UK Home broadband performance:

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

Published: 24 March 2016

Ofcom

About this document

The report contains data and analysis regarding the performance of UK residential fixed-line broadband services. Specifically, it provides information on the average performance of ADSL, cable and fibre-to-the-cabinet broadband packages, which is presented at a national level, as well as separately for a number of popular ISP packages. This is consistent with Ofcom's duty to carry out and publish research on the experience of consumers.

We have produced this report to provide stakeholders with useful information on the performance of broadband services. Also, we have published a short consumer guide to home broadband[1] which includes high-level summaries of some of the analysis in this report.

[1] Available at http://stakeholders.ofcom.org.uk/binaries/research/broadband-research/march2016/fixed-bb-speeds-nov15-consumer-summary.pdf

Contents

Section 1

Dashboard

	2014	2015
Fixed broadband availability (proportion of premises)		
All fixed broadband	≈100%	≈100%
Superfast broadband (actual download speed 30Mbit/s or higher)	75%	83%
Fixed broadband take-up by headline speed (proportion of lines)		
'Up to' 10Mbit/s and above	91%	93%
'Up to' 30Mbit/s and above	32%	42%
Average download speed, by technology		
All connections	22.8Mbit/s	28.9Mbit/s
ADSL	7.3Mbit/s	7.8Mbit/s
Cable	54.4Mbit/s	73.6Mbit/s
Fibre-to-the-cabinet (FTTC)[1]	41.6Mbit/s	41.2Mbit/s
Distribution of average actual download speeds (proportion of lines)		
<2Mbit/s	10%	7%
2Mbit/s to <10Mbit/s	35%	33%
10Mbit/s to <30Mbit/s	26%	23%
30Mbit/s to <100Mbit/s	27%	31%
≥100Mbit/s	3%	6%
Average upload speed, by technology		
All connections	2.9Mbit/s	3.7Mbit/s
ADSL	0.8Mbit/s	0.8Mbit/s
Cable	4.1Mbit/s	5.3Mbit/s
Fibre-to-the-cabinet (FTTC)[1]	10.0Mbit/s	9.4Mbit/s

Source: Ofcom
Note: Different technologies have different theoretical maximum and headline speeds. ADSL can provide theoretical speeds of up to 24Mbit/s, FTTC usually has headline speeds of either 'up to' 38Mbit/s or 'up to' 76Mbit/s, and cable currently is provided to new consumers with headline speeds of 50Mbit/s 'up to', 100Mbit/s 'up to' or 'up to' 200Mbit/s; weightings used for Scotland's average speed results may not fully reflect the geographical profile of Scottish residential broadband connections.

Section 2

Executive Summary

Access to high quality fixed internet services has become essential to the increasingly online lives of the UK's population. Households use their broadband connections for a variety of activities including entertainment, home working, education and social networking. Each year we publish a report on the performance of residential fixed broadband services as part of our work to monitor the UK communications industry.

The research uses data collected by our research partner, SamKnows Limited, in November 2015 which was gathered from a residential panel of over 2,000 volunteers who have connected a hardware measurement unit to their broadband router. These units run tests measuring various metrics that help determine the user-experience of undertaking various online activities.

Residential fixed broadband performance

In November 2015, forty two per cent of residential fixed broadband lines were superfast products (connections with a *headline* speed of 'up to' 30Mbit/s or more). This represents an increase of nine percentage points compared to a year previously. The proportion of lines with a *headline* speed of 'up to' 10Mbit/s or higher increased by two percentage points to 93% over this period.[2]

Our latest panel research shows that the average *actual* UK residential fixed broadband download speed increased from 22.8Mbit/s in November 2014 to 28.9Mbit/s in November 2015[3]. The 27% rise in the average UK download speed was due to growing take-up of higher-speed connections and increasing average speeds for these packages.

Our research shows that the average actual speed of superfast products was 56.8Mbit/s in November 2015, a 6.4Mbit/s (13%) increase compared to a year previously. This was mainly due to cable broadband users migrating onto higher-speed packages.

Sixty one per cent of UK fixed broadband connections had an average actual download speed of 10Mbit/s or faster in November 2015 up from 56% in 2014.[4] Whereas connections delivering average speeds of 30Mbit/s or higher rose from 30% to 38%.

However, just under four in ten fixed broadband connections provided average actual speeds of less than 10Mbit/s. This figure is driven by both the availability of broadband services delivering speeds of 10Mbit/s or higher[5], as well as the service that consumers choose to take up.

Download speeds typically vary by time of day and tend to fall during peak times, when a larger number of connections are being used, as a result of capacity constraints (contention)

[2] Data collected from the UK's largest ISPs.
[3] Due to changes made in the composition of the panel in November 2015, comparisons between November 2015 data and that from previous periods should be taken as indicative.
[4] Note that this figure should not be confused with the claim in the Connected Nations Report that 86% of lines were capable of receiving 10 Mbps or better since the latter measures the percentage of lines able to achieve 10Mbit/s or more, not the proportion of lines that are currently achieving these speeds as in this report.
[5] In the UK as a whole, over 8% of premises cannot receive a speed greater than 10Mbit/s (Connected Nations, 2015).

in internet service providers' networks. In November 2015 the actual average speed across all connections was 27.0Mbit/s during the 8pm to 10pm weekday peak-time period. This was 85% of the 31.6Mbit/s average maximum speed and 93% of the 28.9Mbit/s 24-hour average.

Although broadband advertising tends to focus on download speeds, upload speeds are also important, in particular when sharing large files and using real-time two-way video communications. Our research shows that the average actual upload speed was 3.7Mbit/s, a 0.8Mbit/s (28%) increase compared to a year previously.

Urban versus rural performance[6]

A gap exists between the provision and performance of high speed broadband services in urban and rural areas, mainly due to the difficulty (and cost) of providing superfast products to rural homes. Several government and independent programmes exist to attempt to narrow this gap: Broadband Delivery UK (BDUK) is the most obvious and largest scale example of such a programme, with £780 million of public funding being set aside to fulfil the ambition of extending superfast broadband availability to 95% of UK premises by the end of 2017.[7]

Our research shows that average download speeds in urban areas (50.5Mbit/s) were over three times those in rural areas (13.7Mbit/s).[8] The main reasons for this difference were the lower availability of fibre and cable broadband in rural areas and slower average ADSL and fibre-to-the-cabinet (FTTC) connection speeds.

The report also looks at the proportion of fixed broadband connections that received an average actual speed of 10Mbit/s or higher in November 2015. This proportion averaged 61% across the UK as a whole, but was much higher in urban areas (69%) than in rural ones (25%). Note: the rural classification used in this report covers just under 15% of the UK population.

These figures are affected both by the availability of broadband services that provide speeds of 10Mbit/s or higher[9], as well as the service that consumers choose to take up.

Download speeds by technology

In November 2015, cable broadband services had the highest average download speeds at 73.6Mbit/s. Fibre-to-the-cabinet (FTTC) services had an average download speed of 41.2Mbit/s over the same period, while the average ADSL download speed was 7.8Mbit/s.

Download speeds by ISP package

Virgin Media's 100Mbit/s and 200Mbit/s services provided the fastest average actual download speeds of all the ISP packages included in the report. Its 'up to' 200Mbit/s service recorded the highest average actual download speed at 174.0Mbit/s.

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[6] In the Ofcom Connected Nations 2015 report we used a different urban/rural classification. Subsequently we have adopted a more granular framework that includes a suburban classification. We intend to apply this to future Ofcom reports. Due to the different classifications, comparisons between urban and rural figures should not be made between this and the Connected Nations report.

[7] https://www.gov.uk/guidance/broadband-delivery-uk

[8] The UK rural, urban and suburban averages above will not match the overall UK results shown elsewhere in this report, as different weightings have been used to enable us to provide comparisons by urbanity. Further statistical methodology is provided in Annex 3.

[9] Nearly 50% of rural premises are connected by lines that are unable to receive speeds greater than 10Mbit/s (Connected Nations 2015).

With the exception of KC's[10] ADSL2+ service, all of the ADSL2+ and FTTC packages included in the report are provided over the BT copper line from the local exchange/street cabinet to the end-user's home. This means that it is unlikely that consumers will see a substantial increase in the performance of their service if switching from one service to another which has the same headline speed and technology, unless the speed of their existing service is being limited by factors within their ISP's control, such as network contention. The main difference between the performance of FTTC services was the amount of slowdown experienced at peak times.

The research found that there were very few differences in average download speeds for ADSL packages with similar headline speeds. ADSL2+ services had an average actual download speed of 8.4Mbit/s. Similarly, there were few differences in results for FTTC packages with similar headline speeds. FTTC packages advertised as offering 'up to' 38Mbit/s and 'up to' 76Mbit/s provided average download speeds of 33.4Mbit/s and 59.4Mbit/s respectively.

While there was little difference in the amount of contention experienced by ADSL2+ packages, we observed differing levels of contention at peak times for FTTC and cable packages. The proportion of panellists receiving 90% or more of their connections' maximum speed at peak times ranged from 35% for Virgin Media's 'up to' 200Mbit/s cable service (with 44% receiving 90% or more of the service's advertised speed at peak times) to 95% for EE's 'up to' 38Mbit/s FTTC service.

Video streaming tests

The quality of video streams that could be streamed reliably varied by technology and package type. Thirteen per cent of ADSL2+ packages streamed Netflix videos reliably in Ultra High Definition (UHD), while this figure was over 90% for cable and FTTC services. The report also contains the results of iPlayer and YouTube video streaming tests.

Other metrics

In addition to looking at average download and upload speeds over the course of the day, we provide information on performance by time of day. We also consider other metrics that are relevant to the consumer experience of using fixed broadband services, including latency, packet loss and DNS failure. Similarly, the report includes metrics relating to the reliability of connections and, for the first time, the results of video streaming tests.

Tools provided by Ofcom

With Ofcom's coverage checker, you can find which services are available in particular locations that are important to you; your home, your work – anywhere.

With Ofcom's Wi-Fi checker app, you can see if your home Wi-Fi is likely to be slowing down your broadband. The app also gives useful tips on how to improve your broadband connection.

These tools are both free and available on the Ofcom website.

[10] The incumbent provider in Kingston upon Hull.

Section 3

Background

Introduction

Ofcom's principal duty under the Communications Act 2003 (the Act) in carrying out its functions is to further the interests of UK citizens and consumers.[11] In doing so we are required to secure a number of things, including the availability of a wide range of electronic communications services, which includes fixed broadband services.[12] 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,[13] and the interests of consumers in respect of choice, price, quality of service and value for money.[14]

The Act 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.[15] 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.[16]

In order to understand the performance of UK fixed-line residential broadband connections, we commission research to identify the average actual download speeds that are delivered, along with a number of other metrics that determine the consumer experience of using these services. Ofcom has undertaken this research, which uses data collected by research partner SamKnows Limited (SamKnows),[17] since 2008, using a volunteer panel of UK residential broadband users.[18]

The approach is different to that used in our Connected Nations 2015 Report,[19] which includes analysis of broadband speeds which is based on information on the "sync speed" [20] or "configured speed" [21] of each active line which is provided to Ofcom by ISPs. This gives a measure of the maximum connection speed achieved between the ISP's access network and the consumer's premises, which are usually a few Mbit/s higher than the "end-to-end" line speed measurements we are presenting here and do not vary significantly during the day.

