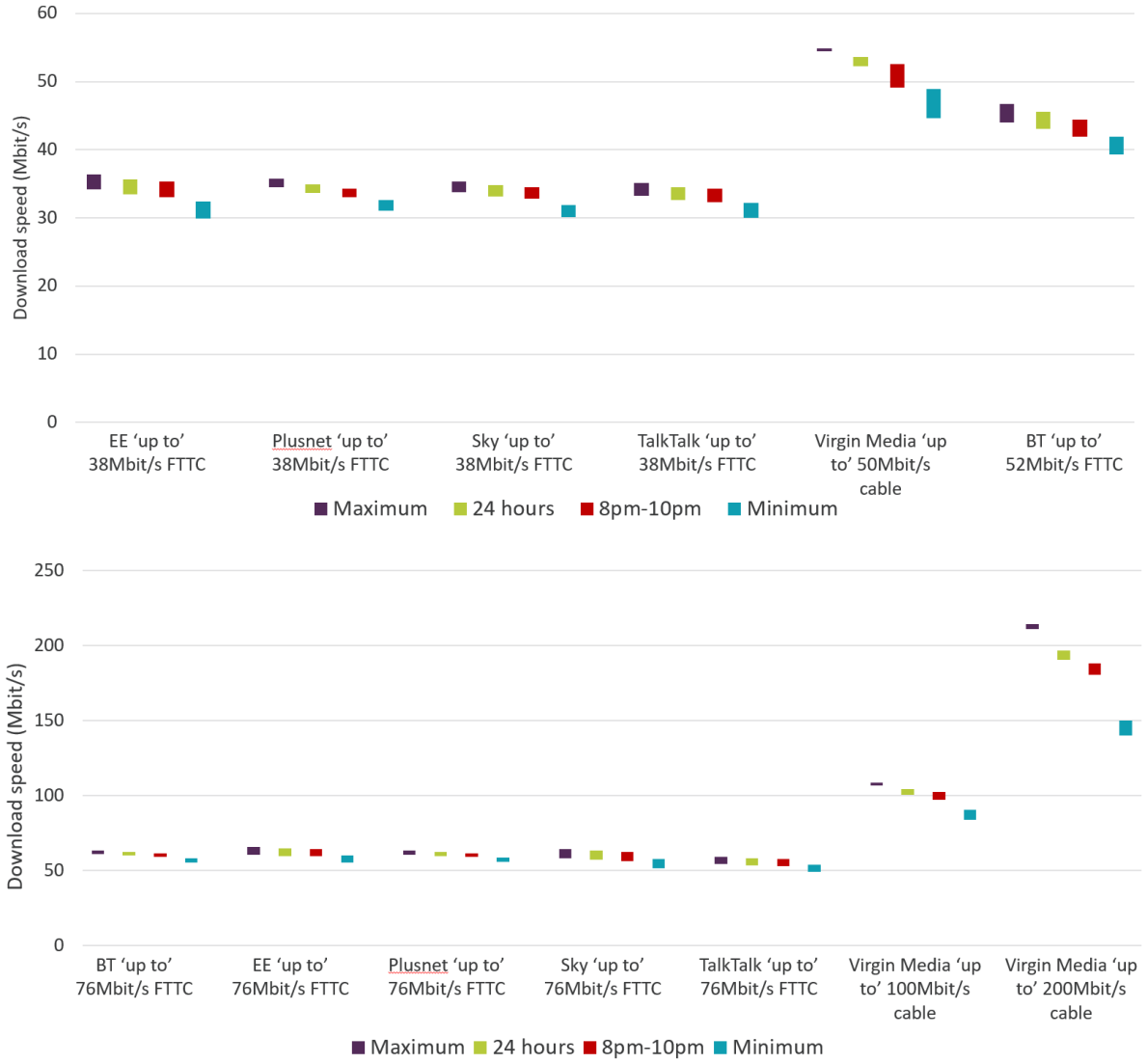


Source: Ofcom, using data provided by SamKnows; see note [23] in the sources section
Note: Where a panellist's maximum speed is higher than the advertised speed of their service, the advertised speed has been used to calculate the figures above.

Variation in performance of superfast broadband packages

- Our research indicates that 8-10pm peak-time average FTTC download speeds do not vary much from their maximum speeds, and in November 2017, all of the FTTC packages included in our research had an average peak-time download speed greater than 95% of their maximum speed.
- For the cable packages included in the research, maximum speeds were higher than for FTTC packages in comparable service tiers, although there was more variation in peak-time speeds.
- Among the three cable packages included in our research, average peak-time speeds represented between 87% and 93% of the average maximum speed (between 92% and 102% of the advertised speeds).
- Peak-time connection slowdown in Virgin Media's cable services was notably lower in November 2017 than in November 2016, suggesting that it has been investing in network upgrades.

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 2017



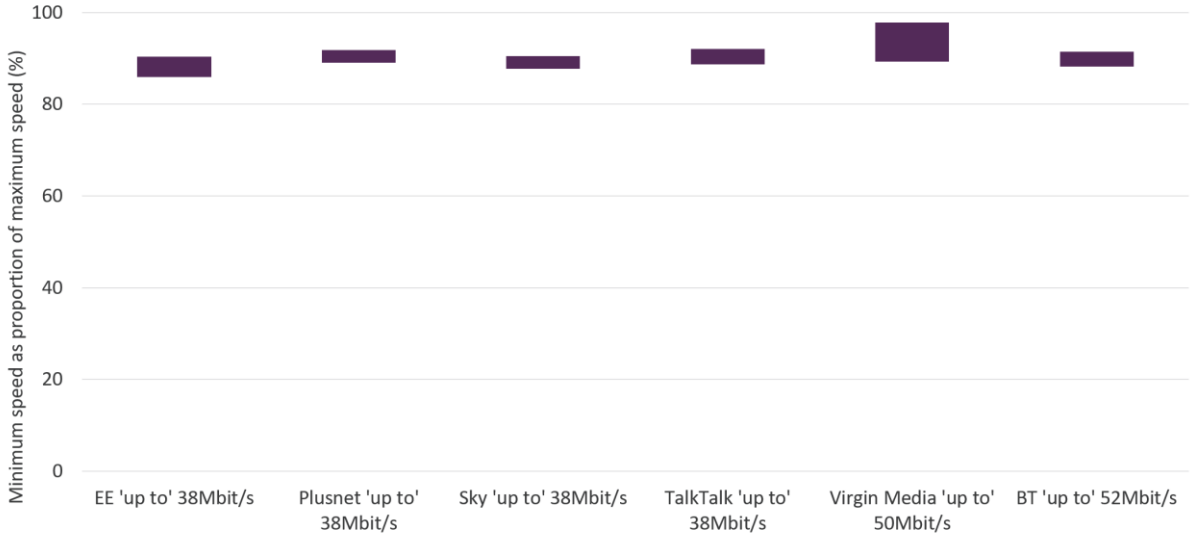
	Maximum	24-hour average	8pm-10pm	Minimum
ISP package	**Was faster than**	**Was faster than**	**Was faster than**	**Was faster than**
VM200	V100, EE76, BT76, PN76, Sky76, TT76, VM50, BT52, PN38, EE38, Sky38, TT38	V100, EE76, BT76, PN76, Sky76, TT76, VM50, BT52, EE38, PN38, Sky38, TT38	V100, EE76, PN76, BT76, Sky76, TT76, VM50, BT52, EE38, Sky38, PN38, TT38	V100, EE76, PN76, BT76, Sky76, TT76, VM50, BT52, PN38, EE38, Sky38, TT38
VM100	EE76, BT76, PN76, Sky76, TT76, VM50, BT52, PN38, EE38, Sky38, TT38	EE76, BT76, PN76, Sky76, TT76, VM50, BT52, EE38, PN38, Sky38, TT38	EE76, PN76, BT76, Sky76, TT76, VM50, BT52, EE38, Sky38, PN38, TT38	EE76, PN76, BT76, Sky76, TT76, VM50, BT52, PN38, EE38, Sky38, TT38
BT76	TT76*, VM50, BT52, PN38, EE38, Sky38, TT38	TT76, VM50, BT52, EE38, PN38, Sky38, TT38	TT76*, VM50, BT52, EE38, Sky38, PN38, TT38	TT76*, VM50, BT52, PN38, EE38, Sky38, TT38
EE76	TT76*, VM50, BT52, PN38, EE38, Sky38, TT38	TT76*, VM50, BT52, EE38, PN38, Sky38, TT38	TT76*, VM50, BT52, EE38, Sky38, PN38, TT38	TT76*, VM50, BT52, PN38, EE38, Sky38, TT38
PN76	TT76*, VM50, BT52, PN38, EE38, Sky38, TT38	TT76*, VM50, BT52, EE38, PN38, Sky38, TT38	TT76*, VM50, BT52, EE38, Sky38, PN38, TT38	TT76*, VM50, BT52, PN38, EE38, Sky38, TT38
Sky76	VM50, BT52, PN38, EE38, Sky38, TT38	VM50, BT52, EE38, PN38, Sky38, TT38	VM50, BT52, EE38, Sky38, PN38, TT38	VM50*, BT52, PN38, EE38, Sky38, TT38
TT76	BT52, PN38, EE38, Sky38, TT38	BT52, EE38, PN38, Sky38, TT38	BT52, EE38, Sky38, PN38, TT38	VM50*, BT52, PN38, EE38, Sky38, TT38
VM50	BT52, PN38, EE38, Sky38, TT38	BT52, EE38, PN38, Sky38, TT38	BT52, EE38, Sky38, PN38, TT38	BT52, PN38, EE38, Sky38, TT38
BT52	PN38, EE38, Sky38, TT38	EE38, PN38, Sky38, TT38	EE38, Sky38, PN38, TT38	PN38, EE38, Sky38, TT38

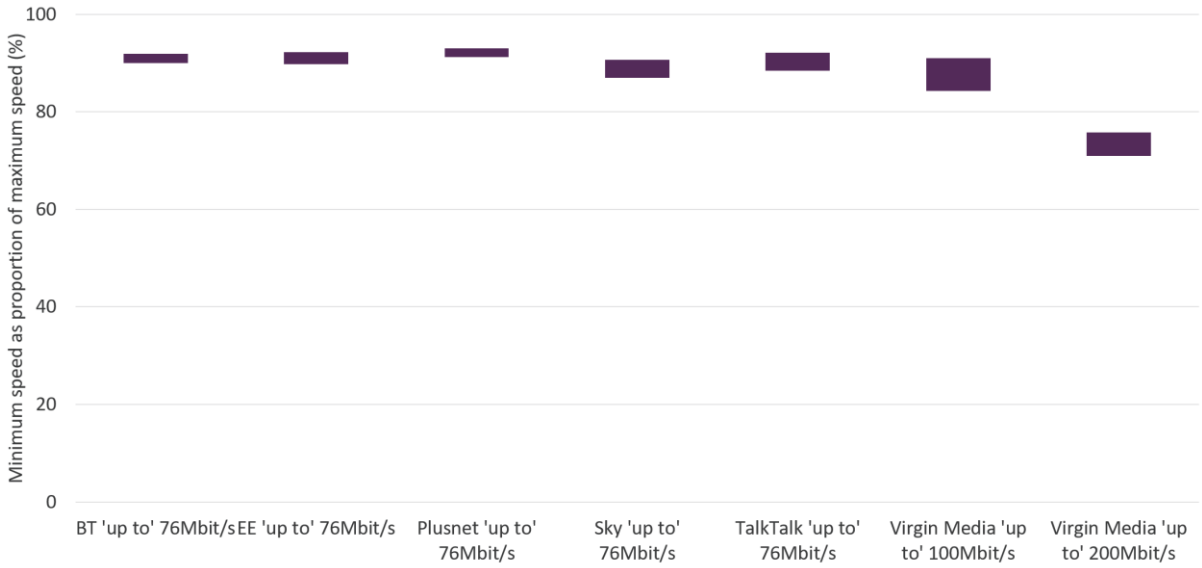
Source: Ofcom, using data provided by SamKnows; see note [24] & [25] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; the table shows significant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

- Virgin Media's 'up to' 50Mbit/s cable service had the lowest level of contention among the superfast products included in our research, with average minimum speeds at 94% of the advertised speed.
- Plusnet's 'up to' 76Mbit/s FTTC service also performed well, with minimum speeds, on average, representing 92% of panellists' maximum speeds.
- The highest level of contention was observed for Virgin Media's 'up to' 200Mbit/s service, with average minimum speeds at 72% of the advertised speed.

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 2017





ISP package	Was better than
VM50	VM200
PN76	VM200
EE76	VM200
BT76	VM200
TT38	VM200
PN38	VM200
TT76	VM200
BT52	VM200
Sky38	VM200
EE38	VM200
Sky76	VM200
VM100	VM200

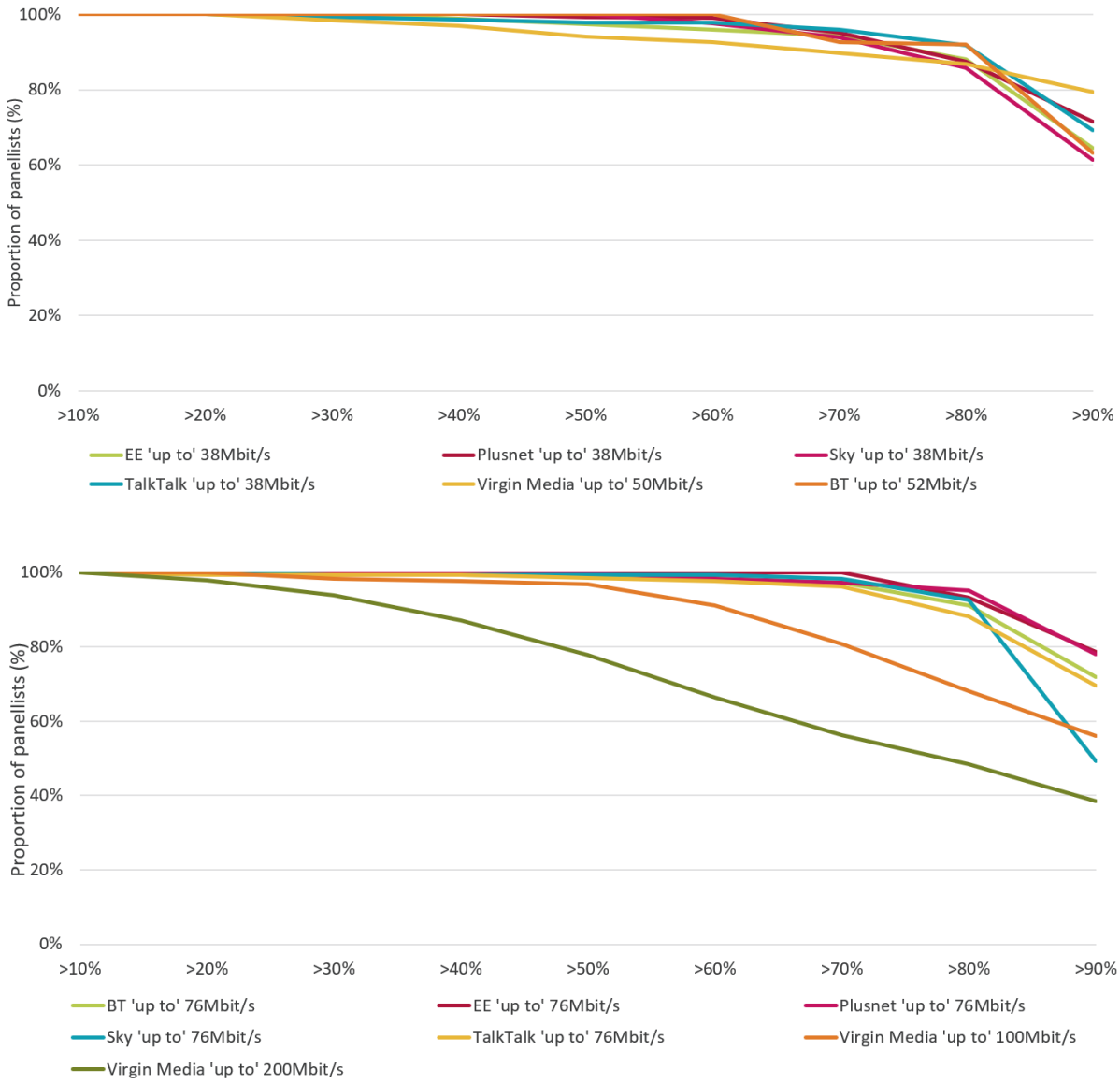
Source: Ofcom, using data provided by SamKnows; see note [26] & [27] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; where a panellist's 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 greater than 90% of its maximum/headline speed was lowest for Virgin Media's 'up to' 200Mbit/s cable service, at 38%.