This report sets out the findings from data collected during November 2015, during which 75.3 million test results were collected from a panel of 2,151 UK residential broadband users. We believe that our technical methodology (set out in Annex 2), combined with the

[11] Section 3(1) of the Act
[12] Section 3(2)(b)
[13] Section 3(4)(a) and (e)
[14] Section 3(5)
[15] Section 14
[16] Section 15
[17] http://www.samknows.com/broadband
[18] Previous reports are available on the Ofcom website at http://stakeholders.ofcom.org.uk/market-data-research/other/telecoms-research/broadband-speeds/?a=0.
[19] http://stakeholders.ofcom.org.uk/binaries/research/infrastructure/2015/downloads/connected_nations2015.pdf
[20] The speed that the ADSL or VDSL modem being used by the consumer has synchronised with the network at.
[21] The maximum speed configured in the network for a particular connection.

scale of data collection and the sophistication of the statistical analysis (set out in Annex 3), makes this research a robust presentation of UK fixed-line broadband speeds.

Fixed broadband performance is an issue for many UK consumers, and Ofcom research conducted in the first half of 2015 suggests that while 80% of fixed broadband users were either 'very' or 'fairly' satisfied with the speed of their service, this was lower than the proportion of users who were 'very' or 'fairly' satisfied with their overall fixed broadband service (86%).[22]

Change in methodology from previous reports

Ofcom has undertaken research into fixed-line broadband performance for a number of years, and the broadband market has evolved significantly over this time, in particular with regard to the growing availability and take-up of higher-speed services, including superfast broadband, and the launch of new, bandwidth-hungry, online services.
Since the last *Fixed-line broadband performance report* (which covered November 2014 and was published in February 2015),[23] we have made a number of changes to the research to reflect these market changes, most notably:

- rebalancing the research panel to allow more robust analysis of fixed broadband performance in urban and rural areas of the UK;
- the normalisation of the test results from fibre-to-the-cabinet (FTTC) connections in the ISP package comparisons section of the report, to enable robust and fair comparisons of the performance of these services; and
- the introduction of new video streaming tests.

It is important to note that the changes in the panel composition and the introduction of FTTC normalisation mean that, in some cases, it is difficult to make like-for-like comparisons between the data covering November 2015 and those relating to previous periods.

Using this report

While Sections 1 and 2 of this report look at fixed broadband upload and download speeds, Section 3 considers the other metrics which affect broadband performance.

Where we refer to 'broadband speeds' in this report (whether average, maximum or headline speeds, etc.), we mean broadband speeds for residential (as opposed to business) connections in the UK. Likewise, where we refer to 'connections', we mean residential connections.

Further, we use three key terms to describe broadband speeds. (See also the glossary in Annex 4 for definitions of these terms.)

- The '**headline speed**' or '**advertised speed**' is the speed at which broadband services are marketed, often expressed as 'up to' xMbit/s (megabits per second).
- The '**average actual speed**', or '**average speed**' represents the average speed that a consumer actually receives, which drives the speed at which files can be uploaded

[22] Ofcom Tech Tracker H1 2015
[23] http://stakeholders.ofcom.org.uk/market-data-research/other/telecoms-research/broadband-speeds/broadband-speeds-november2014/

and downloaded. Where in this report we refer to '**average actual speed**' or simply to '**average speed**', we mean the average actual throughput speed.

- The '**maximum speed**' is the highest download speed that a broadband connection is capable of delivering, and is also known as the access line speed.

Structure of the report

The report is structured as follows:

- Section 1 looks at residential UK broadband speeds at a national level.
- Sections 2 and 3 set out the performance of individual ISP packages in terms of connection speed and the other metrics which affect broadband performance.
- Annex 1 contains additional analysis of the research results.
- Annex 2 sets out the technical and research methodologies used.
- Annex 3 contains the statistical methodology applied to the research.
- Annex 4 contains the glossary of terms.

Hardware vs. software-based testing, and crowd-sourced data

There are many methods for measuring actual broadband performance, both hardware-based and software-based, and a number of different sources of broadband performance information exist. Most of these use crowd-sourced data which is collected using software-based testing, and Ofcom believes that this data collection methodology is potentially less accurate than a hardware-based methodology because:

- crowd-sourced data is prone to inadvertent panel selection bias;
- software-based tests can run only when a device is turned on, or when a user runs a test, making it difficult to gather results covering the 24-hour period; and
- software-based tests are unable to identify whether another device is using a broadband connection, and may also be affected if a device is using Wi-Fi, which is likely to lead to lower performance, particularly if a connection is being used by several devices.

However, hardware-based methodologies also have disadvantages:

- smaller panel sizes are typically seen when hardware based solutions are used, due to the high cost of measurement devices; and
- unlike the current crowd-sourced tests, hardware based testing is not part of the volunteers' typical internet use. Care has to be taken to ensure that testing does not affect volunteers' experience when using the internet.

Additionally, some of the currently available data are gathered from tests measuring the performance of content delivery network (CDN) delivery, which can be affected by peering, transit and interconnection with other internet service providers, rather than end-users' access network speeds.

Nevertheless, on balance, we continue to believe that the approach we have established with SamKnows still has merit and, indeed, has distinct advantages over many of the widely promoted software or application based tools. We are however, also committed to continue to work on other complementary methods of gauging the consumer internet access experience, such as the work we have done with Actual Experience that was featured in last year's Connected Nation Report.

Download speed test investigation

We would note that there is currently a joint investigation between Ofcom, SamKnows and Virgin Media which is looking into the way that our tests perform on Virgin Media's top two service tiers ('up to 100Mbit/s and 200Mbit/s). The investigation is focussing on whether the download speed test configuration adequately stresses the line to get an accurate reading under certain line conditions and, while it is ongoing, there is a belief from Virgin Media that the tests may be underreporting the download speeds of these services. Should the investigation conclude that there is an issue with the tests, it is possible that an updated version of this report will be issued.

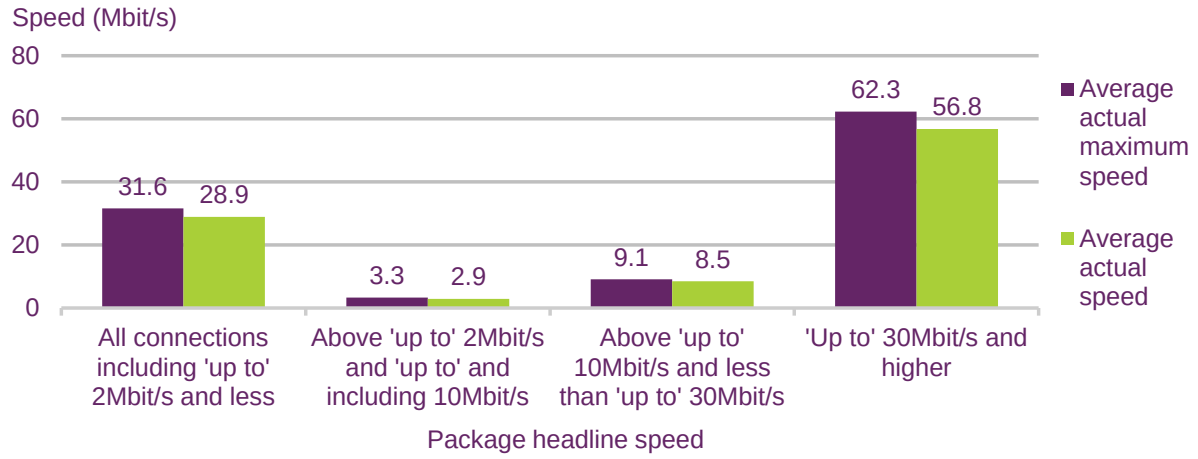
Section 4

Overview of fixed broadband speeds

4.1 The average UK residential fixed broadband speed was 28.9Mbit/s in November 2015

Our research found that the average actual speed of UK residential fixed-line broadband connections was 28.9Mbit/s in November 2015 (Figure 1.1). The average actual speed of superfast products (i.e. connections with a headline speed of 'up to' 30Mbit/s or more)[24] was found to be 56.8Mbit/s, over six times the average actual speed of connections with headline speeds above 'up to' 10Mbit/s and less than 'up to' 30Mbit/s (8.5Mbit/s), and almost 20 times the average actual speed of connections above 'up to' 2Mbit/s and up to and including 10Mbit/s (2.9Mbit/s). Across all connections with a headline speed below 'up to' 30Mbit/s, the average actual download speed was 7.8Mbit/s.

Figure 1.1 Average actual UK fixed broadband download speed: November 2015



Source: SamKnows measurement data for all panel members with a connection in November 2015
Panel base: 1639
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange (ADSL) to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests; (3) The above 'up to' 10Mbit/s and less than 'up to' 30Mbit/s category includes ADSL2+ connections which are not marketed using a connection speed.

4.2 The average UK residential fixed broadband speed increased by 27% in the year to November 2015

The average actual residential fixed broadband recorded speed in November 2015 (28.9Mbit/s) was 6.1Mbit/s (27%) higher than the average speed recorded a year previously in November 2014 (22.8Mbit/s), although the research panel realignment which took place between these dates means that it is difficult to make like-for-like comparisons between these two dates (Figure 1.2).

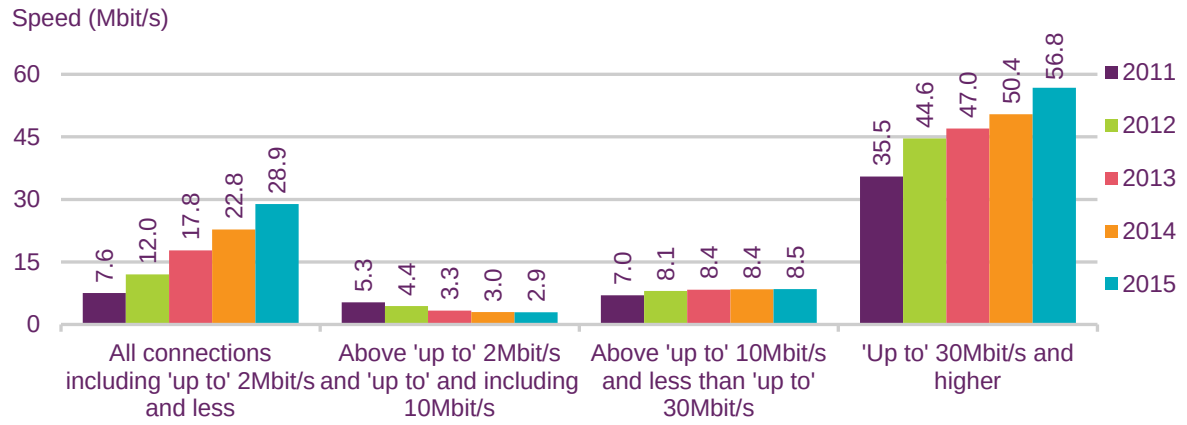
[24] This is distinct from to 'superfast broadband' connections, which are defined as being those with an actual speed of 30Mbit/s or higher.

Over the same period, there was little change in the average speed of standard broadband connections, with those offering an advertised speed above 'up to' 2Mbit/s and 'up to' and including 10Mbit/s" falling by 0.1Mbit/s (3%) to 2.9Mbit/s and those advertised as offering above 'up to' 10Mbit/s and less than 'up to' 30Mbit/s increasing by less than 0.1%, to 8.5Mbit/s.

The largest speed increase was for superfast broadband products (i.e. connections with a headline speed of 'up to' 30Mbit/s or higher), which increased by 6.4Mbit/s (13%) to 56.8Mbit/s. This was as a result of a change in the mix of these connections over this period, with an increase in the proportion of superfast connections that were on higher service tiers, partly due to cable network upgrades.

Sufficient sample sizes are not available among our panel for connections with headline speeds of 'up to' 2Mbit/s and less, because of the low market share of these connections, so the performance of these connections is not shown below, although they are taken into account in the 'all connections' averages.

Figure 1.2 Average actual broadband speeds: November 2012 to November 2015



Source: SamKnows measurement data for all panel members with a connection in November 2015
Panel base: 1639
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange (ADSL) to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests; (3) The above 'up to' 10Mbit/s and less than 'up to' 30Mbit/s category includes ADSL2+ connections which are not marketed using a connection speed.