- The best performance was for EE's 'up to' 76Mbit/s FTTC service and Virgin Media's 'up to' 50Mbit/s cable service, for which 79% of panellists received minimum speeds greater than 90% of the advertised speed.
- The proportion of panellists whose connection had a minimum speed that was less than half its maximum speed was lowest for Sky's 'up to' 38Mbit/s FTTC service, BT's 'up to' 52Mbit/s FTTC service and EE and Plusnet's 'up to' 76Mbit/s FTTC services, at 0%.
- Twenty-two per cent of Virgin Media 'up to' 200Mbit/s cable lines delivered a minimum speed that was less than half of the advertised speed.

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: Average maximum, 24-hour, peak-time and minimum download speeds, by ISP package: November 2017

	Maximum	24 hours	8pm-10pm	Minimum
BT ADSL2+	10.9-12.9Mbit/s	10.5-12.4Mbit/s	10.3-12.2Mbit/s	9.1-10.9Mbit/s
EE ADSL2+	10.1-13.0Mbit/s	9.9-12.7Mbit/s	9.5-12.2Mbit/s	8.7-11.3Mbit/s
KCOM ADSL2+	8.3-10.9Mbit/s	8.0-10.6Mbit/s	7.8-10.4Mbit/s	7.2-9.7Mbit/s
Plusnet ADSL2+	11.0-13.2Mbit/s	10.7-12.9Mbit/s	10.6-12.7Mbit/s	9.8-11.8Mbit/s
Sky ADSL2+	10.3-12.1Mbit/s	10.0-11.8Mbit/s	9.9-11.7Mbit/s	8.8-10.4Mbit/s
TalkTalk ADSL2+	8.9-10.5Mbit/s	8.7-10.2Mbit/s	8.6-10.1Mbit/s	7.8-9.3Mbit/s
EE 'up to' 38Mbit/s	34.2-36.4Mbit/s	33.5-35.7Mbit/s	33.0-35.3Mbit/s	29.9-32.4Mbit/s
Plusnet 'up to' 38Mbit/s	34.5-35.8Mbit/s	33.7-34.9Mbit/s	33.0-34.3Mbit/s	31.0-32.6Mbit/s
Sky 'up to' 38Mbit/s	33.8-35.4Mbit/s	33.1-34.8Mbit/s	32.8-34.5Mbit/s	30.1-31.9Mbit/s
TalkTalk 'up to' 38Mbit/s	33.3-35.1Mbit/s	32.6-34.5Mbit/s	32.3-34.3Mbit/s	30.1-32.2Mbit/s
Virgin Media 'up to' 50Mbit/s	54.4-54.9Mbit/s	52.3-53.6Mbit/s	49.2-52.6Mbit/s	44.7-48.9Mbit/s
BT 'up to' 52Mbit/s	44.0-46.8Mbit/s	43.0-45.6Mbit/s	41.9-44.4Mbit/s	39.3-41.9Mbit/s
BT 'up to' 76Mbit/s	61.2-63.6Mbit/s	60.1-62.6Mbit/s	59.0-61.6Mbit/s	55.5-58.1Mbit/s
EE 'up to' 76Mbit/s	60.8-65.9Mbit/s	59.8-64.9Mbit/s	59.5-64.5Mbit/s	55.2-60.3Mbit/s
Plusnet 'up to' 76Mbit/s	60.8-63.5Mbit/s	59.7-62.5Mbit/s	59.0-61.8Mbit/s	55.9-58.7Mbit/s
Sky 'up to' 76Mbit/s	58.3-64.4Mbit/s	57.3-63.4Mbit/s	56.5-62.6Mbit/s	51.6-57.7Mbit/s
TalkTalk 'up to' 76Mbit/s	54.4-59.2Mbit/s	53.3-58.2Mbit/s	52.8-57.7Mbit/s	49.0-54.1Mbit/s
Virgin Media 'up to' 100Mbit/s	106.8-108.5Mbit/s	100.7-104.3Mbit/s	97.2-102.3Mbit/s	83.8-90.7Mbit/s
Virgin Media 'up to' 200Mbit/s	210.9-214.6Mbit/s	190.6-196.7Mbit/s	180.4-188.3Mbit/s	139.9-150Mbit/s

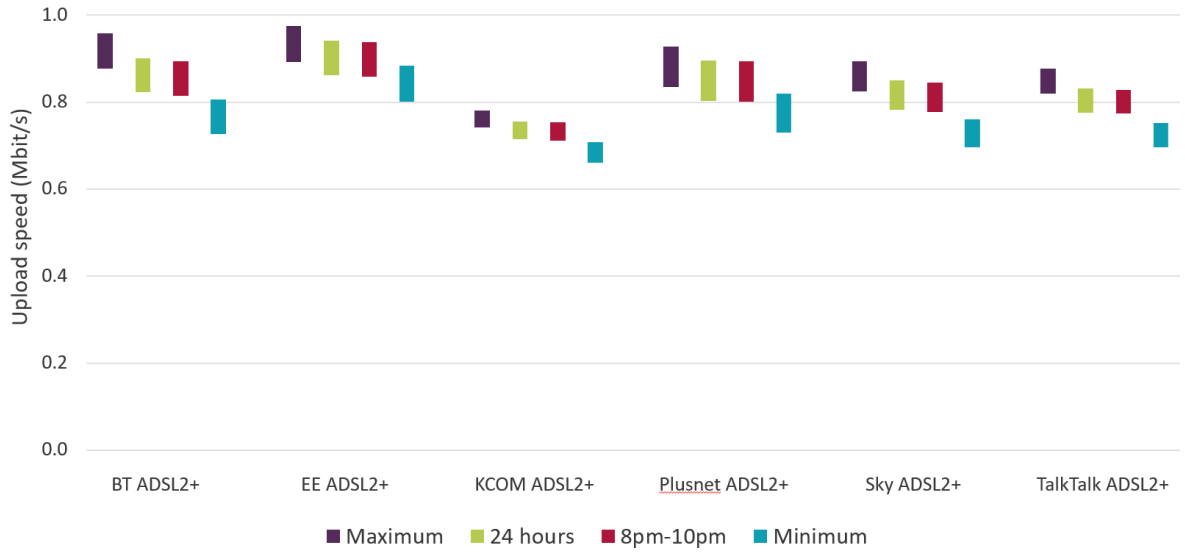
Source: Ofcom, using data provided by SamKnows

Upload speeds

Upload speeds play an important part in the performance of the broadband services for many consumers, especially 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 in November 2017.
- KCOM's ADSL2+ service had the lowest average upload speeds across the services included in our research.

Figure 33: Maximum, average, peak-time and minimum upload speeds for ADSL2+ ISP packages and significant differences, to a 95% level of confidence: November 2017



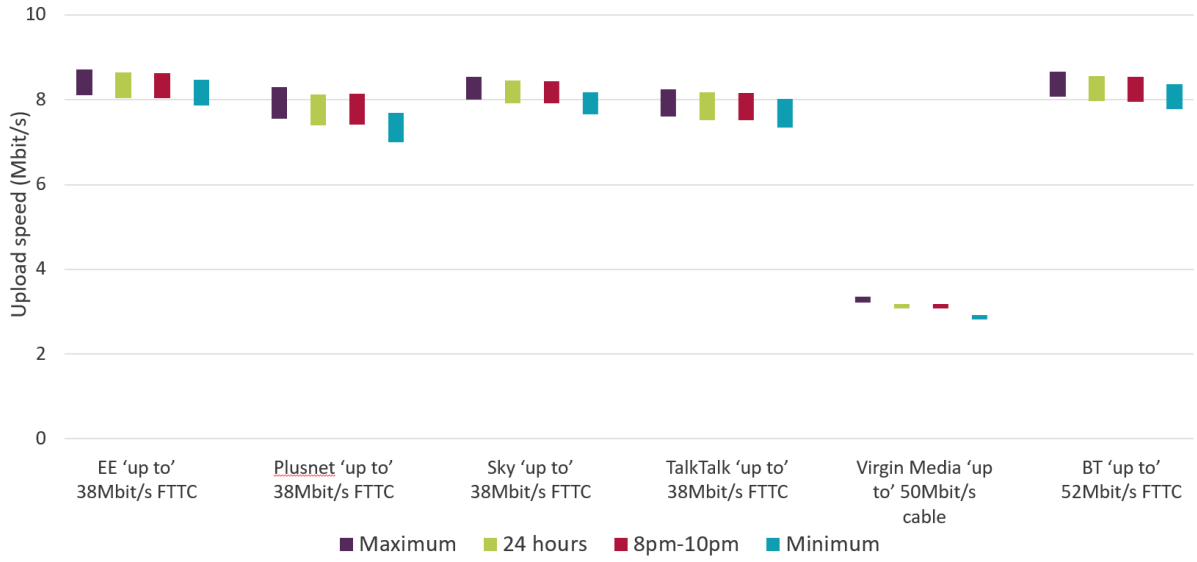
	Maximum	24-hour average	8pm-10pm	Minimum
ISP	**Was faster than**	**Was faster than**	**Was faster than**	**Was faster than**
EE	TalkTalk* & KCOM	Sky*, TalkTalk* & KCOM	Sky*, TalkTalk & KCOM	Sky, TalkTalk & KCOM
BT	TalkTalk* & KCOM	KCOM	KCOM	KCOM*
Plusnet	KCOM	KCOM	KCOM	KCOM
Sky	KCOM	KCOM	KCOM	-
TalkTalk	KCOM	KCOM	KCOM	-

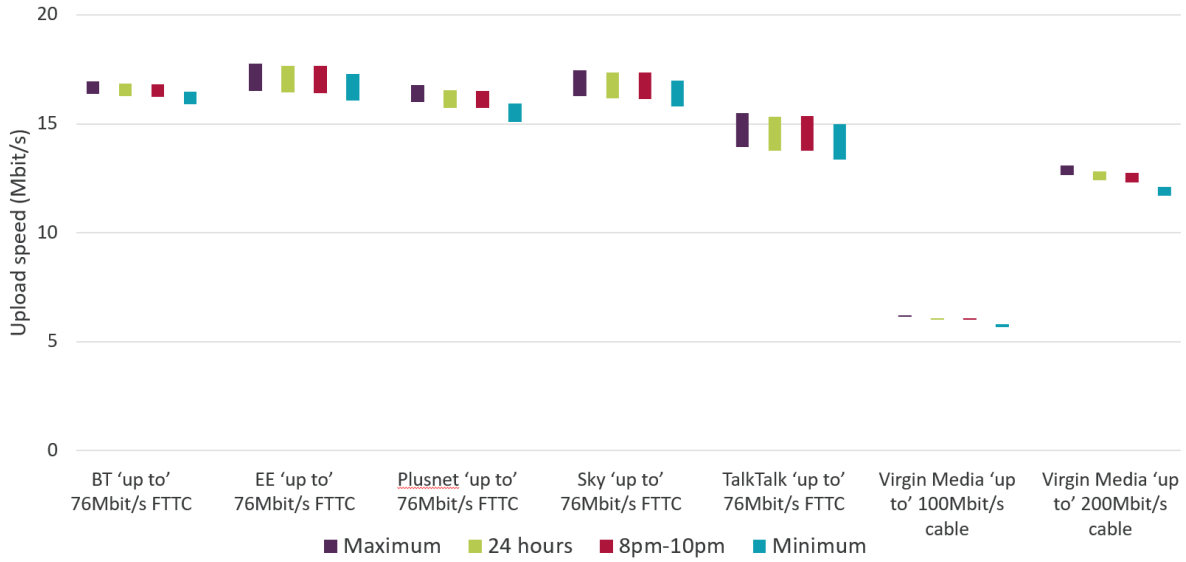
Source: Ofcom, using data provided by SamKnows; see note [30] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges; the table shows significant differences 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, EE's 'up to' 76Mbit/s FTTC service had the fastest upload speeds among the superfast products included in our analysis, averaging 17.1Mbit/s over 24 hours and 17.0Mbit/s during the 8-10pm peak-time period.
- For cable packages, the highest upload speeds were achieved by Virgin Media's 'up to' 200Mbit/s package, which had average 24-hour and peak-time speeds of 12.6Mbit/s and 12.5Mbit/s respectively.
- There were notable improvements in the upload speeds provided by Plusnet and TalkTalk's 'up to' 38Mbit/s FTTC services in the year to November 2017, which was due to many panellists' advertised upload speeds being upgraded from 'up to' 2Mbit/s to 'up to' 9.5Mbit/s.

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 2017





	Maximum	24-hour average	8pm-10pm	Minimum
ISP package	**Was faster than**	**Was faster than**	**Was faster than**	**Was faster than**
EE76	TT76, VM200, EE38, BT52, PN38, Sky38, TT38, VM100, VM50	TT76, VM200, EE38, BT52, Sky38, PN38, TT38, VM100, VM50	TT76, VM200, EE38, BT52, Sky38, PN38, TT38, VM100, VM50	Sky76*, BT76*, PN76*, TT76, VM200, EE38, BT52, Sky38, TT38, PN38, VM100, VM50
Sky76	TT76, VM200, EE38, BT52, PN38, Sky38, TT38, VM100, VM50	TT76, VM200, EE38, BT52, Sky38, PN38, TT38, VM100, VM50	TT76, VM200, EE38, BT52, Sky38, PN38, TT38, VM100, VM50	TT76, VM200, EE38, BT52, Sky38, TT38, PN38, VM100, VM50
BT76	TT76, VM200, EE38, BT52, PN38, Sky38, TT38, VM100, VM50	TT76, VM200, EE38, BT52, Sky38, PN38, TT38, VM100, VM50	TT76, VM200, EE38, BT52, Sky38, PN38, TT38, VM100, VM50	TT76, VM200, EE38, BT52, Sky38, TT38, PN38, VM100, VM50
PN76	*TT76, VM200, EE38, BT52, PN38, Sky38, TT38, VM100, VM50	TT76*, VM200, EE38, BT52, Sky38, PN38, TT38, VM100, VM50	TT76*, VM200, EE38, BT52, Sky38, PN38, TT38, VM100, VM50	TT76*, VM200, EE38, BT52, Sky38, TT38, PN38, VM100, VM50
TT76	VM200, EE38, BT52, PN38, Sky38, TT38, VM100, VM50	VM200, EE38, BT52, Sky38, PN38, TT38, VM100, VM50	VM200, EE38, BT52, Sky38, PN38, TT38, VM100, VM50	VM200, EE38, BT52, Sky38, TT38, PN38, VM100, VM50
VM200	EE38, BT52, PN38, Sky38, TT38, VM100, VM50	EE38, BT52, Sky38, PN38, TT38, VM100, VM50	EE38, BT52, Sky38, PN38, TT38, VM100, VM50	EE38, BT52, Sky38, TT38, PN38, VM100, VM50
EE38	VM100, VM50	VM100, VM50	BT52, Sky38, PN38, TT38, VM100, VM50	VM50
BT52	VM100, VM50	VM100, VM50	VM100, VM50	VM50
Sky38	VM100, VM50	VM100, VM50	VM100, VM50	VM50
PN38	VM100, VM50	VM100, VM50	VM100, VM50	VM50
TT38	VM100, VM50	VM100, VM50	VM100, VM50	VM50
VM100	VM50	VM50	VM50	VM50

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

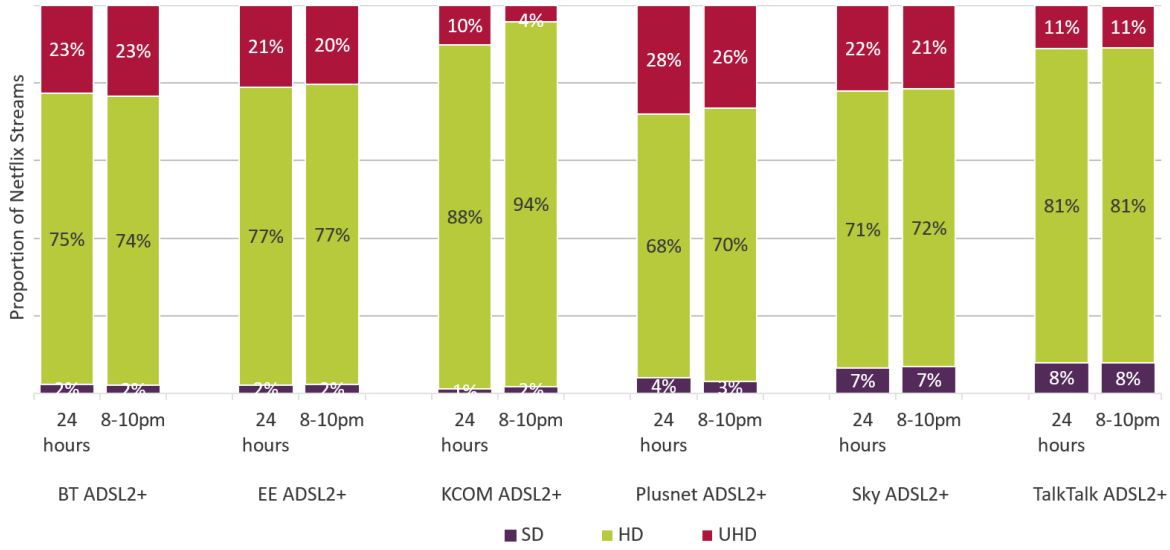
table shows significant differences to a 95% confidence level; an asterisk (*) denotes that a difference is not significant to a (higher) 99% level of confidence.

Single-stream video streaming quality, by ISP package

Streaming Netflix videos over ADSL2+ ISP packages

- Again, it should be noted that these results represent one user streaming Netflix content over a broadband connection, and the streaming quality that can be achieved may drop when multiple users are simultaneously using the same connection.
- For all of the ADSL2+ services included in our analysis, the majority of Netflix content could reliably be streamed in HD resolution during both the 24-hour and peak-time periods.
- BT, EE and KCOM's ADSL2+ services had the lowest proportion of 8-10pm peak-time speeds that could be reliably streamed only in SD (all 2%), while Plusnet's service had the highest proportion of peak-time streams that could be delivered in UHD (26%).

Figure 35: Proportion of Netflix videos delivered at the given video quality without rebuffering 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

- All the superfast services included in our research reliably achieved UHD resolution for more than 95% of Netflix streams.

Figure 36: Proportion of Netflix videos delivered at the given video quality without rebuffering 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

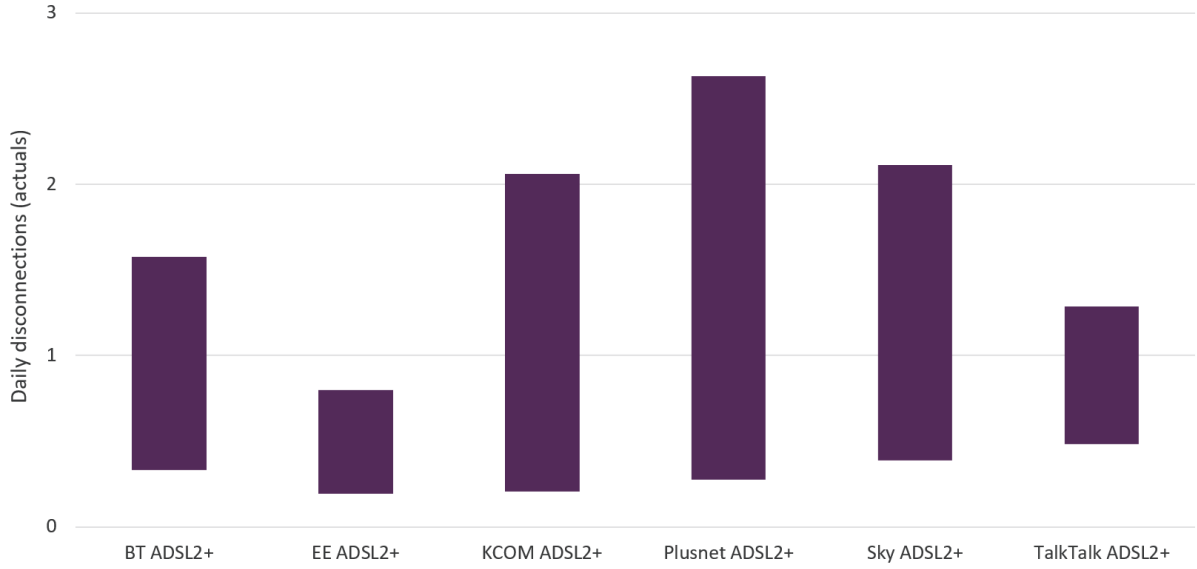
The average daily disconnections metric measures the frequency and duration of broadband service disconnections. Users cannot undertake any online activities when their service loses internet connectivity, and disconnections can be inconvenient and frustrating for users.

Again, should be noted that that all not all disconnections are due to network performance: for example, a panellist rebooting their router would be classified as a disconnection event by our test.

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 2017.

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



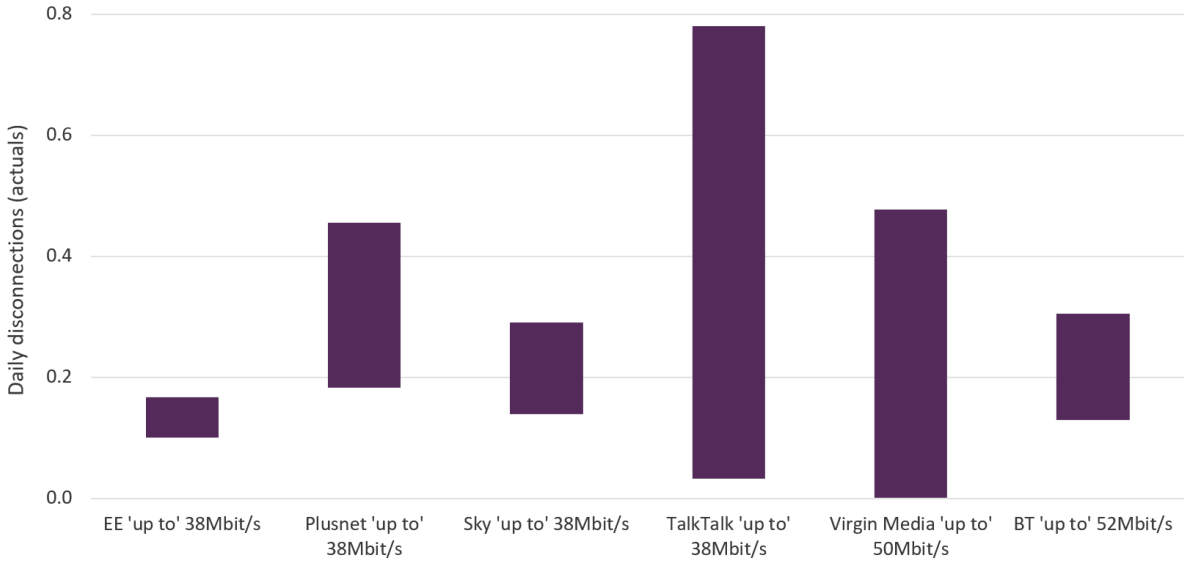
ISP	Performed better than
No differences	No differences

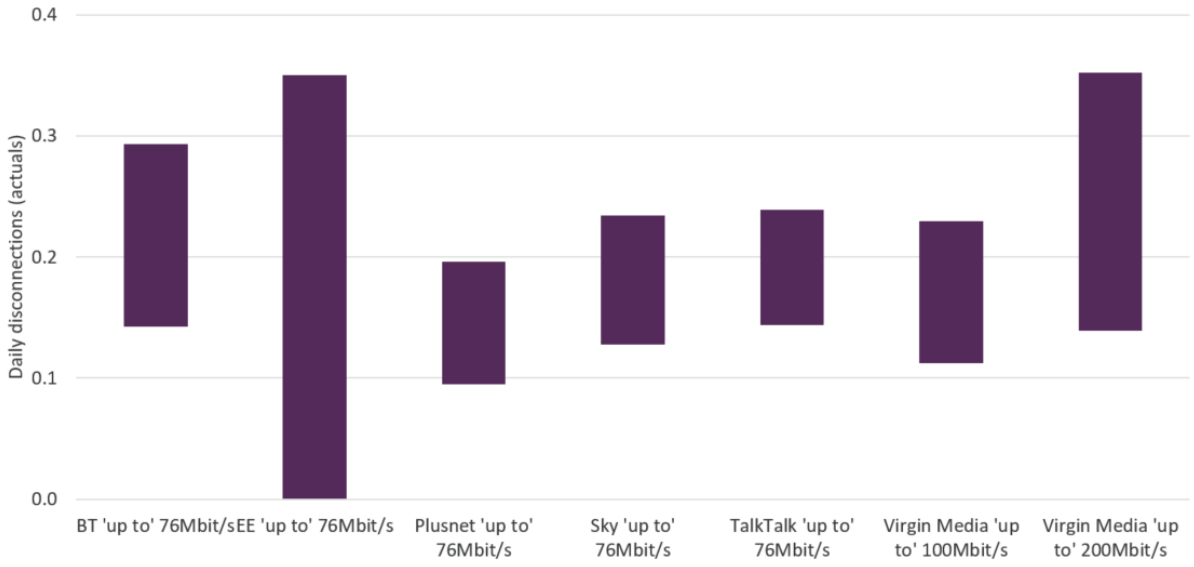
Source: Ofcom, using data provided by SamKnows; see note [36] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown.

Disconnections for superfast broadband packages

- EE's 'up to' 38Mbit/s and Plusnet's 'up to' 76Mbit/s FTTC packages performed well in terms of disconnections in November 2017, both averaging 0.1 disconnections of 30 seconds or longer per day.

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 2017





ISP package	Performed better than
EE38	PN38

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.

Other metrics affecting performance

There are a number of other metrics that determine the performance of fixed-line broadband services, and the most important of these are outlined in the table below.

As the technologies and providers that 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 packages.

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) form 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*

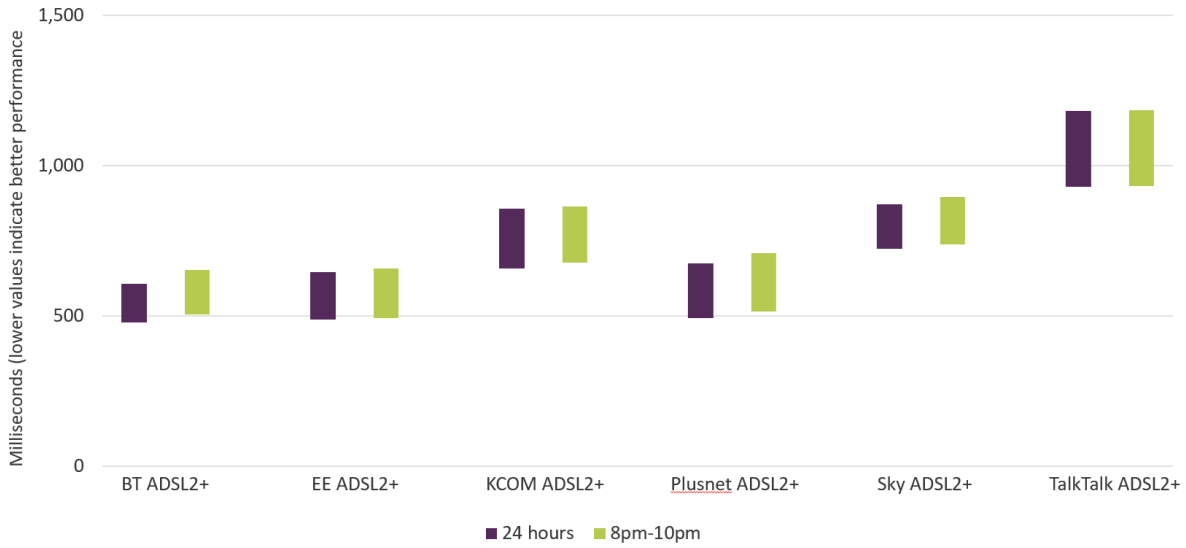
Source: Ofcom

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

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. Lower bars indicate better performance.