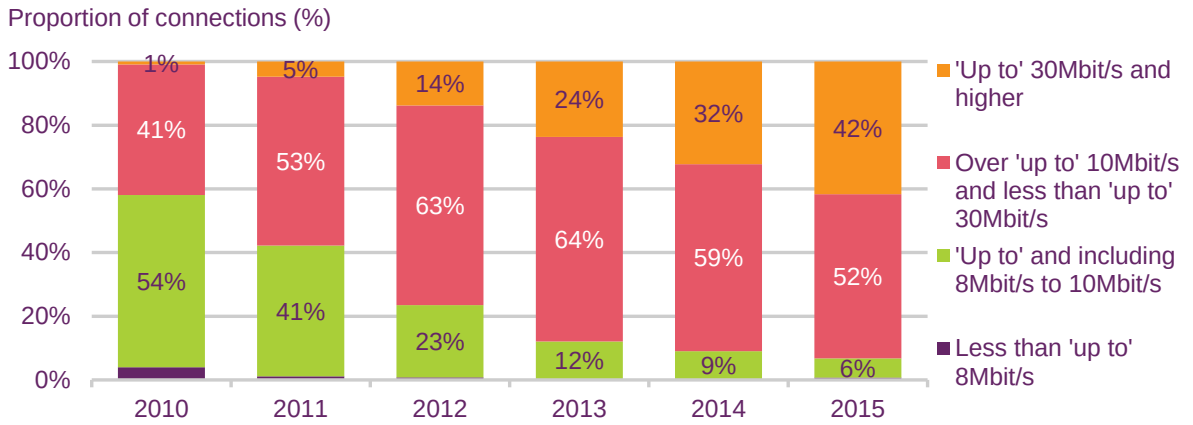
4.3 Forty-two per cent of UK residential broadband connections had a headline speed of 'up to' 30Mbit/s or higher in November 2015

As shown previously, the increase in average residential broadband speeds across all UK connections in the year to November 2015 (27%) was higher than the increase recorded among any of the connection classifications shown in Figure 1.2 over the same period.

This is due to the changing mix in connections over this period, with a key driver of the increase in average fixed broadband download speeds across all UK connections being consumer migration to faster services, including superfast broadband. The proportion of residential broadband connections that had a headline speed of 'up to' 30Mbit/s and higher was 42% in November 2015, an increase of nine percentage points since November 2014 and three times the proportion recorded in 2012 (14%).

The migration to superfast products resulted in a seven percentage point fall, to 52%, in the proportion of connections with headline speeds between 'up to' 10Mbit/s and 'up to' 30Mbit/s in the year to November 2015, and a three percentage point decline in the proportion of connections that were 'up to' and including 8Mbit/s to 10Mbit/s, down to 6%. Connections with a headline speed of less than 'up to' 8Mbit/s continued to account for less than 1% of all residential connections in November 2015.

Figure 1.3 UK residential broadband connections, by headline speed



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
Note: The above 'up to' 10Mbit/s and less than 'up to' 30Mbit/s category includes ADSL2+ connections which are not marketed using a connection speed.

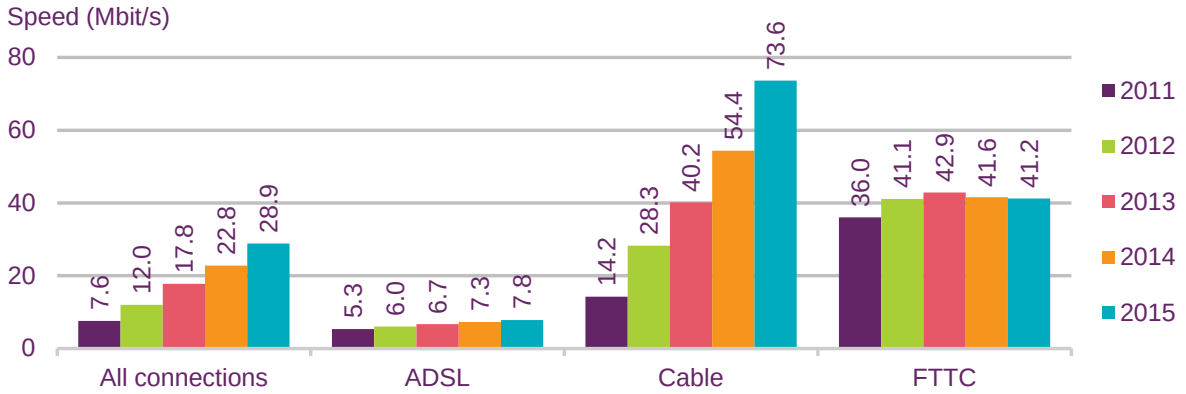
4.4 Cable services had the highest average download speed of all the technologies covered in November 2015

As is shown in Figure 1.4 below, the average speed of cable broadband connections reached 73.6Mbit/s in November 2015. This was a 19.2Mbit/s (35%) increase compared to November 2014, and was due to Virgin Media customers migrating onto faster packages, and the introduction of an 'opt-in' speed upgrade programme for its top-tier fixed broadband customers, which enabled them to increase the headline speed of their service from 'up to' 152Mbit/s to 'up to' 200Mbit/s.[25]

Our analysis indicates that the average download speed offered by fibre-to-the-cabinet (FTTC) connections fell slightly, by 0.4Mbit/s (1%) to 41.2Mbit/s, in the year to November 2015, while the average speed of ADSL connections increased by 0.5Mbit/s (7%) to 7.8Mbit/s over this period.

[25] http://about.virginmedia.com/press-release/9478/virgin-media-paints-a-vivid-future-for-uk-broadband

Figure 1.4 Average broadband speeds for fixed broadband connections, all connections including 'up to' 2Mbit/s and less, by technology



Source: SamKnows measurement data for all panel members, data as at November of each year
Panel base: 1639
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

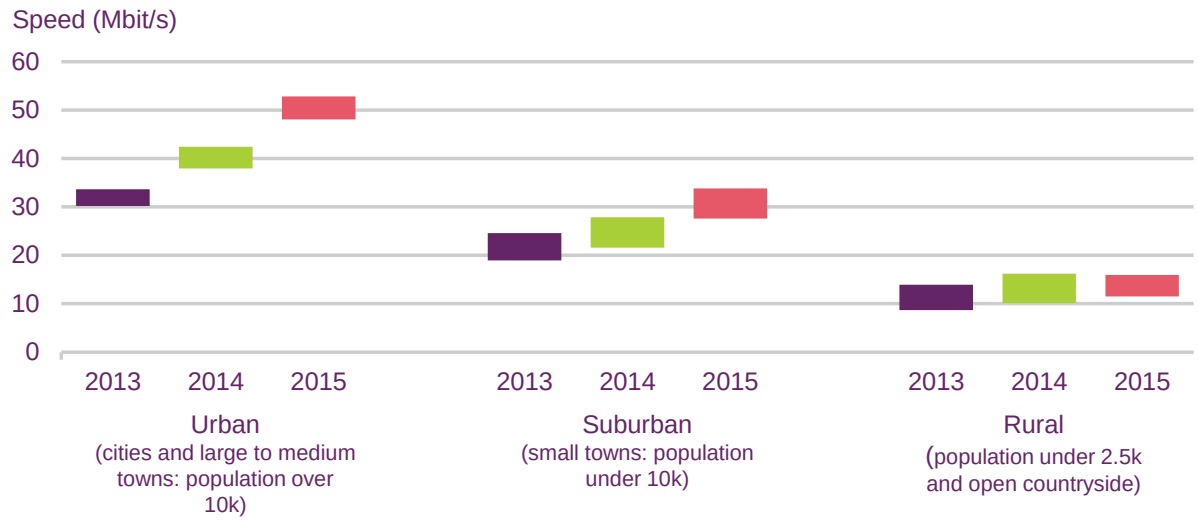
4.5 Rural speeds were significantly lower than both urban and suburban speeds in November 2015

In the Ofcom Connected Nations 2015 report we used a different urban/rural classification. Subsequently we have adopted a more granular framework that includes a suburban classification and intend to apply this to future Ofcom reports. Comparisons between urban and rural figures should not be made between this and the Connected Nations report.

Average speeds in urban areas tend to exceed those in suburban and rural areas due to the higher availability of superfast cable and fibre broadband services, and because average line lengths are shorter in urban areas due to the higher population density. The longer line lengths between local exchanges and customers' premises in rural areas result in signal degradation and lower actual ADSL speeds, while longer line lengths between the street cabinet and customer premises result in lower speeds over FTTC connections.

Together, these factors resulted in urban areas having average actual speeds that were more than three times those recorded in rural areas (50.5Mbit/s and 13.7Mbit/s respectively) in November 2015 (Figure 1.5).

Figure 1.5 Average download speeds for fixed broadband connections in urban, suburban and rural areas: November 2013 to November 2015



Source: SamKnows
Panel base: 2013 November urban 746, suburban 292; rural 271; 2014 November urban 1092, suburban 413, rural 337; 2015 November urban 1678, suburban 638 and rural 494.
Notes: The UK averages above will not match that shown elsewhere in this report, as different weightings have been used to enable us to provide comparisons by urbanity. Further statistical methodology is provided in Annex 3.

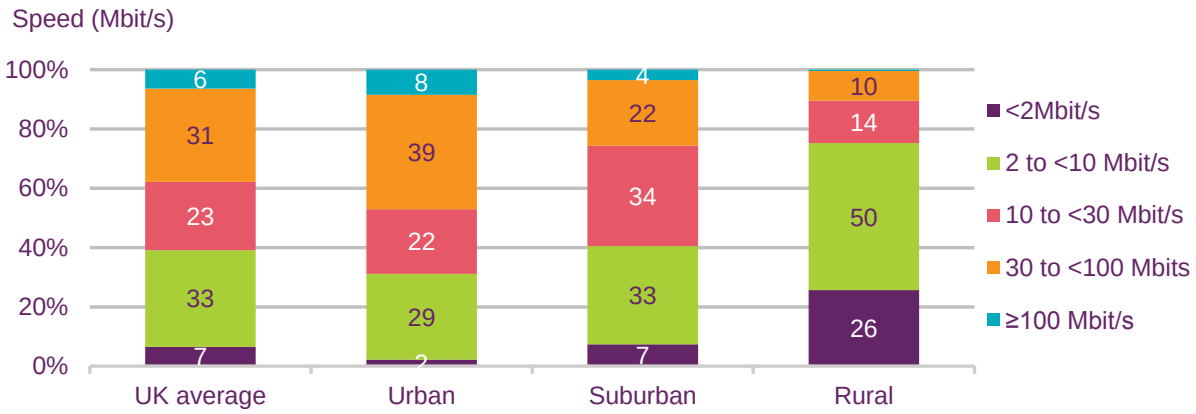
4.6 Forty-seven per cent of urban fixed broadband connections had average speeds of 30Mbit/s or higher in November 2015, compared to 10% in rural areas

Analysis of the distribution of average speeds across urban, suburban and rural areas highlights the differences in fixed broadband performance across the UK.

In rural areas, where cable and FTTC availability is less prevalent and longer line lengths mean that ADSL and fibre speeds tend to be lower than average, over a quarter of fixed broadband connections (26%) had an average actual speed of less than 2Mbit/s in November 2015. This was a larger proportion than the 25% that benefitted from average speeds of 10Mbit/s or higher, the connection speed that Ofcom believes is necessary to deliver an acceptable fixed broadband user experience (Figure 1.6). In comparison, just 2% of connections in urban areas had an average speed under 2Mbit/s, with 69% having average speeds of 10Mbit/s or higher.

The differences in the proportions of connections with an average speed of 30Mbit/s or higher were just as striking, with just under half of connections in urban areas (47%) benefitting from superfast speeds in November 2015, compared to 10% in rural areas. Across the UK as a whole, 61% of fixed broadband connections had an average speed of 10Mbit/s or higher in November 2015, with 38% experiencing an average speed of 30Mbit/s or higher, slightly lower than the proportion of connections that had an advertised speed of 30Mbit/s or higher shown in Figure 1.3 (42%), which is mainly the result of FTTC lines than cannot support superfast speeds.

Figure 1.6 Distribution of average actual fixed broadband download speeds in urban, suburban and rural areas, November 2015



Source: SamKnows
Panel base: UK 1639, urban 1,099, suburban 311; rural 229
Notes: Further details regarding the statistical methodology is provided in Annex 3. The urban and rural definitions used in this report differ from those in Ofcom's Connected Nations 2015 report. Comparisons between the two should be avoided.

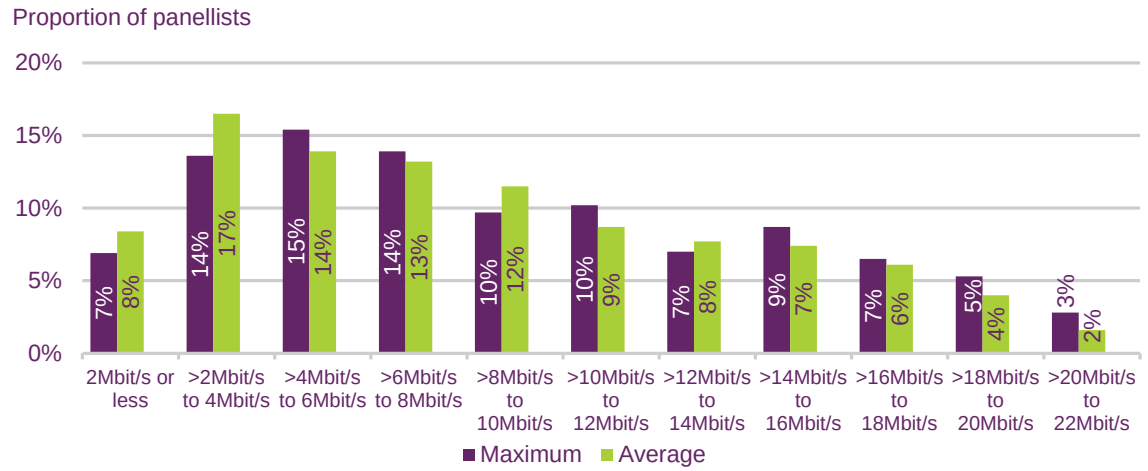
4.7 There is more variation in the average and maximum speeds delivered by ADSL and FTTC broadband services that there is for cable packages

Figure 1.7 to Figure 1.12 show the distribution of average and maximum speeds among our panellists in November 2015. Given that these figures are weighted to be nationally representative, they partly reflect of the differing availabilities of the networks in question.[26]

The distribution of speeds received by our ADSL2+ panellists in November 2015 is shown in Figure 1.7. The interquartile range for the maximum speed of these services (the difference between the largest and smallest values in the middle 50% of results) was 8.9Mbit/s (from 6.1Mbit/s to 15.1Mbit/s. The highest maximum speed received by the lowest 10% of ADSL2+ panellists (the bottom decile) was 3.3Mbit/s, while the lowest speed received among the top 10% of panellists (the top decile) was 18.4Mbit/s.

[26] In December 2014, almost all UK premises were connected to an ADSL-enabled local exchange. Similarly, by May 2015 the proportion of UK premises that were able to receive fibre broadband over Openreach or KC's fibre networks was 82%, while the proportion that could receive cable broadband over Virgin Media's network was 44%. In addition to having higher overall availability than cable services, ADSL and fibre broadband services also have higher rural availability (see Ofcom's 2015 Communications Market Reports: Nations and Regions: http://stakeholders.ofcom.org.uk/market-data-research/market-data/communications-market-reports/cmr15/).

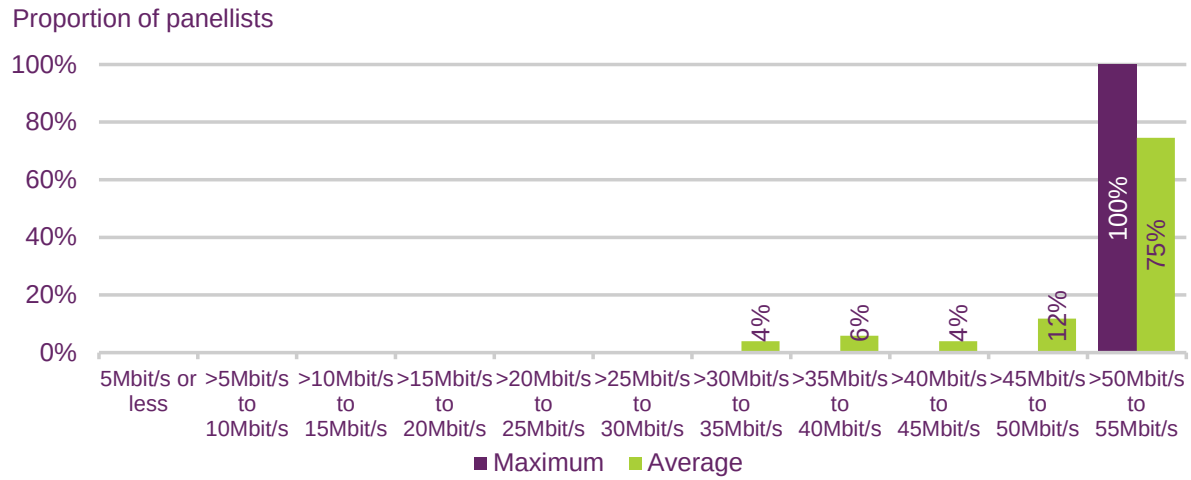
Figure 1.7 Distribution of average download speeds for ADSL packages: November 2015



Source: SamKnows measurement data for panel members with a connection in November 2015.
Notes: Data collected from multi-thread download speed tests.

The maximum and average actual speed distributions for panellists' 'up to' 50Mbit/s cable services is shown in Figure 1.8. This shows that there was very little variation in the maximum speeds provided by these connections, with all lines providing a maximum speed between 50Mbit/s to 55Mbit/s, i.e. above the services advertised speed, and 75% of users receiving a 24-hour average speed above the advertised speed.

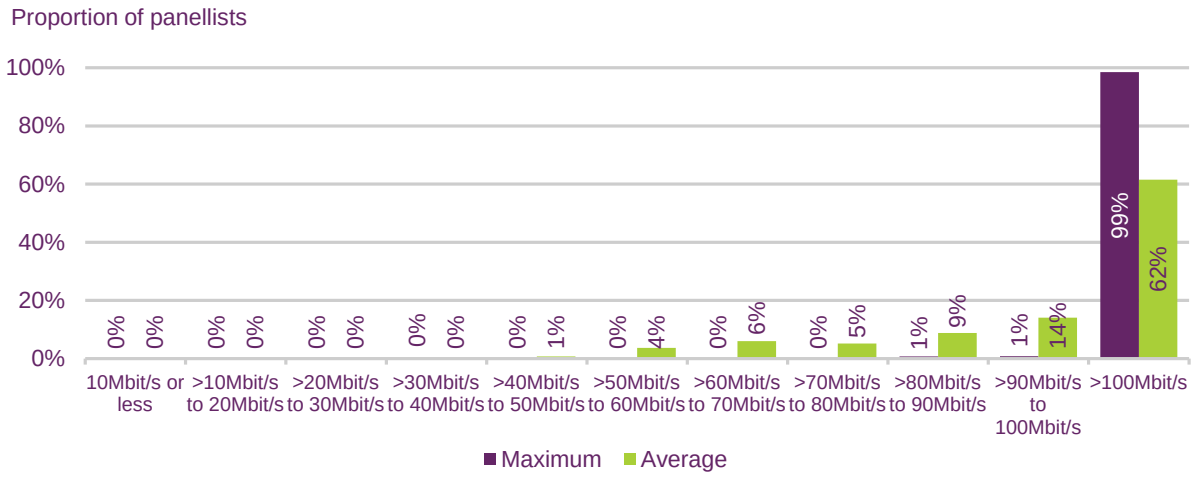
Figure 1.8 Distribution of average download speeds for 'up to' 50Mbit/s cable packages: November 2015



Source: SamKnows measurement data for panel members with a connection in November 2015.
Notes: Data collected from multi-thread download speed tests.

As was the case with 'up to' 50Mbit/s cable services, there was very little variation in the maximum speeds offered by panellists' 'up to' 100Mbit/s services in November 2015, with 99% receiving a maximum speed higher than the service's advertised speed (Figure 1.9). There was, however, greater variation in the average speed provided by 'up to' 100Mbit/s cable services that 'up to' 50Mbit/s cable lines, with 62% of 'up to' 100Mbit/s panellists receiving an average speed that was higher than the advertised speed.

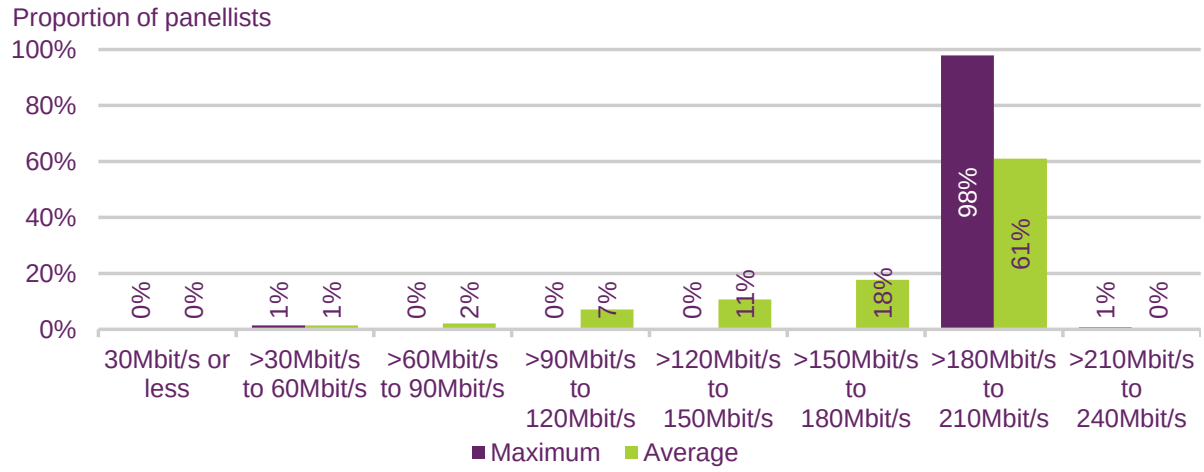
Figure 1.9 Distribution of average download speeds for 'up to' 100Mbit/s cable packages: November 2015



Source: SamKnows measurement data for panel members with a connection in November 2015.
Notes: Data collected from multi-thread download speed tests.

Similarly to the lower tier cable services, our research found that there was very little variation in the maximum speeds offered by panellists' 'up to' 200Mbit/s cable services (Figure 1.10). The interquartile maximum speed range for panellists with these connections was just 2.0Mbit/s (from 207.9Mbit/s to 209.9Mbit/s), while the lowest decile received maximum speeds of 207.2Mbit/s or less and the top decile maximum speeds of at least 209.9Mbit/s.