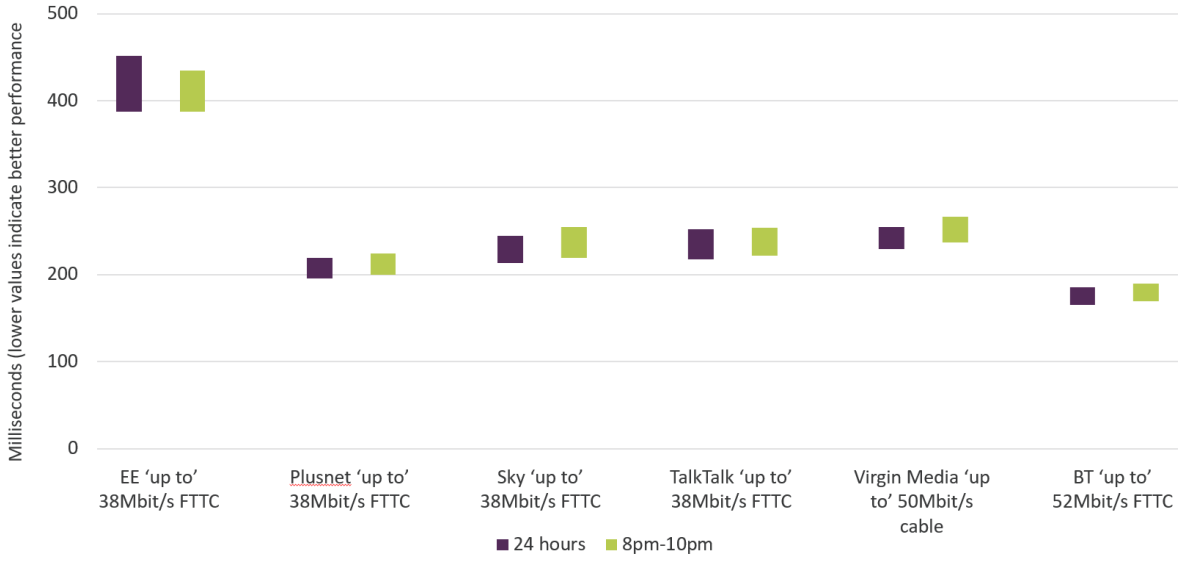
Figure 40: Average and peak-time loading of web pages for ADSL2+ ISP packages, and significant differences, to a 95% level of confidence: November 2017

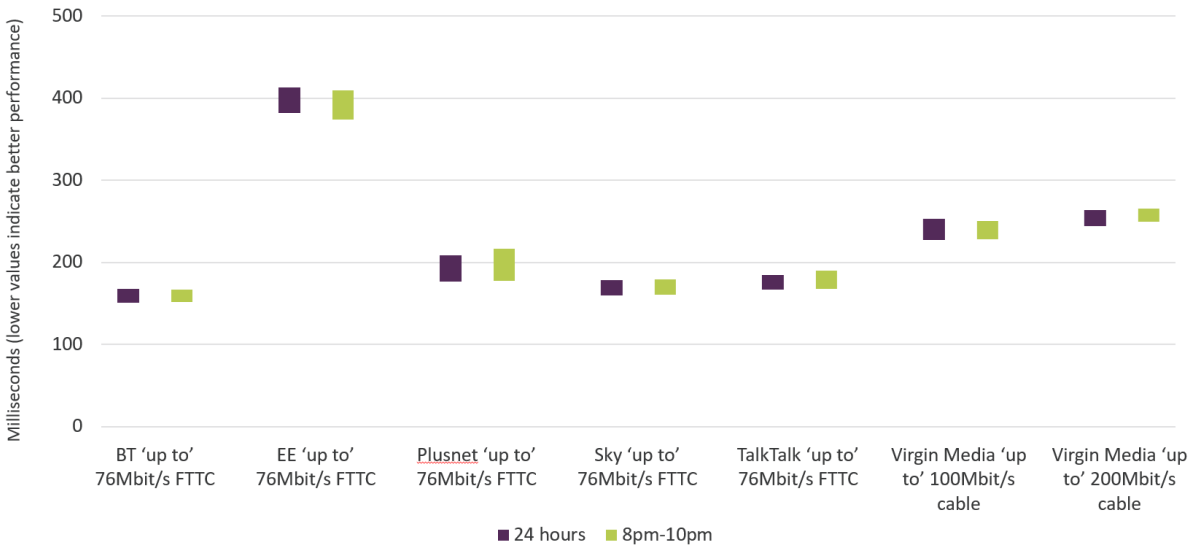


	24-hour average	8pm-10pm
ISP	**Performed better than**	**Performed better than**
BT	KCOM*, Sky and TalkTalk	KCOM*, Sky and TalkTalk
EE	KCOM*, Sky and TalkTalk	KCOM*, Sky and TalkTalk
Plusnet	Sky* and TalkTalk	Sky* and TalkTalk
KCOM	TalkTalk	TalkTalk*

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 'up to' 30Mbit/s and above ISP packages, and significant differences, to a 95% level of confidence: November 2017





	24-hour average	8pm-10pm
ISP package	**Performed better than**	**Performed better than**
BT76	PN76*, PN38, Sky38, TT38, VM100, VM50, VM200, EE76 & EE38	PN76*, PN38, Sky38, TT38, VM100, VM50, VM200, EE76 & EE38
Sky76	PN38, Sky38, TT38, VM100, VM50, VM200, EE76 & EE38	PN38, Sky38, TT38, VM100, VM50, VM200, EE76 & EE38
BT52	PN38, Sky38, TT38, VM100, VM50, VM200, EE76 & EE38	PN38*, Sky38, TT38, VM100, VM50, VM200, EE76 & EE38
TT76	PN38, Sky38, TT38, VM100, VM50, VM200, EE76 & EE38	PN38, Sky38, TT38, VM100, VM50, VM200, EE76 & EE38
PN76	TT38, VM100, VM50, VM200, EE76 & EE38	VM100*, VM50, VM200, EE76 & EE38
PN38	VM100*, VM50, VM200, EE76 & EE38	VM100*, VM50, VM200, EE76 & EE38
Sky38	VM200*, EE76 & EE38	EE76 & EE38
TT38	EE76 & EE38	EE76 & EE38
VM100	EE76 & EE38	EE76 & EE38
VM50	EE76 & EE38	EE76 & EE38
VM200	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.

Latency

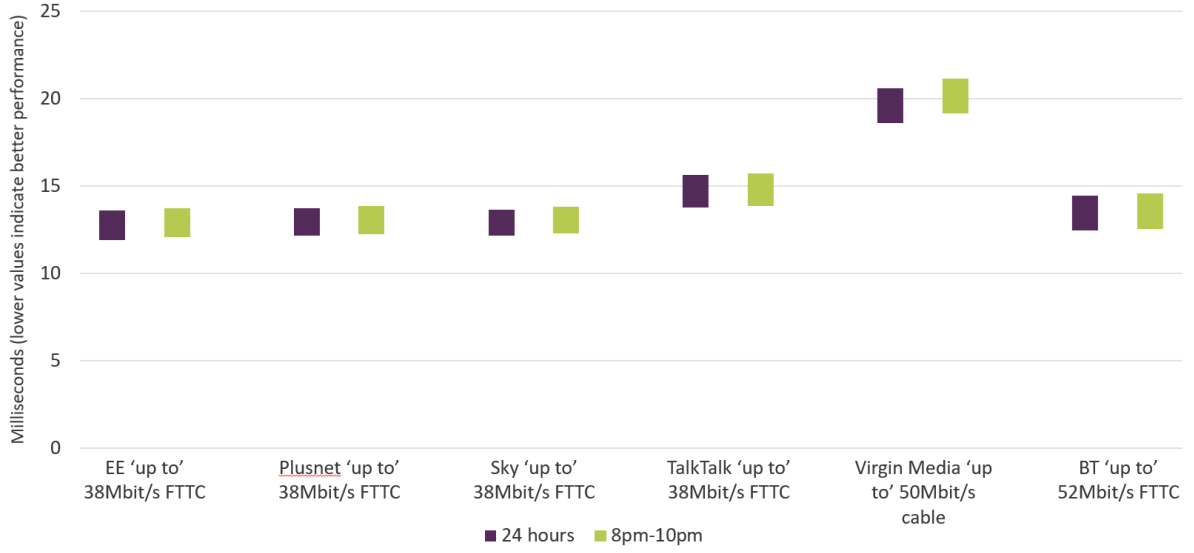
Latency is the time it takes for a single packet of data to travel to a third-party server and back again. The figure is commonly measured in milliseconds, and a connection with low latency will seem more responsive for the delivery of simple tasks such as web browsing. Particular applications also perform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

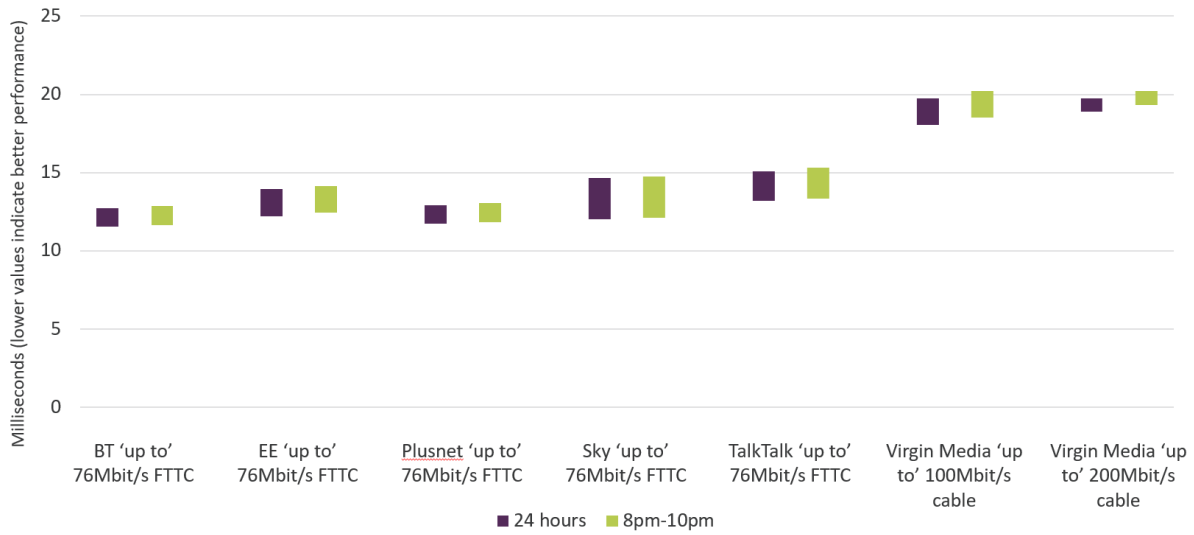
Figure 42: Average and peak-time latency for ADSL2+ ISP packages and significant differences, to a 95% level of confidence: November 2017

	24-hour average	8pm-10pm
ISP	**Performed better than**	**Performed better than**
EE	Sky, TalkTalk & KCOM	Sky, TalkTalk & KCOM
Plusnet	Sky, TalkTalk & KCOM	Sky, TalkTalk & KCOM
BT	Sky*, TalkTalk & KCOM	Sky*, TalkTalk & KCOM
Sky	TalkTalk & KCOM	TalkTalk & 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 'up to' 30Mbit/s and above ISP packages and significant differences, to a 95% level of confidence: November 2017





	24-hour average	8pm-10pm
ISP package	**Performed better than**	**Performed better than**
BT76	TT76*, TT38, VM100, VM200, VM50	TT76*, TT38, VM100, VM200, VM50
PN76	TT76*, TT38, VM100, VM200, VM50	TT76*, TT38, VM100, VM200, VM50
EE38	TT38*, VM100, VM200, VM50	TT38*, VM100, VM200, VM50
Sky38	TT38*, VM100, VM200, VM50	TT38*, VM100, VM200, VM50
PN38	TT38*, VM100, VM200, VM50	TT76*, TT38, VM100, VM200, VM50
EE76	VM100, VM200, VM50	VM100, VM200, VM50
Sky76	VM100, VM200, VM50	VM100, VM200, VM50
BT52	VM100, VM200, VM50	VM100, VM200, VM50
TT76	VM100, VM200, VM50	VM100, VM200, VM50
TT38	VM100, VM200, VM50	VM100, VM200, VM50

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.

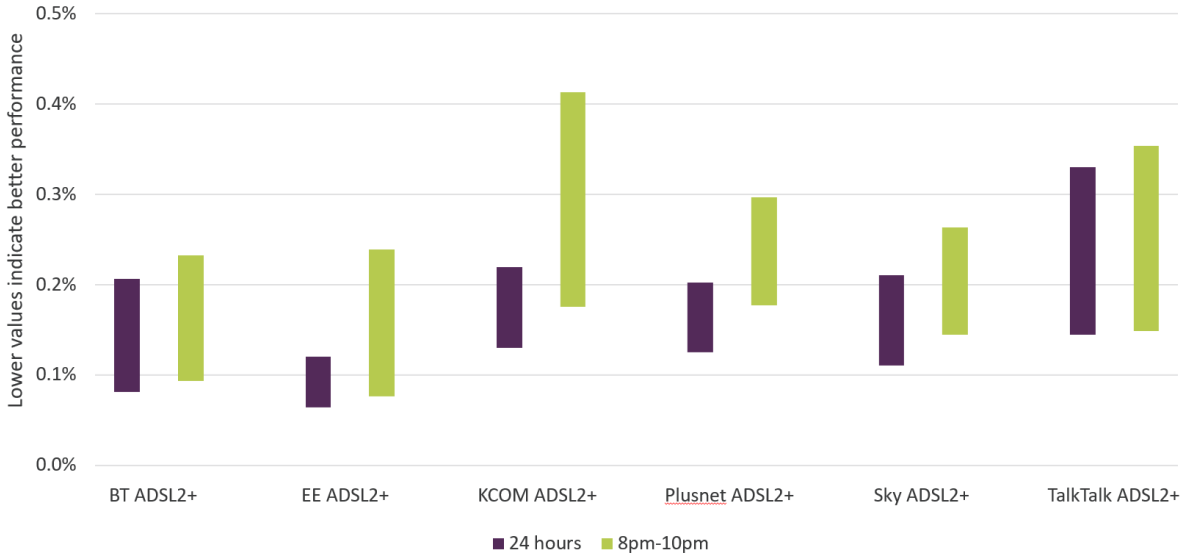
Packet loss

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). Lower bars indicate better performance.