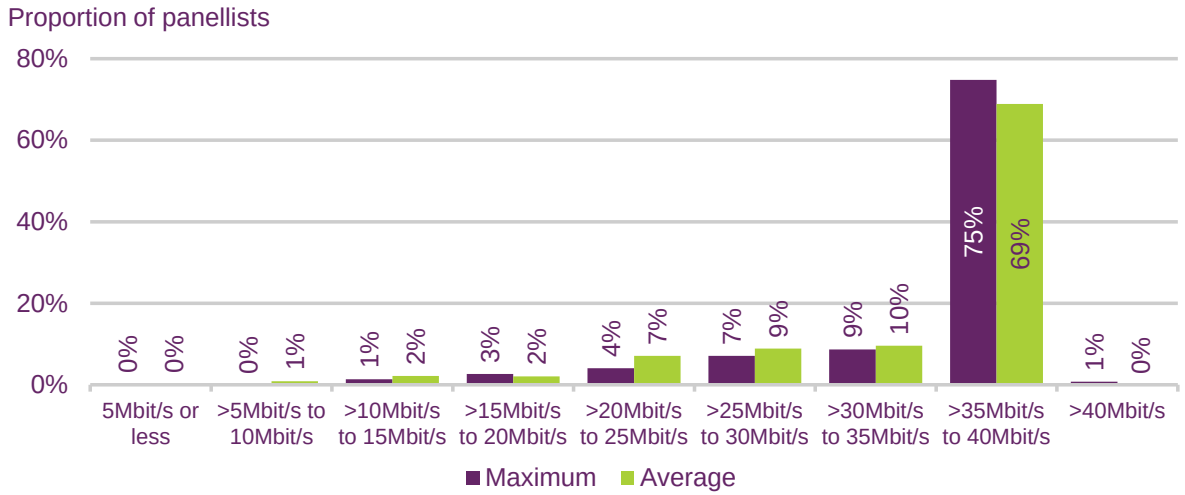
Figure 1.10 Distribution of average download speeds for 'up to' 200Mbit/s cable packages: November 2015



Source: SamKnows measurement data for panel members with a connection in November 2015.
Notes: Data collected from multi-thread download speed tests.

Figure 1.11 shows the distribution of maximum and average download speeds for 'up to' 38Mbit/s FTTC services in November 2015. The interquartile maximum speed range for these services was 1.1Mbit/s (from 36.3Mbit/s to 37.4Mbit/s), with the top decile receiving a maximum speed of at least 37.5Mbit/s, and the lowest decile speeds of 26.7Mbit/s or less.

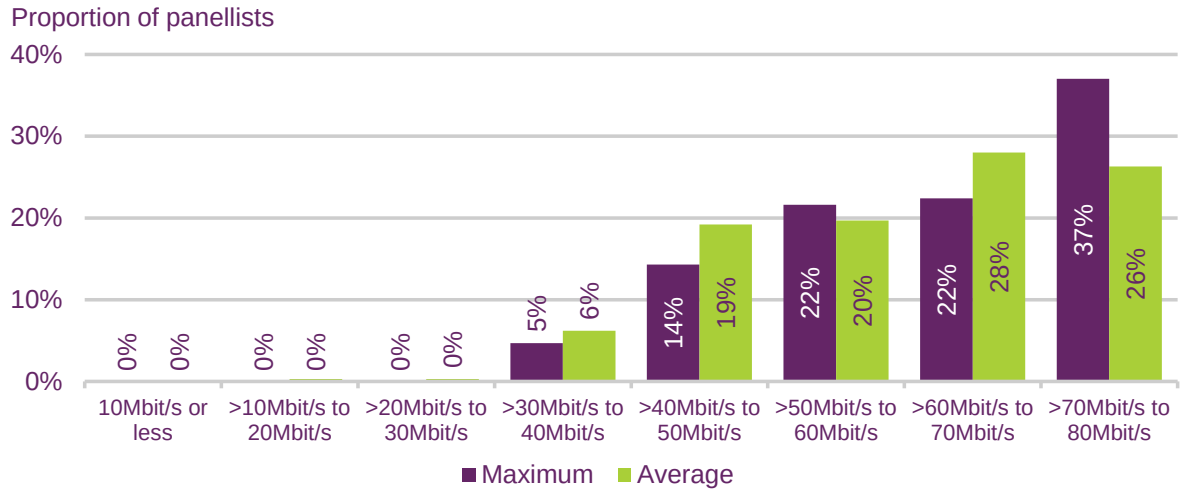
Figure 1.11 Distribution of average download speeds for ' up to' 38Mbit/s FTTC packages: November 2015



Source: SamKnows measurement data for panel members with a connection in November 2015.
Notes: Data collected from multi-thread download speed tests.

There were significant variations in the average and maximum speeds provided by panellists' 'up to' 76Mbit/s FTTC connections in November 2015 (Figure 1.12). In terms of maximum speeds, the interquartile range for these services was 23.2Mbit/s (from 51.0Mbit/s to 74.3Mbit/s), while the lowest 10% received maximum speeds of 43.6Mbit/s or less, and the highest decile maximum speeds of 74.3Mbit/s or higher.

Figure 1.12 Distribution of average download speeds for ' up to' 76Mbit/s FTTC packages: November 2015



Source: SamKnows measurement data for panel members with a connection in November 2015.
Notes: Data collected from multi-thread download speed tests.

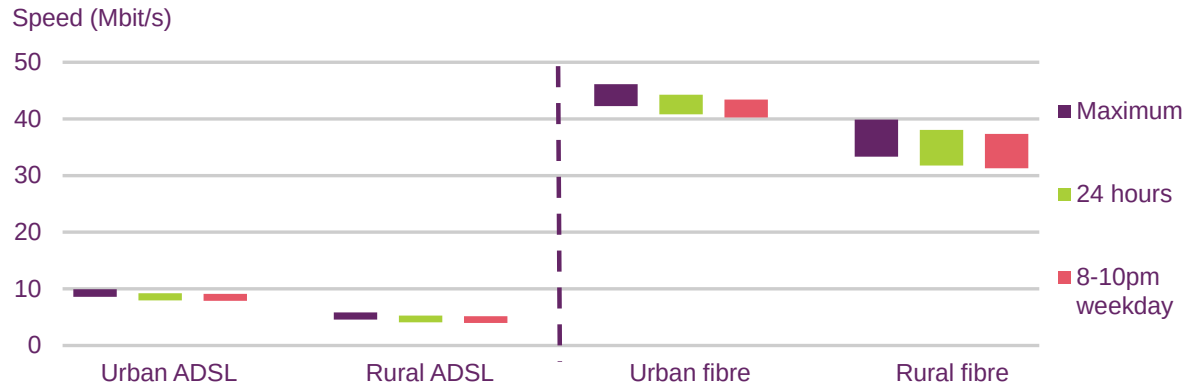
4.8 Rural ADSL connections tended to be more affected by contention at peak times than those in urban areas

The low availability of cable broadband services in rural areas means that ADSL and fibre broadband services are more prevalent in these locations. Our research shows that rural ADSL and fibre connections provided lower average download speeds than those in urban

areas in November 2015. Rural ADSL connections had an average actual 24-hour download speed of 4.7Mbit/s, compared to 8.6Mbit/s for urban connections. For FTTx connections, urban consumers achieved a 24-hour average actual download speed of 42.5Mbit/s, compared to 34.9Mbit/s for rural consumers.

On average, contention (which results in slower speeds at busy times), affected rural consumers more than urban consumers in November 2015: rural ADSL connections received an average of 88% of their maximum speed during the 8pm to 10pm weekday peak period, compared to 92% for urban ADSL connections. This was not the case for fibre packages; rural fibre connections received an average of 94% of their maximum speed at peak times, compared to 95% for urban connections.

Figure 1.13 Average actual urban and rural ADSL and FTTx download speeds: November 2015



Source: SamKnows, November 2015
Panel base: Urban fibre 555, rural fibre 73. Urban ADSL 365, rural ADSL 115.

4.9 The extent to which download speeds are affected by peak-time network contention varies by technology

Download speeds typically vary by time of day and tend to fall during peak times, when a larger number of connections are being used, as a result of capacity constraints (contention) in internet service providers (ISPs) networks (Figure 1.14). For all the connection categories analysed, average actual speeds during the 8pm to 10pm weekday peak-time period were lower than both the average maximum speed and the 24-hour actual average speed.

In November 2015 the actual average speed across all connections was 27.0Mbit/s during the 8pm to 10pm weekday peak-time period, 85% of the 31.6Mbit/s average maximum speed and 93% of the 28.9Mbit/s 24-hour average.

Cable connections with headline speeds of ‘up to’ 200Mbit/s experienced the largest proportional drop in peak-time average speeds in November 2015, when compared to both average maximum speeds and average 24-hour actual speeds. At peak time these connections had an average speed of 156.2Mbit/s, 76% of the average maximum speed (206.4Mbit/s) and 90% of the 24-hour average (174.0Mbit/s).

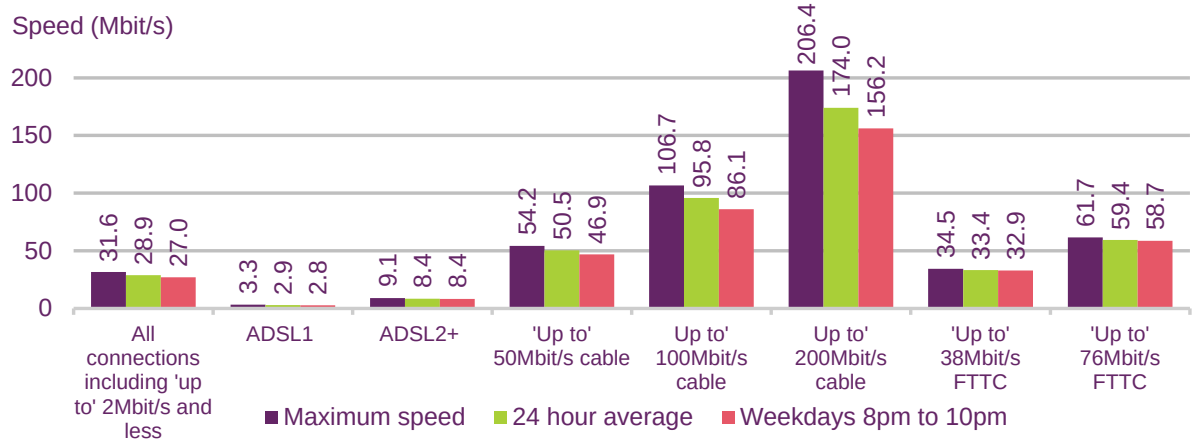
‘Up to’ 100Mbit/s cable connections were less affected by contention, receiving 81% of average maximum speed, and 90% of the 24-hour average speed during peak times. ‘Up to’

50Mbit/s cable services were less affected in peak-time periods, providing 86% of the average maximum speed and 93% of the 24-hour average.[27]

FTTC connections were less affected by peak-time contention than 'up to' 50Mbit/s, 'up to' 100Mbit/s and 'up to' 200Mbit/s cable connections. The peak-time download speeds on 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC connections were 32.9Mbit/s (96% of the maximum average speed) and 58.7Mbit/s (95% of the maximum average speed) respectively, these both being 99% of their 24-hour averages.

ADSL2+ connections with headline speeds of above 'up to' 10Mbit/s, or without a headline speed, achieved an average peak-time speed of 8.4Mbit/s in November 2015; this was 92% of the average maximum speed for these connections and 99% of the 24-hour average speed. ADSL1 connections experienced higher levels of variation in average download speeds by time of day, receiving an average of 2.8Mbit/s at peak times, equivalent to 97% of the 2.9Mbit/s 24-hour average speed and 85% of the 3.3Mbit/s average maximum speed.

Figure 1.14 Variations in download speeds, by time of day: November 2015



Source: SamKnows measurement data for all panel members with a connection in November 2015 Panel base: 1639
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange (ADSL) to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests

4.10 The average actual upload speed of a UK residential fixed-line broadband connection was 3.7Mbit/s in November 2015

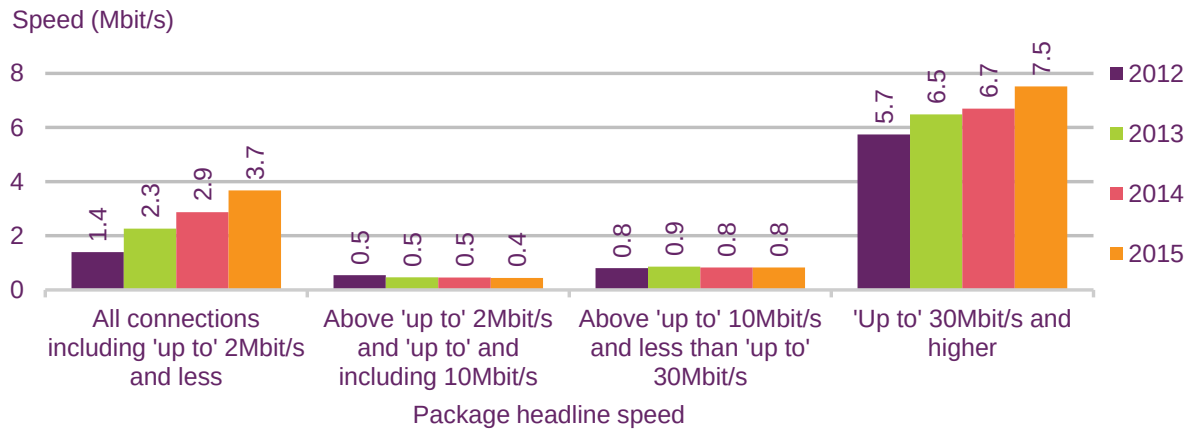
Although broadband advertising tends to focus on download speeds, upload speeds are also important to consumers, in particular those sharing large files and using real-time two-way video communications. Our research shows that the average actual upload speed was 3.7Mbit/s in November 2015, an increase of 0.8Mbit/s (28%) compared to a year previously.

Connections with headline speeds of 'up to' 30Mbit/s and higher had an average upload speed of 7.5Mbit/s in November 2015. Those with headline speeds of above 'up to' 10Mbit/s

[27] As Virgin Media's cable services' maximum speeds are higher than their headline speeds, the proportions of headline speeds that consumers receive at peak times can be higher than the figures given above. For Virgin Media's 'up to' 50Mbit/s, 100Mbit/s and 200Mbit/s services, the proportions of headline speeds recorded at peak times in November 2015 were 100%, 96% and 87% respectively.

and less than ‘up to’ 30Mbit/s had an average upload speed of 0.8Mbit/s, twice the 0.4Mbit/s recorded for above ‘up to’ 2Mbit/s and ‘up to’ and including 10Mbit/s connections.

Figure 1.15 Average actual fixed broadband upload speeds



Source: SamKnows measurement data for all panel members with a connection in November 2015
Panel base: 1639
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange (ADSL) to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

4.11 Video streaming tests

Video streaming services have become increasingly popular over the last few years, and the streaming of video content is one of the most bandwidth hungry activities that consumers use their broadband connection for.

In order to enable us to monitor how well various fixed broadband connection types handle the streaming of video content, we introduced three new video streaming tests into our research in November 2015. The results of these tests are shown below in Figure 1.16 to 0. The results are not presented on a package-by-package basis, as we had low sample sizes for a number of services.

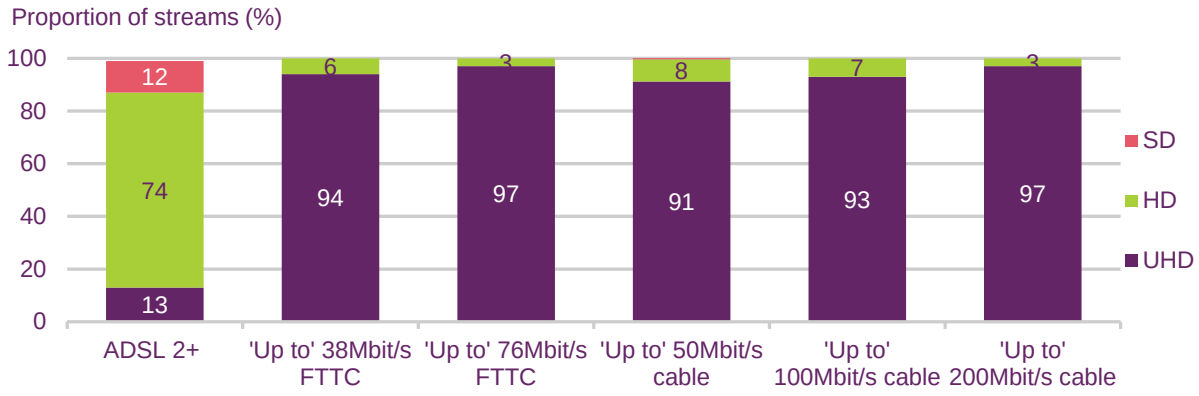
Each of the three tests is designed to measure the streaming performance of broadband connections when accessing content from one of the UK’s most popular video streaming services: Netflix, YouTube and BBC iPlayer. In essence, these tests all work in the same way, in that they stream content (or simulate the streaming of content) from one of these services and identify the highest video resolution that can be reliably streamed over the connection (i.e. without experiencing any re-buffering events). The charts below therefore show the proportions of 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.

Full details regarding the tests can be found in the report’s Technical Annex.

The first results we present are for the Netflix streaming test, which was developed by SamKnows in conjunction with Netflix. The tests involves streaming a binary file from Netflix using the same CDN selection logic that a real Netflix client would use and, as the test steams a file rather than actual video content, every stream can potentially result in UHD being the resolution reliably streamed.

As is shown in Figure 1.16 below, the majority of Netflix tests over ADSL2+ connections in November 2015 (74%) resulted in HD being the resolution reliably streamed, with similar proportions of tests recording SD and UHD being the reliably streamed resolution (14% and 12% respectively). For all of the cable and FTTC connection types included in the analysis, over 90% of tests resulted in UHD being the resolution reliably streamed, with fewer than 1% being SD and the remainder being HD.

Figure 1.16 Percentage of Netflix videos delivered at the given video quality without re-buffering events, by technology

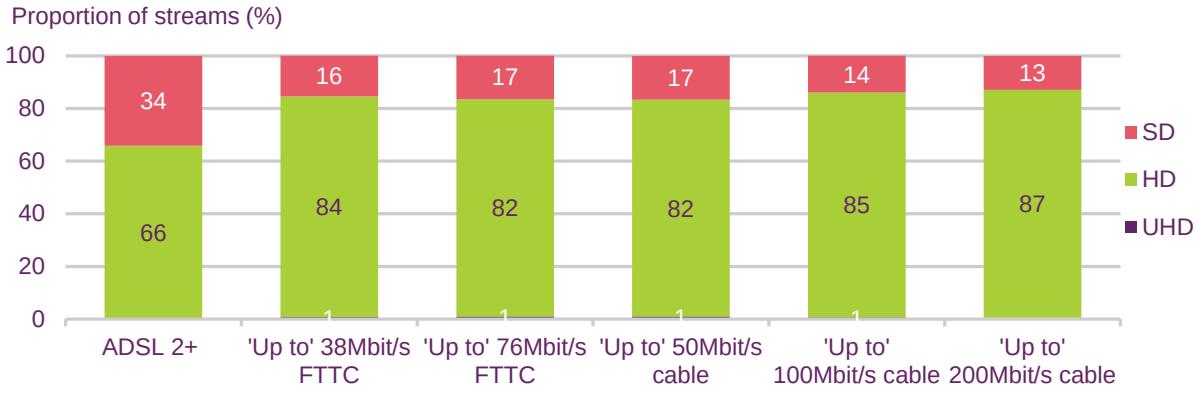


Source: SamKnows measurement data for all panel members with a connection in November 2015.

The YouTube test works by streaming the most popular YouTube video clip of at least one minute in duration that is available in at least HD, meaning that it will not be possible for many tests to result in UHD being the resolution reliably streamed as a large proportion of YouTube content a piece of content is not available in UHD. This is reflected in Figure 1.17 below, which shows that no more than 1% of streams were in UHD for any of the service types included in the analysis.

The results of our testing show that around two-thirds of YouTube streams over ADSL2+ connections (66%) were in HD in November 2015, with 33% being in SD. Again, there were similar results across all of the cable and fibre connection types included in the research, with over 80% being in HD and almost all of the remaining tests resulting in SD being the resolution reliably streamed.

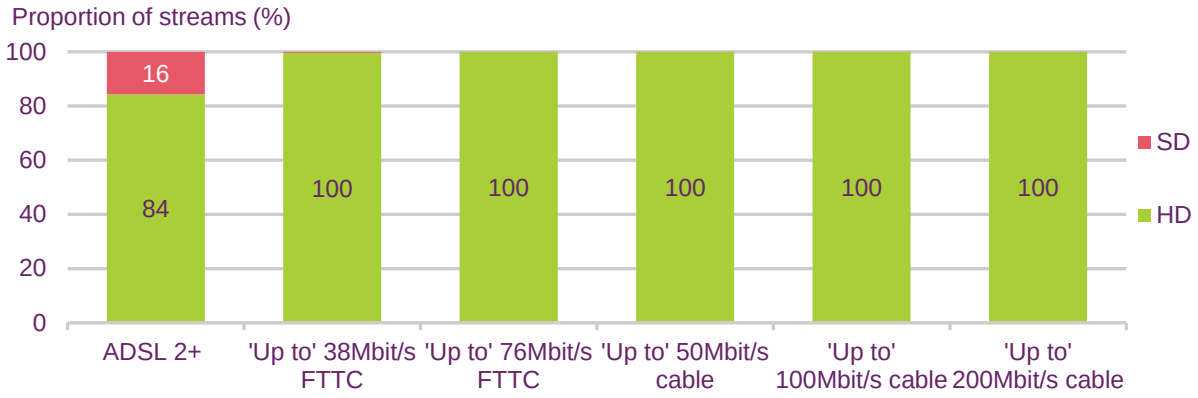
Figure 1.17 Percentage of YouTube videos delivered at the given video quality without re-buffering events, by technology



Source: SamKnows measurement data for all panel members with a connection in November 2015.

BBC iPlayer does not offer UHD content, so the highest available resolution reliably streamed is HD, with the content being streamed being the most popular video. For almost all of the connection types shown below, over 99% of iPlayer streams resulted in HD being the resolution reliably streamed (Figure 1.18). The only exception was ADSL2+ connections, for which 16% of streams were delivered in SD.

Figure 1.18 Percentage of iPlayer videos delivered at the given video quality without re-buffering events, by technology



Source: SamKnows measurement data for all panel members with a connection in November 2015.

Performance in different parts of the internet connection chain

Delivering services across the internet, e.g. browsing the web or streaming a video, requires the interconnection of many different networks. This infrastructure, illustrated in Figure 1.19, is made up of many technologies, each with different characteristics. Therefore it is not straightforward to predict what the consumer's broadband experience will be. For example:

- **A home network:** This is increasingly the Wi-Fi network that extends the reach of the broadband connection throughout the home. In this case the consumer's broadband experience will depend on the distance from the access point, the thickness of walls, the age of the equipment the consumer is using, and how many other people are using the network at the same time.