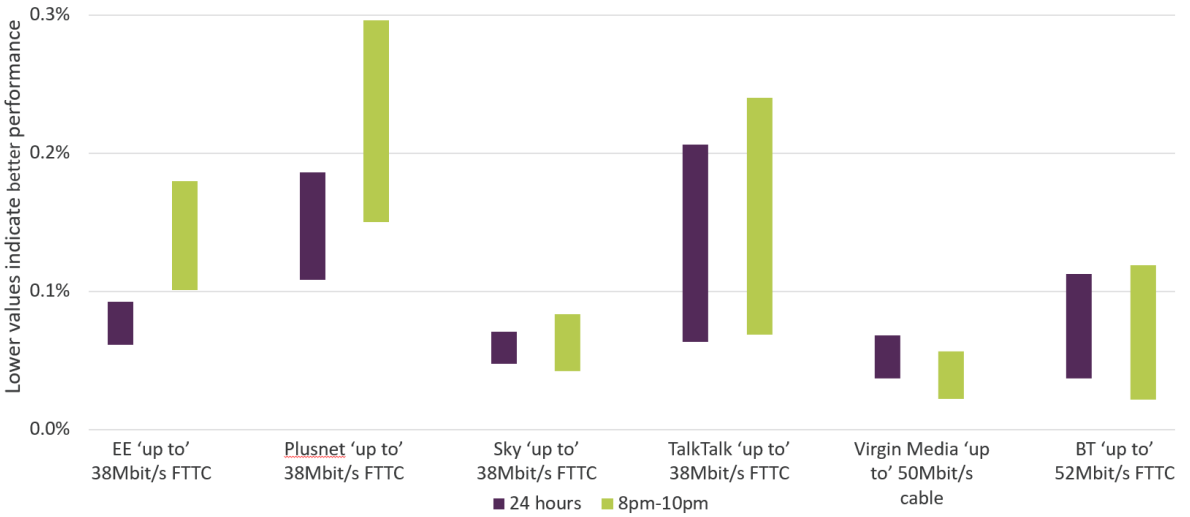
Figure 44: Average and peak-time packet loss for ADSL2+ ISP packages, and significant differences, to a 95% level of confidence: November 2017

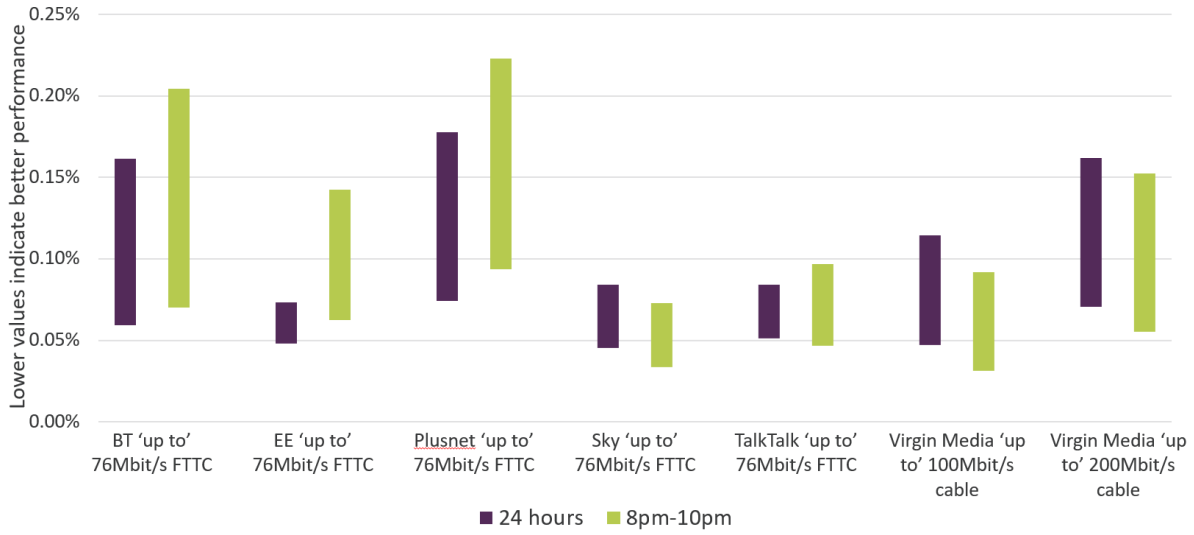


	24-hour average	8pm-10pm
ISP	**Performed better than**	**Performed better than**
EE	Plusnet*, KCOM* and TalkTalk*	No differences

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 45: Average and peak-time packet loss for 'up to' 30Mbit/s and above ISP packages, and significant differences, to a 95% level of confidence: November 2017





	24-hour average	8pm-10pm
ISP package	**Performed better than**	**Performed better than**
VM50	PN38*	PN76*, VM200*, TT38*, EE38, PN38
Sky38	PN38*	EE38*, PN38
EE76	PN38*	-
Sky76	PN38*	EE38, PN38
TT76	PN38*	PN38
VM100	-	EE38*, PN38
BT52	-	PN38*

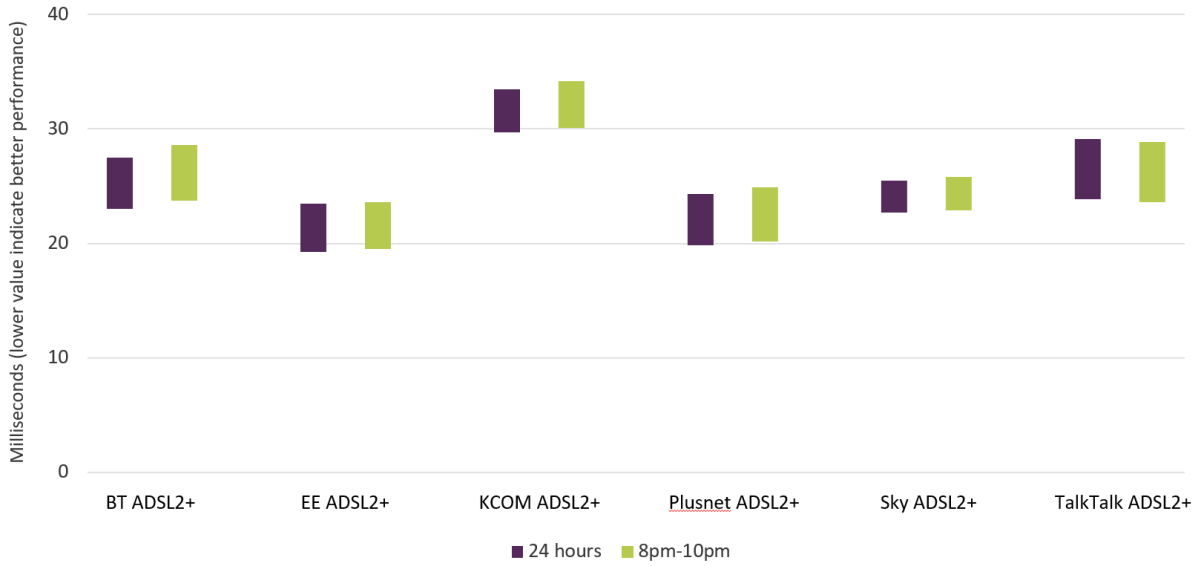
Source: Ofcom, using data provided by SamKnows; see note [37] & [38] in the sources section
Note: The chart bars show that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists in our sample) falls within the ranges shown; the table shows significant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

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. Lower bars indicate better performance.

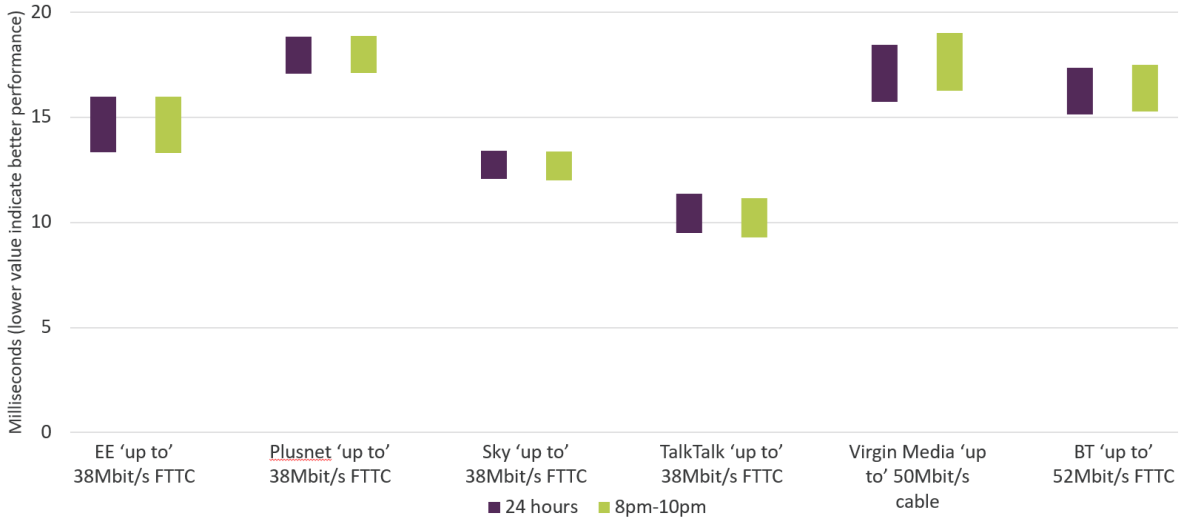
Figure 46: Average and peak-time DNS resolution time for ADSL2+ ISP packages and significant differences, to a 95% level of confidence: November 2017

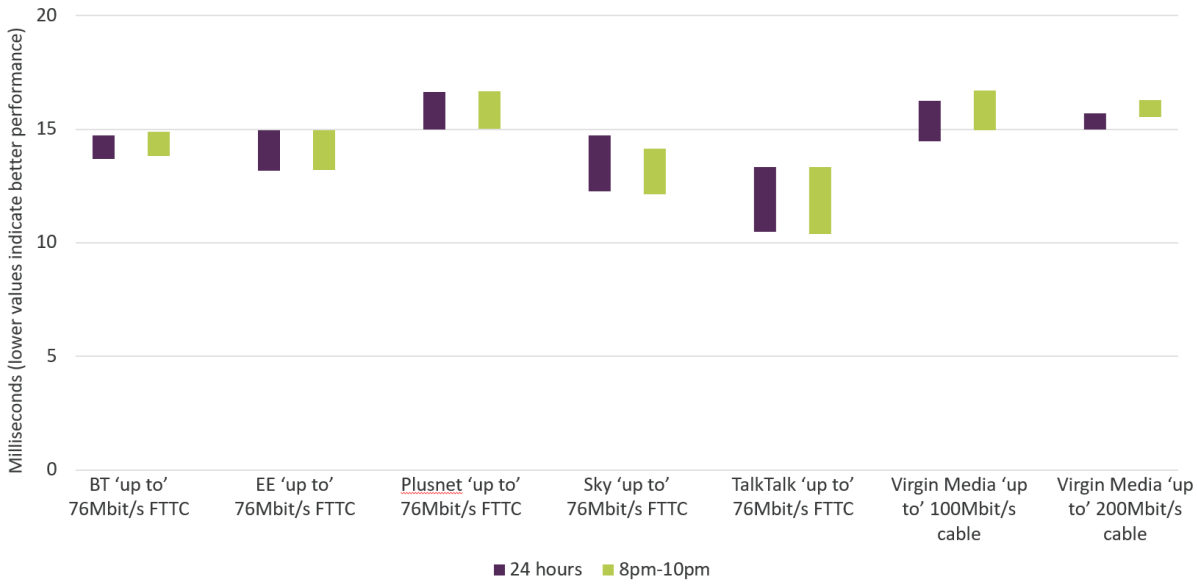


	24-hour average	8pm-10pm
ISP	**Performed better than**	**Performed better than**
EE	TalkTalk* & KCOM	BT*, TalkTalk* & KCOM
Plusnet	KCOM	KCOM
Sky	KCOM	KCOM
BT	KCOM	KCOM
TalkTalk	-	KCOM*

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 47: Average and peak-time DNS resolution time for 'up to' 30Mbit/s and above ISP packages and significant differences, to a 95% level of confidence: November 2017





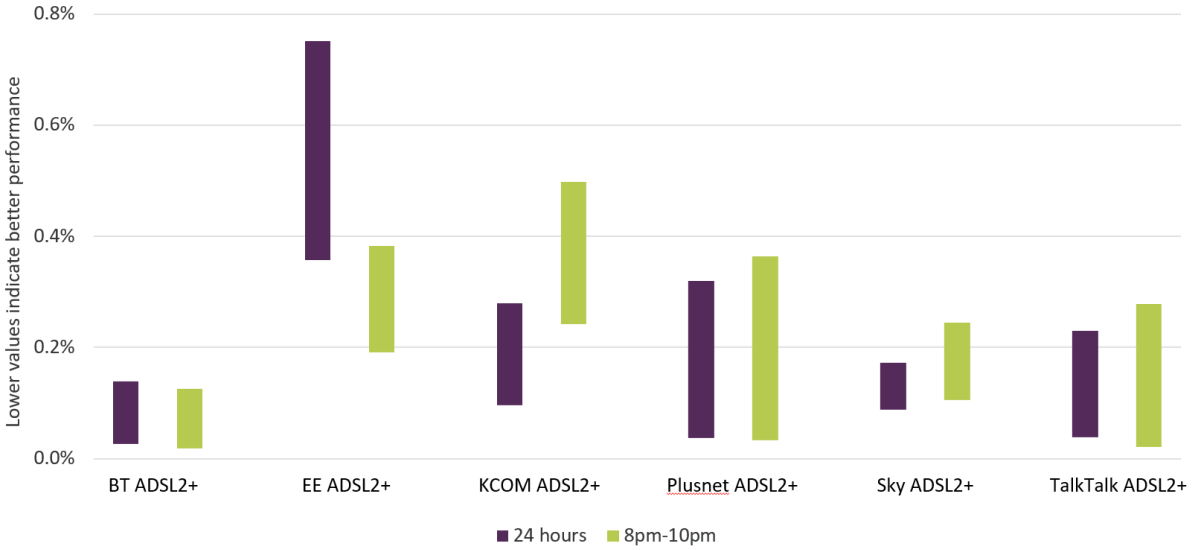
	24-hour average	8pm-10pm
ISP package	**Performed better than**	**Performed better than**
TT38	Sky76*, Sky38, EE76, EE38, BT76, VM200, V100, PN76, BT52, VM50, PN38	Sky76*, Sky38, EE76, BT76, EE38, VM100, PN76, VM200, BT52, VM50, PN38
TT76	BT76*, VM200, V100, PN76, BT52, VM50, PN38	BT76*, EE38*, VM100, PN76, VM200, BT52, VM50, PN38
Sky38	BT76*, VM200, V100, PN76, BT52, VM50, PN38	BT76*, VM100, PN76, VM200, BT52, VM50, PN38
Sky76	VM50, PN38	VM100*, PN76*, VM200, BT52*, VM50, PN38
EE76	VM50, PN38	VM200*, VM50, PN38
BT76	VM200*, M50, PN38	VM200, VM50, PN38
EE38	VM50, PN38	VM50*, PN38
VM200	VM50, PN38	VM50*, PN38
VM100	VM50, PN38	PN38*
PN76	VM50*, PN38*	PN38*

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. Lower bars indicate better performance.