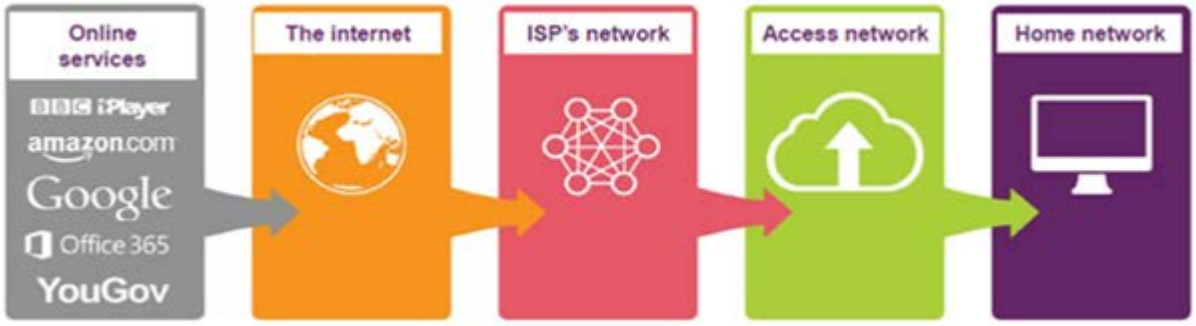
- **An access network:** This is the connection between the home and the internet service provider (ISP) or network operator, such as BT or Virgin Media. Originally, this connection was made of copper. In recent years, however, some or all of this connection has been replaced with fibre optic or a wireless technology such as 4G. The consumer's broadband experience may depend on how far their premises are from the street cabinet or exchange, and on the material from which the cables are made.

- **The ISP's network:** This is the network that is internal to the ISP and which brings together the traffic of all of its customers. This network is mostly made up of fibre optic connections and high capacity/high speed core routing equipment. The consumer's broadband experience will depend on the number of users who are simultaneously trying to access content.

- **The wider internet:** This is the collection of interconnected networks across the world that allows consumers in one country to access data in other countries. The consumer's broadband experience will vary depending on the content they wish to access, with some popular content delivered directly and therefore more quickly between networks.

ISPs are able to influence the performance of these four different parts of the connection chain to varying degrees. The results, based on SamKnows data elsewhere in this report, show differences in performance that are probably due to one or more of the three parts of the connection chain, excluding the 'Home network'.

Figure 1.19 Simplified illustration of delivering services over the internet



Source: Ofcom

The performance of these different parts of the connection chain, and how they are perceived by consumers, is more widely dependent on:

- **The internet application being used:** this is because different internet services have different levels of sensitivity to connection performance.

- **The expectations of the consumer:** consumers may have differing broadband performance expectations. For example, those relying on their domestic broadband connection to run a small business, or those who have paid a higher price for a higher speed connection, may have greater expectations than those making infrequent use of a broadband connection using a lower-priced subscription.

Over recent years, ISPs have been investing heavily in their networks to support higher speeds. Much of this investment has been focused on the access network, involving the replacement of some or all of the copper cables with fibre optic connections. These upgrades, alongside enhancements in transmission and routing equipment, form the basis of many superfast broadband services.[28]

Ofcom commissioned research from Actual Experience, which uses a new internet measurement approach, to help identify how the parts of the internet connection chain are likely to affect the consumer experience of using online services. Predictions around how consumers are likely to rate the quality of their broadband connection made using this approach appear to correlate closely with actual consumer ratings.

The Actual Experience research uses a small piece of software that takes continuous measurements of network performance. These are then analysed to understand the performance of the digital supply chain, and the results are processed to produce scores and correlations that can be used to benchmark digital supply chains and identify sources of underperformance that affect the quality of the services delivered.

The research suggests that those consumers with faster connections are more likely to rate their broadband experience as good, as shown in Figure 1.20. In general, 10Mbit/s appears to be the tipping point beyond which most consumers rate their broadband experience as

[28] http://stakeholders.ofcom.org.uk/binaries/research/infrastructure/2015/downloads/qoe-analysis.pdf

'good' or better, supporting Ofcom's view that a minimum of 10Mbit/s is required by the typical household.

Figure 1.20 Proportion of broadband users likely to rate their internet experience as 'good' or better

Source: Actual Experience for Ofcom

The performance of other parts of the connection chain

The research also identified that factors beyond the speed of the access network can have a meaningful effect on broadband connections likely to be rated by consumers as 'less than good' (Figure 1.21).

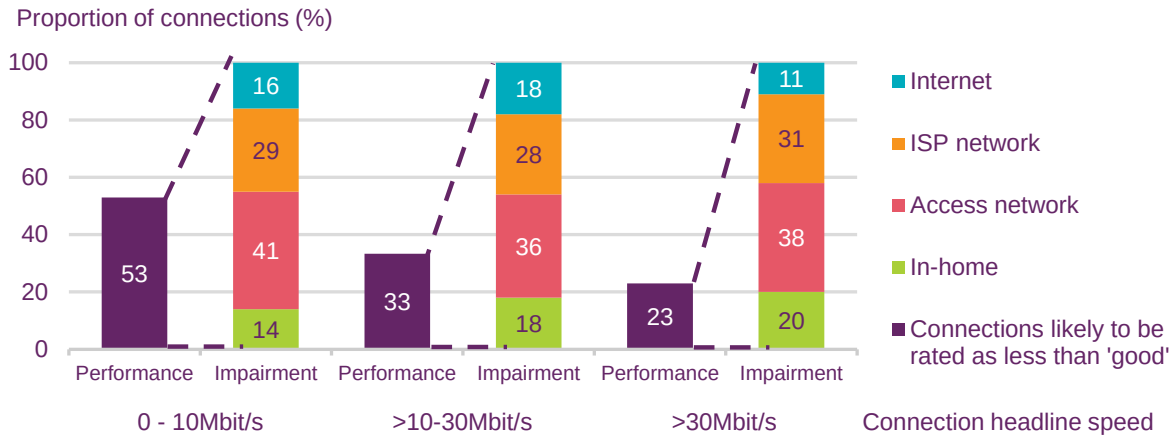
Faster broadband makes it possible for consumers to connect more devices to the internet at the same time, and Wi-Fi, which is used to share the broadband connection in many UK homes, has become vital to the broadband experience.

The research found that Wi-Fi performance and congestion in the wider internet (not the ISP's network), can combine to affect the broadband experience of consumers both with standard and with superfast connections. In particular, it found that the performance of in-home Wi-Fi networks plays a significant role in approximately 25% of households that experience problems with their broadband.

Ofcom has launched an app for smartphones and tablets that tests Wi-Fi networks for performance issues, helps consumers identify if their broadband is not performing as it should, and suggests simple troubleshooting steps to improve performance.[29]

[29] http://stakeholders.ofcom.org.uk/market-data-research/market-data/infrastructure/connected-nations-2015/wifi-checker-app/

Figure 1.21 The parts of the internet connection chain affecting connections likely to be rated as 'less than good', by headline speed



Source: Actual Experience for Ofcom

Section 5

Speeds, 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 and 24-hour download and upload speeds of ADSL2+, cable and fibre-to-the-cabinet (FTTC) ISP packages.

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

Data normalisation

An important factor affecting the actual speeds provided by asymmetric digital subscriber line (ADSL) broadband connections is the length of the wiring between the local exchange and the end-user's premises. To take into account the differing ISP profiles when comparing the performance of ADSL ISP packages, we 'normalise' the test data by distance from the exchange to take into account differing ISP customer profiles. This enables us to make like-for-like comparisons of performance across ADSL services.

FTTC services use very high data rate digital subscriber line (VDSL), a faster form of DSL technology than ADSL, to transmit data from the street cabinet to the end-user's premises, and FTTC speeds are therefore also affected by the length (and quality) of the wiring over which the data signal is transmitted. This means that differing ISP user profiles may result in similar systematic biases to those associated with ADSL in FTTC test result data.

Working closely with Openreach and SamKnows, we identified the most appropriate methodology for normalising the FTTC data, and engaged an external statistician to perform the normalisation on the November 2015 FTTC test results data on our behalf. Using this analysis, we have now concluded that it is appropriate to normalise the FTTC test results, as the statistical analysis shows that the differing geographic profiles of ISP customer bases are having a material effect on the average FTTC download speeds reported in our research.

This is the first time that the statistical analysis carried out by an external statistician has come to this conclusion.

This report is therefore the first time that we have normalised FTTC results to attempt to offset the effects of the differing geographic profiles of ISPs. More information on the ADSL and FTTC normalisations can be found in the statistical methodology in Annex 3 of this report.

ISP packages

Our ability to compare specific ISP packages is dependent upon achieving sufficient panel sizes for the packages. In November 2015 we were able to recruit sufficient panellists for the following ISP packages (listed in alphabetical order):

- BT's ADSL2+, 'up to' 38Mbit/s FTTC and 'up to' 76Mbit/s FTTC services;
- EE's ADSL2+, 'up to' 38Mbit/s FTTC and 'up to' 76Mbit/s FTTC services;
- KC's[30] ADSL2+ service;
- Plusnet's ADSL2+, 'up to' 38Mbit/s FTTC and 'up to' 76Mbit/s FTTC services;
- Sky's ADSL2+, 'up to' 38Mbit/s FTTC and 'up to' 76Mbit/s FTTC services;
- TalkTalk's ADSL2+ and 'up to' 38Mbit/s FTTC services; and
- Virgin Media's 'up to' 50Mbit/s, 'up to' 100Mbit/s and 'up to' 200Mbit/s cable services.

Consumers should note that there are many other services and ISP packages available, some of which may match, or better, the performance of the ISP packages included in this report.

Presentation of results

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

The sample size for each group, and the variation of performance among panellists within the same group, combine to determine the size of the bars. We must emphasise that these bars indicate the average (mean) performance rather than the range of performance delivered.

The sampling and statistical methodologies have been designed to allow us to compare ISP packages on a like-for-like basis. For details see the research methodology set out in Annex 2 and the statistical methodology set out in Annex 3.

[30] Previously known as Karoo or Kcom.

Download speeds summary

Our research found that there were relatively few variations between the performance of the ADSL2+ and FTTC packages included in the research in November 2015:

- There were no statistically significant differences to a 99% level of confidence in the average 24-hour download speeds recorded for the ADSL2+ services included in the report;
- Similarly, there were no such differences between the 24-hour average speeds recorded for the ‘up to’ 38Mbit/s FTTC packages that are included in the research; and
- There was only one difference in the average 24-hour speeds recorded for 'up to' 76Mbit/s FTTC services that was statistically significant to a 99% level of confidence.

This is related to all but one of these services (KC’s ADSL2+ package) being provided over the same copper network (BT’s).

Virgin Media’s ‘up to’ 200Mbit/s package had the fastest 24-hour average download speed among the ISP packages covered in our research in November 2015, at 174.0Mbit/s.

ADSL2+ connections: download speeds

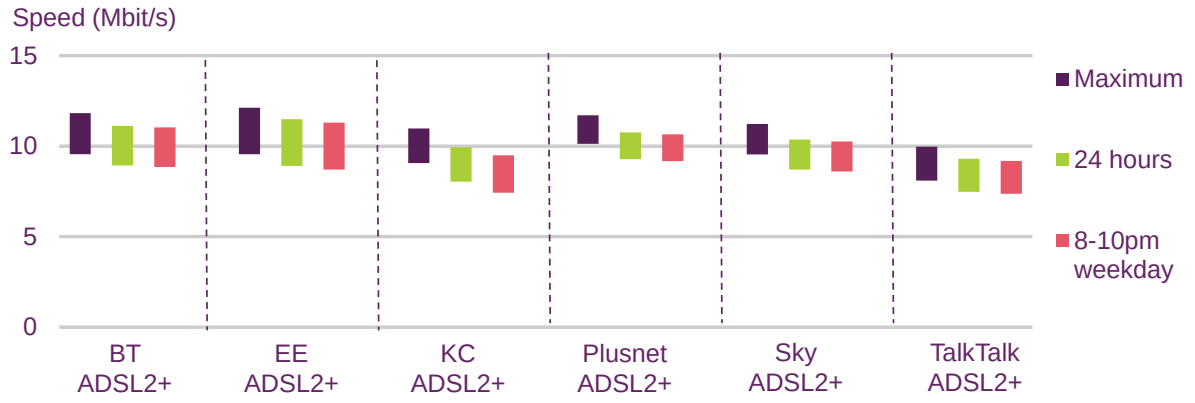
5.1 Maximum, average and peak-time download speeds for ADSL2+ ISP packages

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 (Figure 1.22) we have discounted those premises that are more than 5km away from their local exchange, in order more accurately to measure the ISP’s performance, and we have normalised 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 3 of this report.