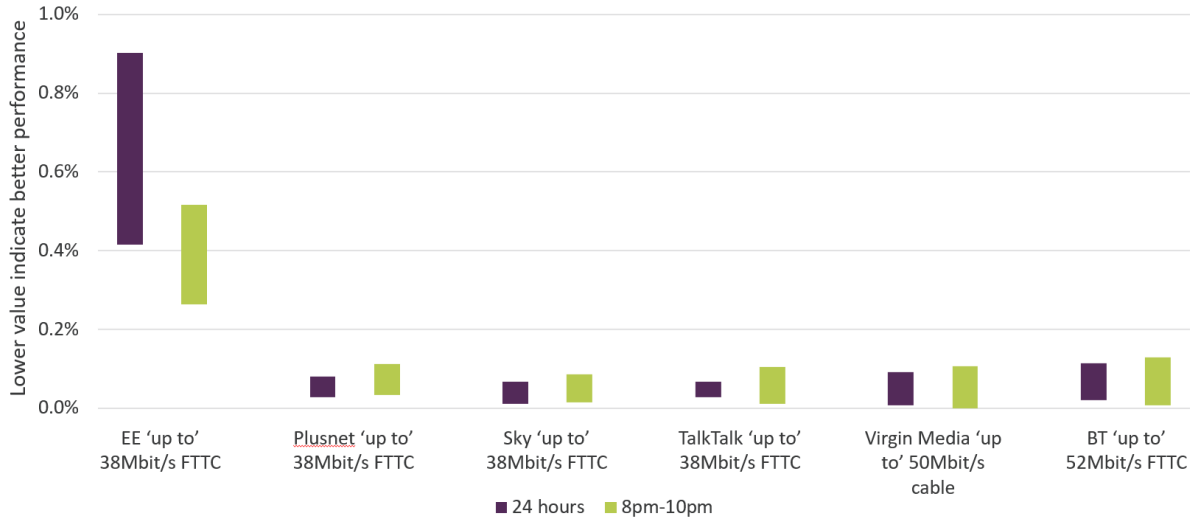
Figure 48: Average and peak-time DNS failure rates for ADSL2+ ISP packages and significant differences, to a 95% level of confidence: November 2017

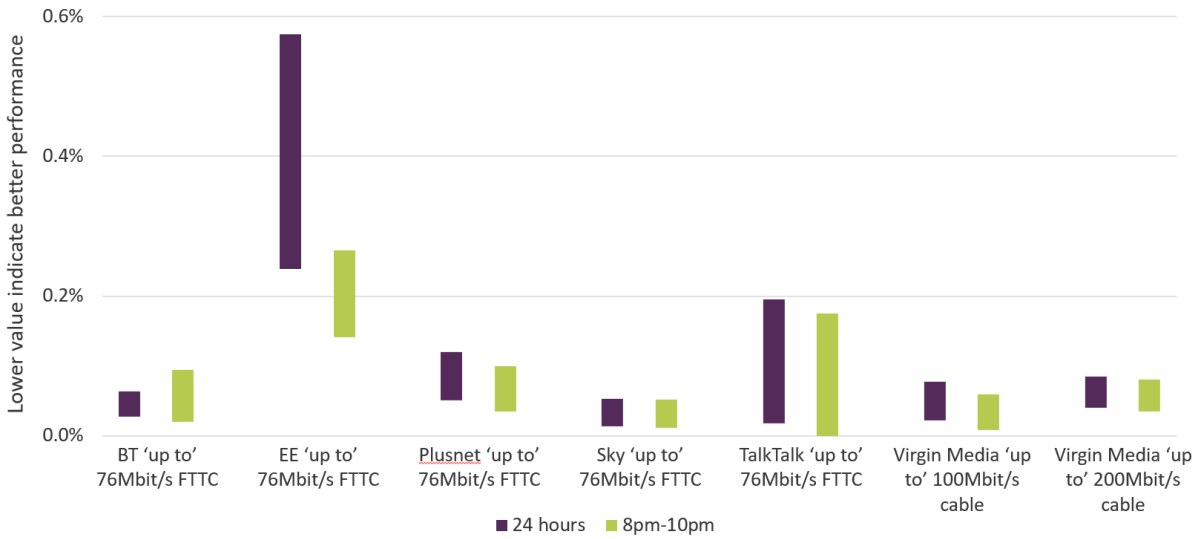


	24-hour average	8pm-10pm
ISP	**Performed better than**	**Performed better than**
BT	EE	EE & KCOM
Sky	EE	-
TalkTalk	EE	-
PN	EE*	-

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 'up to' 30Mbit/s and above ISP packages and significant differences, to a 95% level of confidence: November 2017





	24-hour average	8pm-10pm
ISP package	**Performed better than**	**Performed better than**
Sky76	EE76, EE38	EE76
Sky38	EE76, EE38	EE76
BT76	EE76, EE38	EE76*
TT38	EE76, EE38	EE76*
VM50	EE76, EE38	EE76*
VM200	EE76, EE38	EE76*
PN38	EE76, EE38	EE76*
VM100	EE76, EE38	EE76
BT52	EE76*, EE38	-
PN76	EE76*, EE38	EE76*
TT76	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. Lower bars indicate better performance.

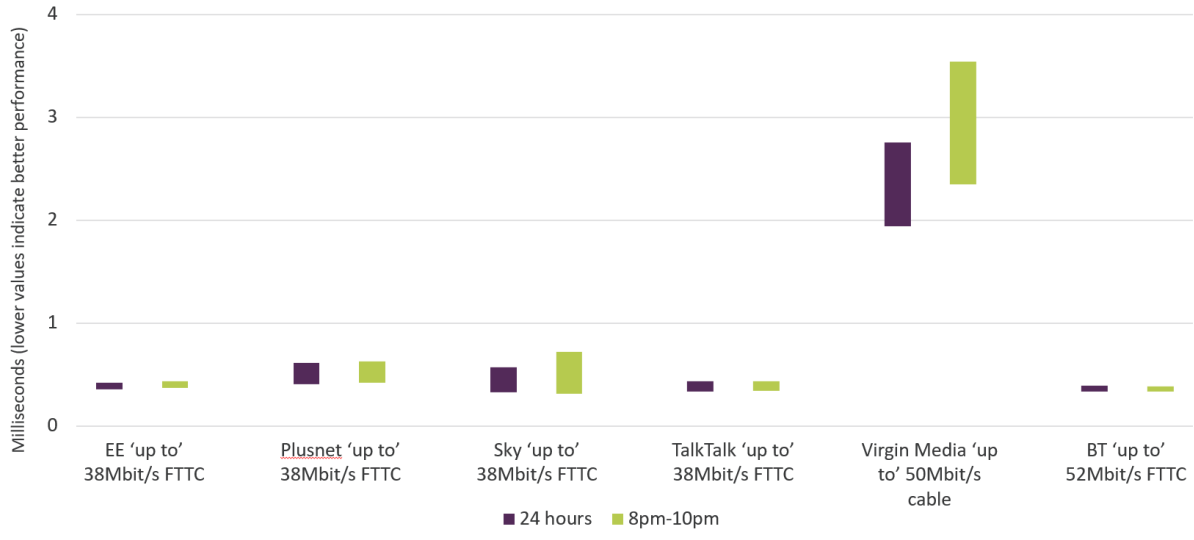
Upstream jitter

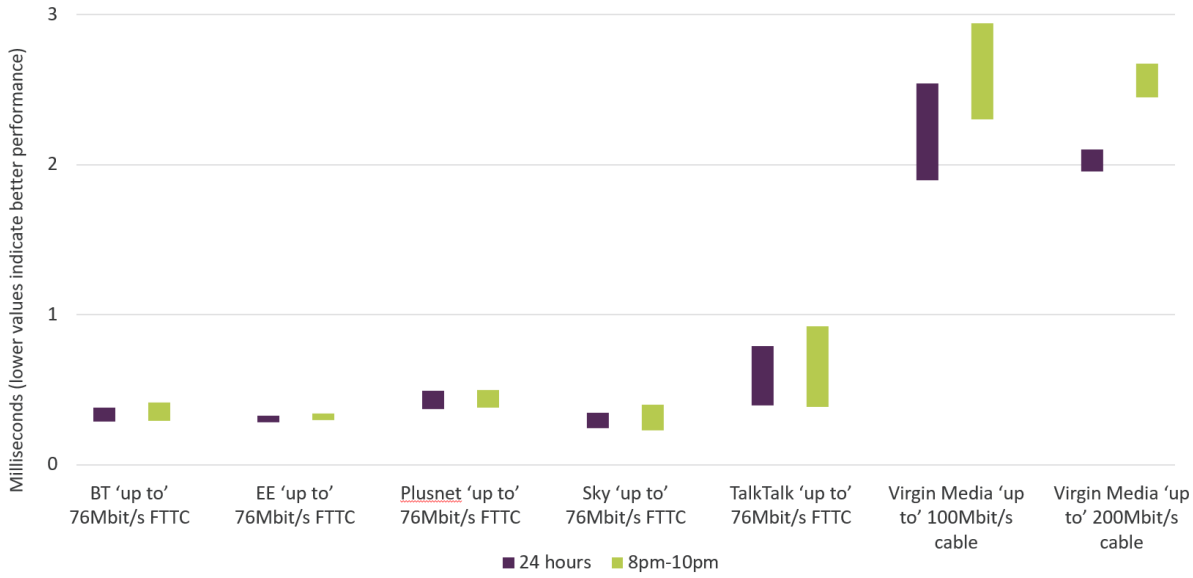
Figure 50: Average and peak-time upstream jitter for ADSL2+ ISP packages and significant differences, to a 95% level of confidence: November 2017

	24-hour average	8pm-10pm
ISP	**Performed better than**	**Performed better than**
No differences	No differences	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 'up to' 30Mbit/s and above ISP packages and significant differences, to a 95% level of confidence: November 2017



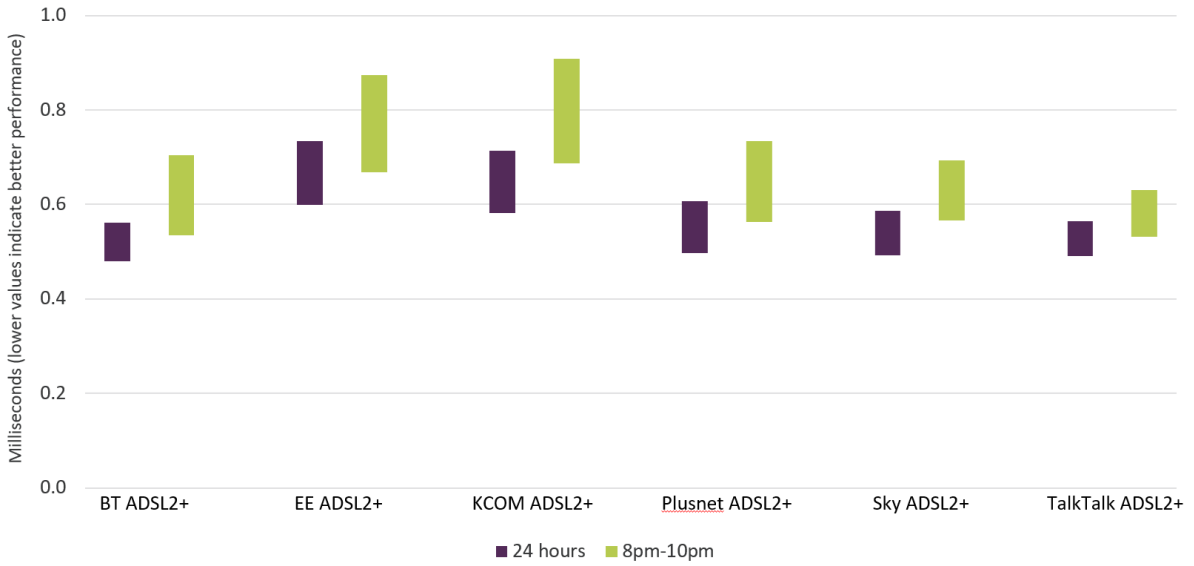


	24-hour average	8pm-10pm
ISP package	**Performed better than**	**Performed better than**
Sky76	PN76*, PN38*, TT76*, VM200, VM100, VM50	VM200, VM100, VM50
EE76	EE38*, PN76*,PN38*, TT76*, VM200, VM100, VM50	EE38*, PN76*, PN38, TT76*, VM200, VM100, VM50
BT76	PN38*, TT76*, VM200, VM100, VM50	VM200, VM100, VM50
BT52	PN38*, VM200, VM100, VM50	PN38*, VM200, VM100, VM50
TT38	VM200, VM100, VM50	VM200, VM100, VM50
EE38	VM200, VM100, VM50	VM200, VM100, VM50
PN76	VM200, VM100, VM50	VM200, VM100, VM50
Sky38	VM200, VM100, VM50	VM200, VM100, VM50
PN38	VM200, VM100, VM50	VM200, VM100, VM50
TT76	VM200, VM100, VM50	VM200, VM100, VM50

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.

Downstream jitter

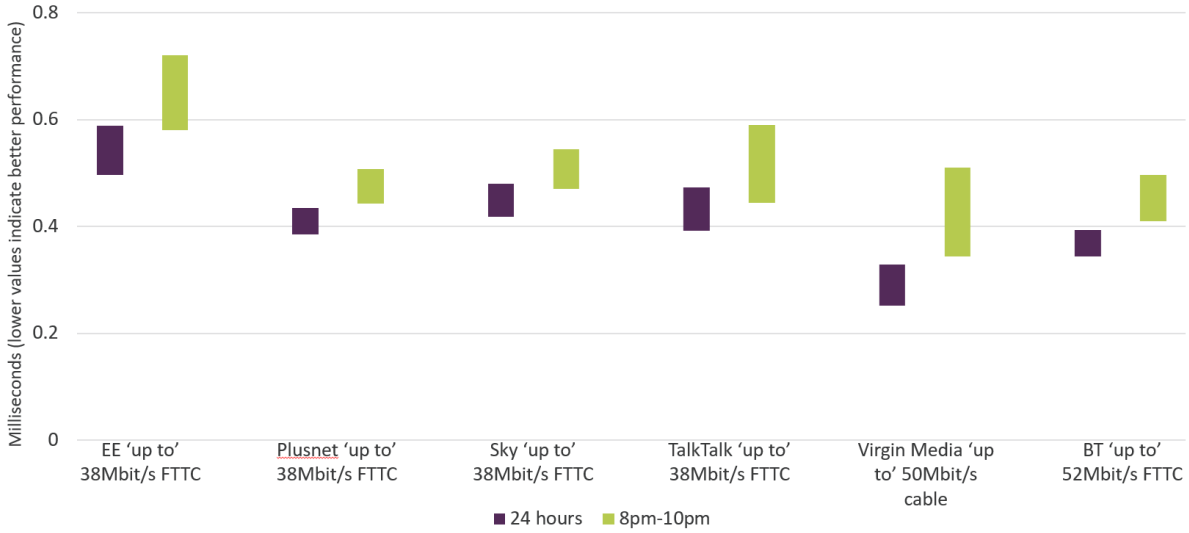
Figure 52: Average and peak-time downstream jitter for ADSL2+ ISP packages and significant differences, to a 95% level of confidence: November 2017

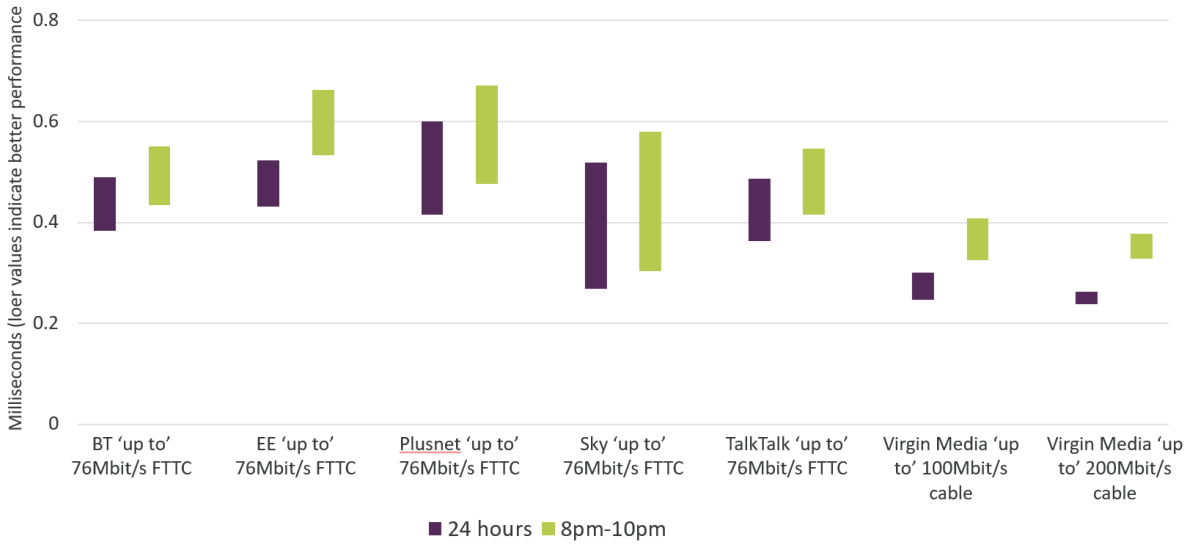


	24-hour average	8pm-10pm
ISP	**Performed better than**	**Performed better than**
BT	KCOM* & EE	-
TalkTalk	KCOM* & EE	EE* & KCOM
Sky	EE*	-

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 53: Average and peak-time downstream jitter for 'up to' 30Mbit/s and above ISP packages and significant differences, to a 95% level of confidence: November 2017





	24-hour average	8pm-10pm
ISP package	**Performed better than**	**Performed better than**
VM200	BT52, PN38, TT76, TT38, BT76, Sky38, EE76, PN76, EE38	BT52*, TT76, PN38, BT76*, Sky38, TT38, PN76, EE76, EE38
VM100	BT52, PN38, TT76, TT38, BT76, Sky38, EE76, PN76, EE38	TT76*, PN38, BT76*, Sky38, TT38, PN76*, EE76, EE38
VM50	BT52*, PN38, TT76, TT38, BT76, Sky38, EE76, PN76, EE38	EE76*, EE38
BT52	Sky38*, EE76*, EE38	EE76*, EE38
PN38	EE38	EE38
TT76	EE38*	EE38*
TT38	EE38*	-
BT76	-	EE38*
Sky38	-	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.

Sources

[1] Source: SamKnows measurement data for all national panel members with a connection in November 2017. Panel base: 1369 (Above 'up to 2Mbit/s' and 'up to' and including 10Mbit/s – 74; Above 'up to 10Mbit/s and less than 'up to' 30Mbit/s - 465; 'Up to 30Mbit/s and higher – 830) 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. Panel members with a connection in November 2017. Panel base: 1369 (ADSL – 539; FTTC – 491 and cable 334) 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.

[3] Source: SamKnows measurement data for all national panel with a connection in November 2017.

[4] Source: SamKnows measurement data for all national panel members with a connection in November 2017. Panel base: 1369 (urban ADSL – 376; rural ADSL - 163; urban FTTC – 420 and rural FTTC - 72) 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 2017. Panel base: 1369 (urban - 1115; rural - 253) 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 2017 where density and nation data available. Panel base: 4861 (England 3836; Scotland 517; Wales 352 and Northern Ireland 156) 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 2017 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 2017. Panel base: 1369 (ADSL1 – 74; ADSL2+ - 465; FTTC38 – 279; FTTC52 – 80; FTTC 76 – 132; cable 'up to' 50Mbit/s 68; cable 'up to' 100Mbit/s 125 and cable 'up to 200Mbit/s' 441) 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 2017. Panel base: 1369 (ADSL1 – 74; ADSL2+ - 465; FTTC38 – 279; FTTC52 – 80; FTTC 76 – 132; cable 'up to' 50Mbit/s 68; cable 'up to' 100Mbit/s 125 and cable 'up to 200Mbit/s' 441) 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 2017. Panel base: 1369 (urban: ADSL1 – 28; ADSL2+ - 348; FTTC38 – 230; FTTC52 – 79; FTTC 76 – 110; cable 'up to' 50Mbit/s 63; cable 'up to' 100Mbit/s 123 and cable 'up to 200Mbit/s' 432; Rural: ADSL1 – 46; ADSL2+ - 117; FTTC38 – 49; FTTC52 – 1; FTTC 76 – 22) 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 2017 where density and nation data available. Panel base: 4861 (England urban 3063; England rural 773; Scotland urban 338; Scotland rural 179; Wales urban 197; Wales rural 155; Northern Ireland Urban 99 and Northern Ireland rural 57) 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 2017 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 2017. Panel base: 1369 (above 'up to 2Mbit/s' and 'up to' and including 10Mbit/s" – 74; above 'up to 10Mbit/s and less than 'up to' 30Mbit/s - 465; 'Up to 30Mbit/s and higher – 830) 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 2017. Panel base: 1369 (ADSL1 – 74; ADSL2+ - 465; FTTC38 – 279; FTTC52 – 80; FTTC 76 – 132; cable 'up to' 50Mbit/s 68; cable 'up to' 100Mbit/s 125 and cable 'up to 200Mbit/s' 441) 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 2017. Panel base: ADSL2+ - 465 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 2017. 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 2017. Panel base: Cable 'up to' 100Mbit/s 125 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 2017. Panel base: Cable 'up to' 200Mbit/s 441 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 2017. Panel base: FTTC 'up to' 38Mbit/s 279 Notes: (1) Data have been weighted by ISP package market share, rural/urban and geographic market UK fixed-line broadband performance, November 2017: Research Report 53 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 2017. Panel base: FTTC 'up to' 52Mbit/s 80 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 2017. Panel base: FTTC 'up to' 76Mbit/s 334 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 2017. Panel base: 1369 (ADSL1 – 74; ADSL2+ - 465; FTTC38 – 279; FTTC52 – 80; FTTC 76 – 132; cable 'up to' 50Mbit/s 68; cable 'up to' 100Mbit/s 125 and cable 'up to 200Mbit/s' 441) 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 2017. Panel base: 1369 (ADSL1 – 74; ADSL2+ - 465; FTTC38 – 279; FTTC52 – 80; FTTC 76 – 132; cable 'up to' 50Mbit/s 68; cable 'up to' 100Mbit/s 125 and cable 'up to 200Mbit/s' 441) 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 2017. Panel base: BT ADSL2+ 97; EE ADSL2+ 54; KCOM ADSL2+ 45; Plusnet ADSL2+ 84; Sky ADSL2+ 135; TalkTalk ADSL2+ 126 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 2017. Panel base: BT ADSL2+ 97; EE ADSL2+ 54; KCOM ADSL2+ 45; Plusnet ADSL2+ 84; Sky ADSL2+ 135; TalkTalk ADSL2+ 126 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 2017. Panel base: BT 'up to' 52Mbit/s 114; EE 'up to' 38Mbit/s 104; Plusnet 'up to' 38Mbit/s 180; Sky 'up to' 38Mbit/s 187; TalkTalk 'up to' 38Mbit/s 163; Virgin Media '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 2017. Panel base: BT 'up to' 76Mbit/s 413; EE 'up to' 76Mbit/s 81; Plusnet 'up to' 76Mbit/s 259; Sky 'up to' 76Mbit/s 82; TalkTalk 'up to' 76Mbit/s 143; Virgin Media 'up to' 100Mbit/s 125; Virgin Media 'up to' 200Mbit/s 441 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 2017. Panel base: BT 'up to' 52Mbit/s 114; EE 'up to' 38Mbit/s 104; Plusnet 'up to' 38Mbit/s 180; Sky 'up to' 38Mbit/s 187 ; TalkTalk 'up to' 38Mbit/s 143; Virgin Media '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 2017. Panel base: BT 'up to' 76Mbit/s 413; EE 'up to' 76Mbit/s 81; Plusnet 'up to' 76Mbit/s 259; Sky 'up to' 76Mbit/s 82; TalkTalk 'up to' 76Mbit/s 153; Virgin Media 'up to' 100Mbit/s 125; Virgin Media 'up to' 200Mbit/s 441. 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 2017. Panel base: BT 'up to' 52Mbit/s 114; EE 'up to' 38Mbit/s 104; Plusnet 'up to' 38Mbit/s 180; Sky 'up to' 38Mbit/s 187; TalkTalk 'up to' 38Mbit/s 163; Virgin Media '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 2017. Panel base: BT 'up to' 76Mbit/s 413; EE 'up to' 76Mbit/s 81; Plusnet 'up to' 76Mbit/s 259; Sky 'up to' 38Mbit/s 82; TalkTalk 'up to' 38Mbit/s 143; Virgin Media 'up to' 100Mbit/s 125; Virgin Media 'up to' 200Mbit/s 441. 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 2017. Panel base: BT ADSL2+ 97; EE ADSL2+ 54; KCOM ADSL2+ 45; Plusnet ADSL2+ 84; Sky ADSL2+ 135; TalkTalk ADSL2+ 126. 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 2017. Panel base: BT 'up to' 52Mbit/s 114; EE 'up to' 38Mbit/s 104; Plusnet 'up to' 38Mbit/s 180; Sky 'up to' 38Mbit/s 187; TalkTalk 'up to' 38Mbit/s 163; Virgin Media '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 2017. Panel base: BT 'up to' 76Mbit/s 413; EE 'up to' 76Mbit/s 81; Plusnet 'up to'

76Mbit/s 259; Sky ‘up to’ 76Mbit/s 82; TalkTalk ‘up to’ 76Mbit/s 143; Virgin Media ‘up to’ 100Mbit/s 125; Virgin Media ‘up to’ 200Mbit/s 441 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 2017. Panel base: BT ADSL2+ 97; EE ADSL2+ 54; KCOM ADSL2+ 45; Plusnet ADSL2+ 84; Sky ADSL2+ 135; TalkTalk ADSL2+ 126 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 2017. Panel base: BT ‘up to’ 52Mbit/s 114; EE ‘up to’ 38Mbit/s 104; Plusnet ‘up to’ 38Mbit/s 180; Sky ‘up to’ 38Mbit/s 187; TalkTalk ‘up to’ 38Mbit/s 163; Virgin Media ‘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 2017. Panel base: BT ‘up to’ 76Mbit/s 413; EE ‘up to’ 76Mbit/s 81; Plusnet ‘up to’ 76Mbit/s 259; Sky ‘up to’ 76Mbit/s 82; TalkTalk ‘up to’ 76Mbit/s 143; Virgin Media ‘up to’ 100Mbit/s 125; Virgin Media ‘up to’ 200Mbit/s 441 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 2017. Panel base: BT ADSL2+ 97; EE ADSL2+ 54; KCOM ADSL2+ 45; Plusnet ADSL2+ 84; Sky ADSL2+ 135; TalkTalk ADSL2+ 126 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 2017. Panel base: BT ‘up to’ 52Mbit/s 114; EE ‘up to’ 38Mbit/s 104; Plusnet ‘up to’ 38Mbit/s 180; Sky ‘up to’ 38Mbit/s 187; TalkTalk ‘up to’ 38Mbit/s 163; Virgin Media ‘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 2017. Panel base: BT ‘up to’ 76Mbit/s 413; EE ‘up to’ 76Mbit/s 81; Plusnet ‘up to’ 76Mbit/s 259; Sky ‘up to’ 76Mbit/s 82; TalkTalk ‘up to’ 76Mbit/s 143; Virgin Media ‘up to’ 100Mbit/s 125; Virgin Media ‘up to’ 200Mbit/s 441 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 methodology

Technical methodology

This report is Ofcom's sixteenth fixed-line residential broadband speeds report and the thirteenth 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 wifi (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 wifi 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. Eight speed-test servers are deployed in a range of different data centres in and immediately around London to handle the traffic. 32Gbit/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.

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 4,761 (including data from 2,238 panellists on SamKnows' independent global platform, SamKnows One) panellists who had a broadband monitoring unit connected to their routers in November 2017. Figure 1.1 sets out Ofcom's definitions of geographic broadband markets (based on the definitions for the wholesale broadband access (WBA) market. 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 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.

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.

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 1.67 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 methodology

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).

Over the last seven years, further rounds of recruitment have taken place. The main purposes of this recruitment has been to:

- To replace panellists who leave the panel due to natural attrition, such as moving house or losing interest in participating in the research.
- Ensuring adequate samples for all ISPs and replacing panellists who although remaining on the panel have decided to switch their operator and/or package. As the Ofcom panel tends to be comprised of people with an interest in telecoms, there is a strong focus on ensuring coverage of lower speeds packages.

- To enable the ISP-level reporting of new packages such as high-speed fibre and cable as soon as sufficient numbers can be recruited and;
- Permit reporting at devolved nation level and to show the rural-urban split.

Due to shortfalls in some areas, SamKnows provided additional data from its independent global platform, SamKnows One. At the moment, the total active panel is 4,918 – active meaning contributing results to either the ISP, national or devolved nations analysis. 2,736 of these respondents belong to the Ofcom recruited panel and 2,182 to SamKnows' 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 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.

Definition of valid panellists and test volumes

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 1% 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 2017 was 280, from a theoretical maximum of 360 per respondent (i.e. if all panellists had their monitoring unit connected on 1 November 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 and weightings

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.

The results and analysis of the 4,918 panellists' measurement results were divided into three separate datasets, each weighted to targets.

- National panel (over 'up to' 2Mbit/s packages): 1,369 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: 3,065 panellists. Respondents for this panel consist 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 c.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.
- The devolved nations panels: 4,894 panellists. The main difference between this panel and the national one is that the quotas on market share by operator are relaxed. Panellists are weighted on market share by technology and actual package speed and by rural/urban split only.

Sample weighting

- National panel. Weighting by ISP market and package shares by LLU/ non-LLU connections supplied by ISPs as at November 2017, 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). Although BT Openreach provided four curves – 38Mbit/s, 52 Mbit/s and 76Mbit/s, the 52 Mbit/s FTTC lines were not normalised as only BT actively markets this product.
- Cable packages are not weighted, as speed of services is not directly related to distance from the exchange
- Devolved nation. Weighting by actual speed obtained within each technology and urban/rural classification. This slackening of requirements is necessary to allow sufficient samples for the smaller devolved nations.
- 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 2.1: 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 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. BT Openreach provides 2 curves which indicate the national distance profile of lines "up to 8(10) Mbit/s" and "up to 20(24) Mbit/s" for all lines in the UK. Each relevant ISP package ("up to 20 Mbit/s") and the "up to 8 Mbit's" and "up to 20 Mbit's" in the national panel are adjusted to match this national profile.

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

Nation comparison

For this analysis, an alternative weighting was used. 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 as 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 efficiency

Overall, against the entire weighting framework, the national panel achieved a weighting efficiency of 90%. 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 2.2: National panel range of weights

Range	Count	Column N%
Less than 0.5	727	53%
0.5 to 1	601	38%
1 to 1.5	723	6%
1.5 to 2	17	2%
2+	50	1%

Source: Ofcom

Overall, against the entire weight frame, the ISP package panel achieved a weighting efficiency of 85%. This is because Virgin Media cable are not weighted, as distance from exchange does not impair download speeds.

Figure 2.3: ISP package range of weights

Weights	Count	Column N %
Less than 0.5	633	21%
0.5 to 1	785	26%
1 to 1.5	143	48%
1.5 to 2	134	4%
2+	50	2%

Source: Ofcom

Figure 2.4: Weighting efficiency, by ISP package

ISP package	Weighting efficiency
BT ADSL2+	78%
EE ADSL2+	73%
KCOM ADSL2+	85%
Plusnet ADSL2+	88%
Sky ADSL2+	96%
TalkTalk ADSL2+	89%
EE 'up to' 38Mbit/s	94%
Plusnet 'up to' 38Mbit/s	64%
Sky 'up to' 38Mbit/s	95%
TalkTalk ‘up to’ 38 Mbit/s	98%
Virgin Media 'up to' 50Mbit/s	100%
BT 'up to' 52Mbit/s	75%
BT 'up to' 76Mbit/s	81%
EE ‘up to’ 76 Mbit/s	84%
Plusnet 'up to' 76Mbit/s	87%
Sky ‘up to’ 76 Mbit/s	78%
TalkTalk ‘up to’ 76 Mbit/s	87%
Virgin Media 'up to' 100Mbit/s	100%
Virgin Media 'up to' 200Mbit/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 2.5: Average maximum download speeds for ADSL2+ packages: weighted and unweighted data

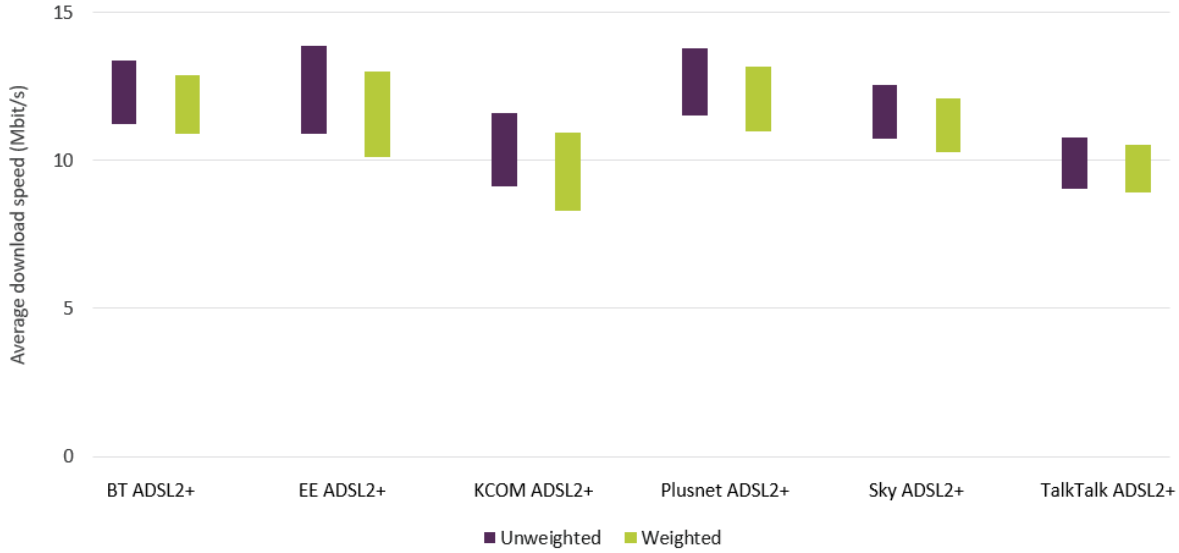


Figure 2.6: 24-hour average download speeds for ADSL2+ packages: weighted and unweighted data

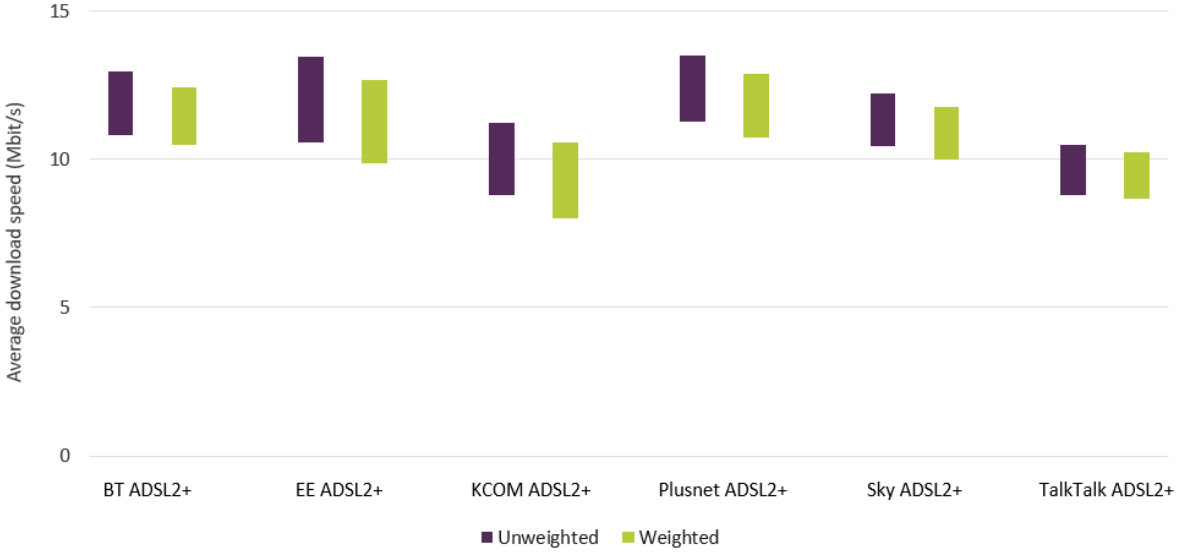


Figure 2.7: Average 8-10pm peak-time download speeds for ADSL2+ packages: weighted and unweighted data

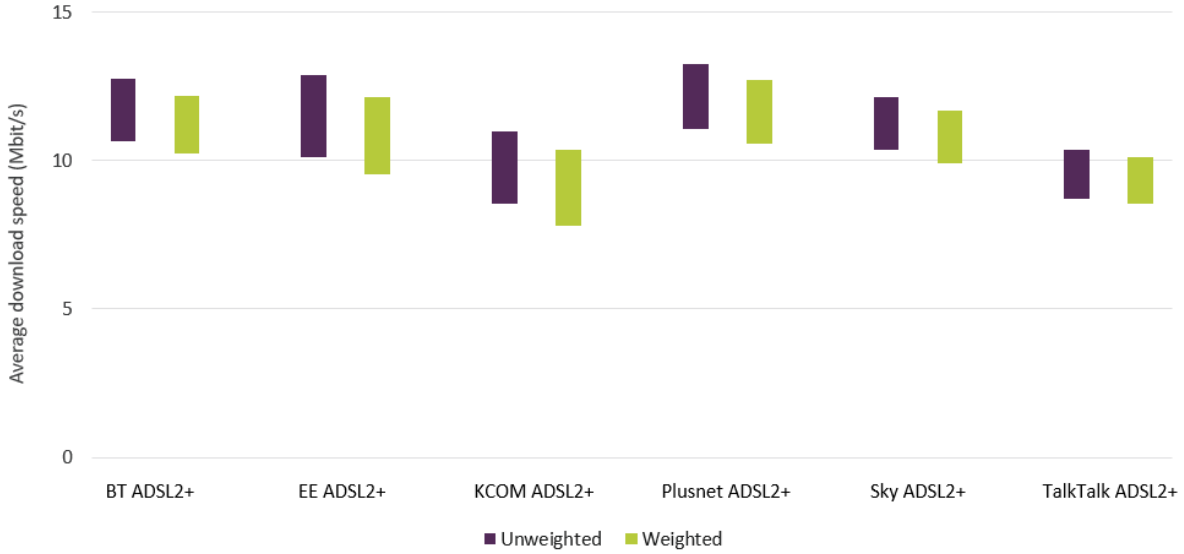
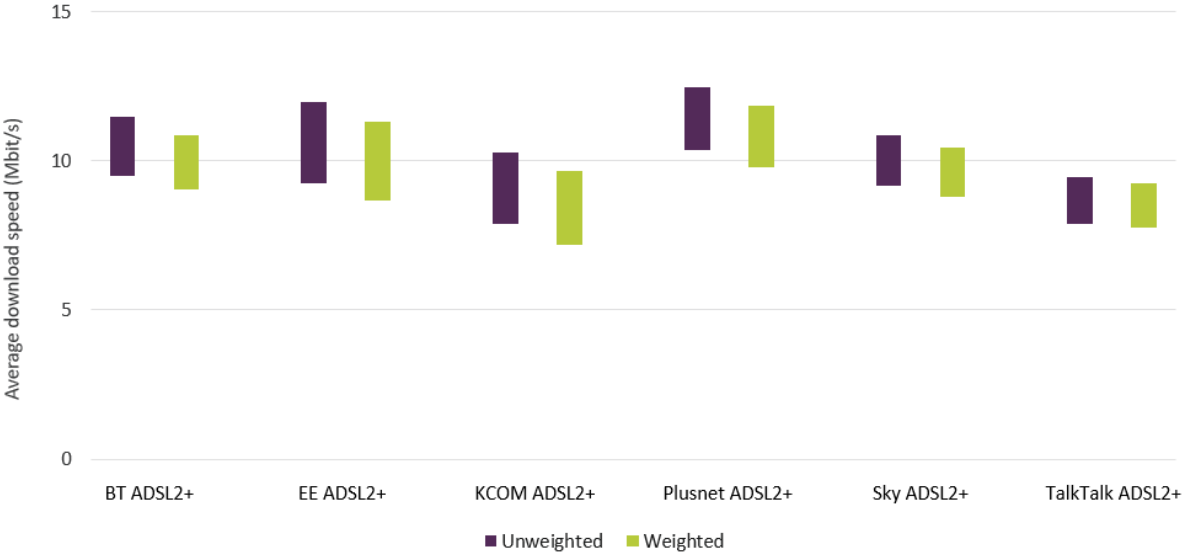


Figure 2.8: Average minimum download speeds for ADSL2+ packages: weighted and unweighted data



Source: SamKnows measurement data for all ISP panel members with a connection in November 2017. Panel base: BT ADSL2+ 97; EE ADSL2+ 54; KCOM ADSL2+ 45; Plusnet ADSL2+ 84; Sky ADSL2+ 135; TalkTalk ADSL2+ 126 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.

Weighted and unweighted measurement data for FTTC ISP packages

Figure 2.9: Average maximum download speeds for FTTC packages: weighted and unweighted data

Figure 2.10: 24-hour average download speeds for FTTC packages: weighted and unweighted data

Figure 2.11: Average 8-10pm peak-time download speeds for FTTC packages: weighted and unweighted data

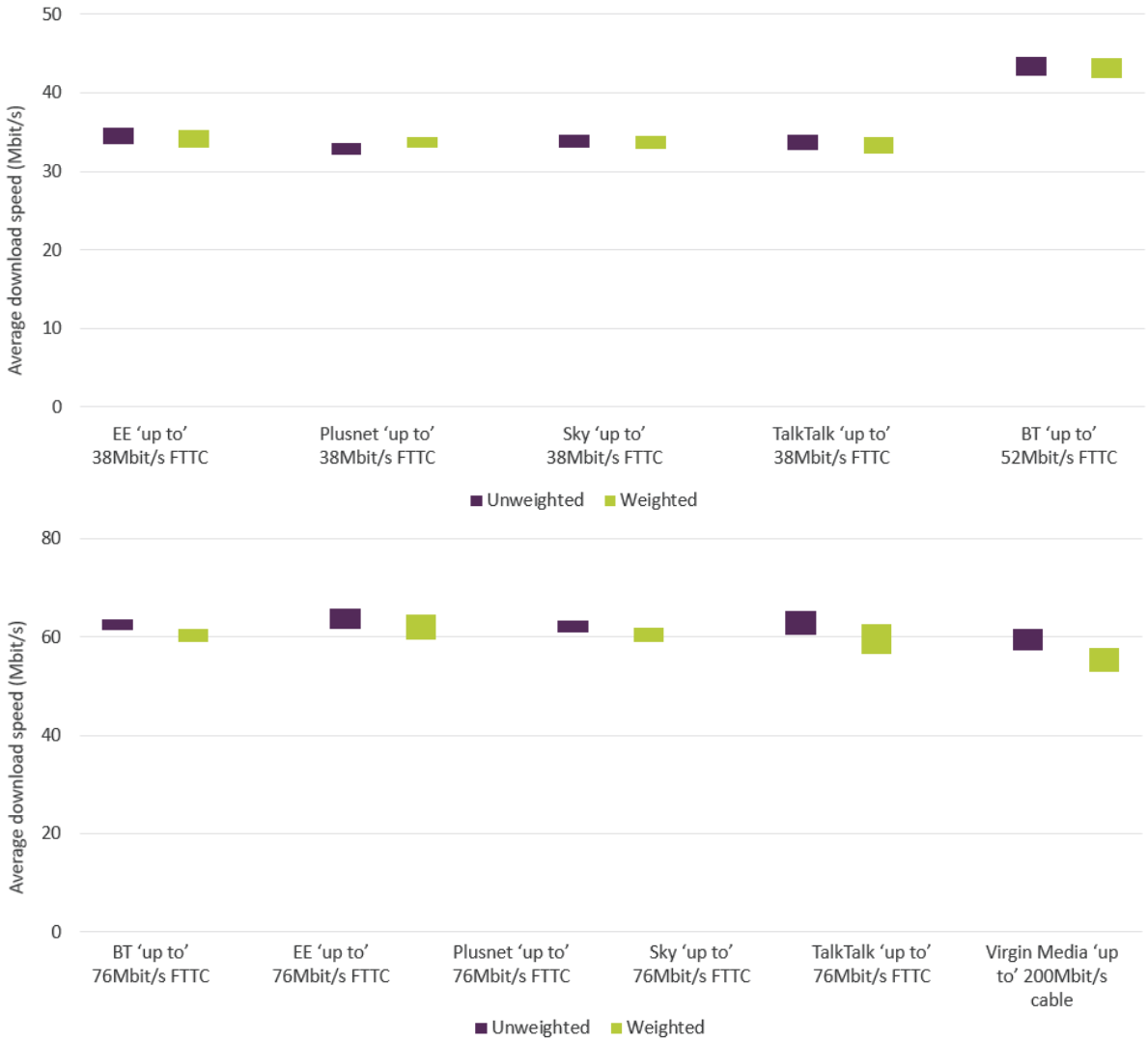


Figure 2.12: Average minimum download speeds for FTTC packages: weighted and unweighted data

Source: SamKnows measurement data for all ISP panel members with a connection in November 2017.
Panel base: BT 'up to' 52Mbit/s 114; EE 'up to' 38Mbit/s 104; Plusnet 'up to' 38Mbit/s 180; Sky 'up to' 38Mbit/s 187; TalkTalk 'up to' 38Mbit/s 163; Virgin Media 'up to' 50Mbit/s 68
Panel base: BT 'up to' 76Mbit/s 413; EE 'up to' 76Mbit/s 81; Plusnet 'up to' 76Mbit/s 259; Sky 'up to' 76Mbit/s 82; TalkTalk 'up to' 76Mbit/s 143; Virgin Media 'up to' 100Mbit/s 125; Virgin Media 'up to' 200Mbit/s 441
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.

Comparison of urban and rural speeds

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 VDSL (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.