With the exception of KC, the incumbent provider in Kingston upon Hull, all of the ADSL2+ packages included in the report are provided over the BT copper line from the local exchange/street cabinet to the end-user’s home. This means that it is unlikely that you will see a substantial increase in the speed of your service by switching from one ADSL2+ package to another unless the speed of your existing service is being limited by factors within your ISP’s control, such as network congestion.

In November 2015, the average actual 24-hour download speed of the ADSL2+ ISP packages included in this report ranged from 8.4Mbit/s for TalkTalk’s service to 10.2Mbit/s for EE’s. The proportion of average maximum speeds delivered during the weekday 8pm to 10pm peak-time period ranged from 85% for KC’s ADSL2+ packages to 93% for BT’s ADSL2+ package, among the services covered by our research.

Figure 1.22 Maximum, average and peak-time download speeds for ADSL2+ ISP packages: November 2015



Source: SamKnows measurement data for all panel members with a connection in November 2015. Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC; (2) Includes on-net customers only for LLU operators (3) Data have been weighted to distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 1.23 summarises the statistically significant differences in the download speed, over different time periods, of the ADSL2+ ISP packages covered in our research.

Figure 1.23 Significant differences between download speeds for ADSL2+ ISP packages: November 2015

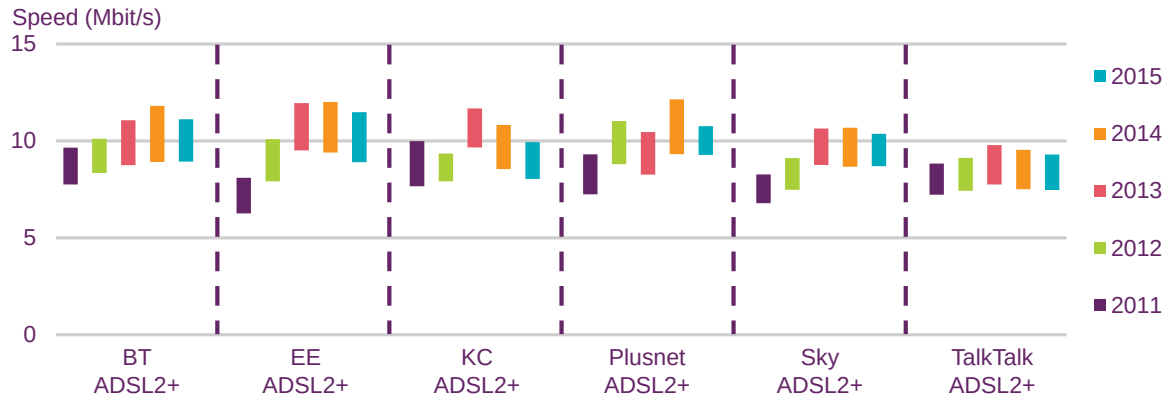
	Maximum	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**	**Is faster than...**
Plusnet ADSL2+	*TalkTalk ADSL2+	No differences	No differences

Source: Ofcom
*Note: Significant differences to 95% confidence level. *Note difference is not significant to a 99% level of confidence*

5.2 Average download speeds for ADSL2+ ISP packages remained similar across ISPs

Figure 1.24 shows the average download speeds recorded in previous reporting periods for the ADSL2+ ISP packages included in this report. There were no statistically significant differences between the average speeds of any of the ADSL2+ packages between November 2014 and November 2015.

Figure 1.24 Average download speeds for ADSL2+ packages: November 2011 to November 2015



Source: SamKnows measurement data for all panel members with a connection in November 2015. Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC; (2) Includes on-net customers only for LLU operators (3) Data have been weighted to distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

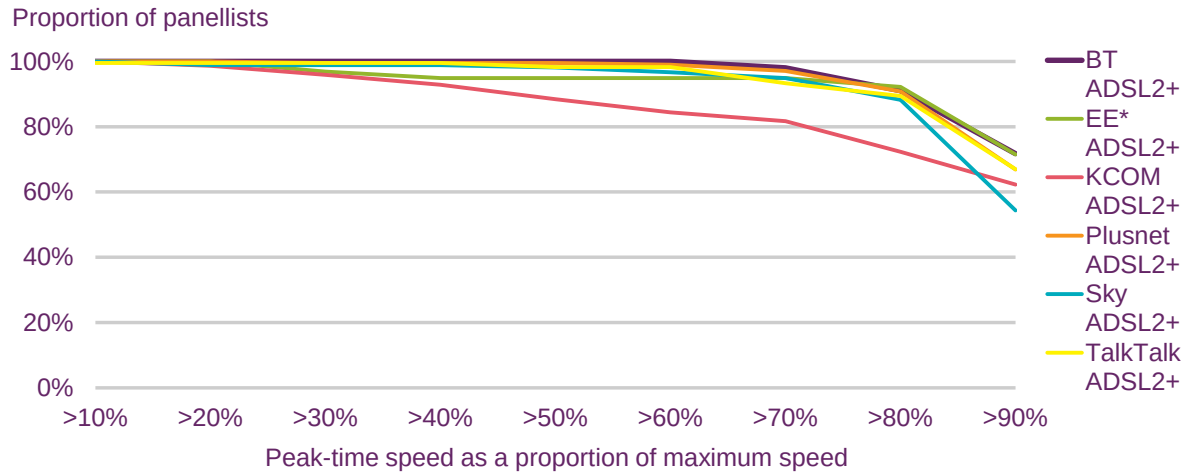
5.3 The proportion of ADSL2+ panellists receiving more than 90% of their maximum speed at peak times varied from 60% to 74% of panellists

Figure 1.25 shows the distribution of average speeds across our ADSL2+ panellists during the 8pm to 10pm weekday peak-time period as a proportion of the maximum speed delivered by their connections. The intention of this analysis is to measure whether certain panellists are disproportionately affected by network contention. Higher levels of network congestion (contention) limit download speeds,[31] and we would therefore expect to see fewer panellists experiencing higher average peak speeds to maximum speed if contention was higher. In this analysis higher lines indicate better performance.

Among all of the ADSL2+ ISP packages compared, more than half the panellists experienced peak-time speeds that were higher than 90% of their average maximum speed. Sky's ADSL2+ service was the worst performing, with 54% of panellists achieving peak-time speeds greater than 90% of their maximum speed in November 2015.

[31] Peak-time speeds, and speeds more generally, can also be affected by the traffic management policies applied by ISPs

Figure 1.25 Distribution of average peak-time speed as a proportion of maximum speed for ADSL2+ ISP packages: November 2015



Source: SamKnows measurement data for all panel members with a connection in November 2015. Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC; (2) Includes on-net customers only for LLU operators (3) Data have been weighted to distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

'Up to' 30Mbit/s and higher connections: download speeds

5.4 Maximum, average and peak-time download speeds for ISP packages 'up to' 30Mbit/s and above

Virgin Media is continuing to upgrade its cable packages; existing customers on its 'up to' 50Mbit/s, 100Mbit/s and 152Mbit/s packages can upgrade to 'up to' 70Mbit/s, 150Mbit/s and 200Mbit/s services respectively, free of charge.

A sufficient number of our panellists had migrated to the new 200Mbit/s service tier by November 2015 to enable us to include this package in this report. As Virgin Media continues to sell 50Mbit/s and 100Mbit/s packages, with 70Mbit/s and 150Mbit/s only available to customers who had joined Virgin Media before 24th November 2015, we are reporting on the 50Mbit/s, 100Mbit/s and 200Mbit/s tiers as they are the speeds offered to new customers.

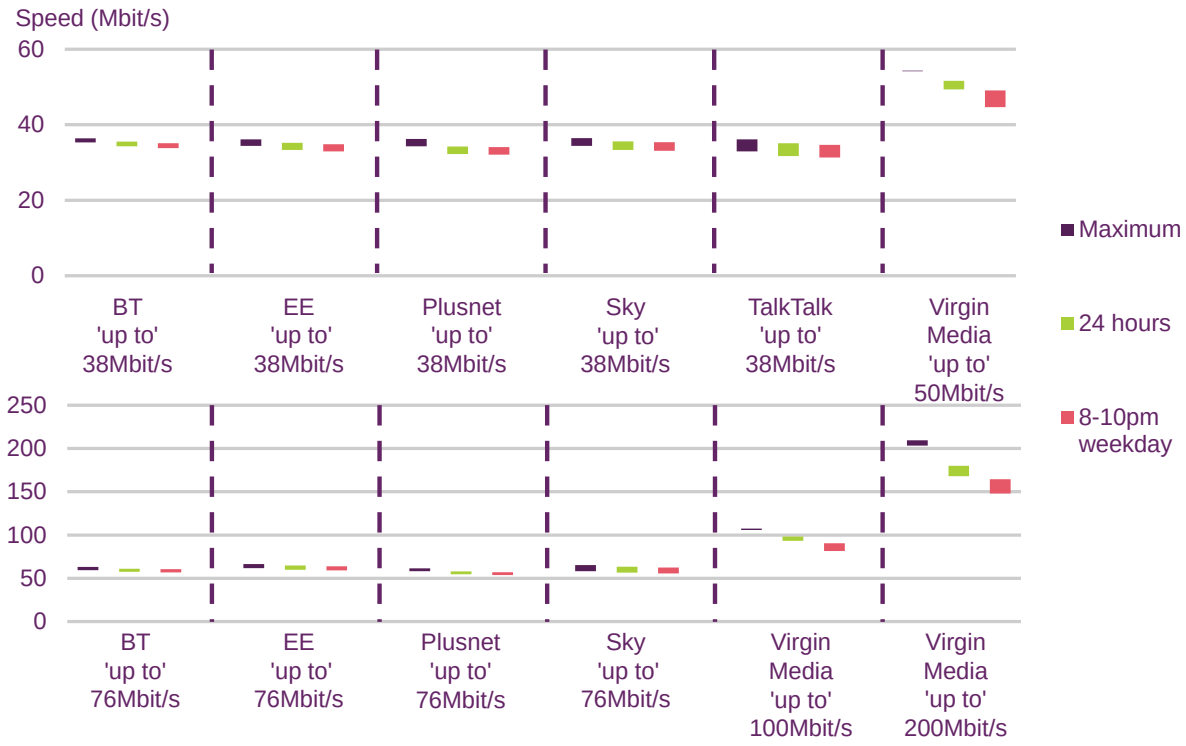
As shown in Figure 1.26, Virgin Media's 'up to' 200Mbit/s package had the fastest download speeds of the ISP packages covered in our research, in terms of its average maximum speed (206.4Mbit/s), 24-hour average speed (174.0Mbit/s) and peak-time average speed (156.2Mbit/s) in November 2015.

The relative performance of the ISP packages in our research with a headline speed of 'up to' 30Mbit/s or higher, in terms of maximum, 24-hour average and 8pm to 10pm weekday peak-time speeds, generally reflected their advertised speeds. Average peak-time speeds as a proportion of maximum speeds ranged from 76% in the case of Virgin Media's 'up to' 200Mbit/s cable package (78% of the service's headline speed), to 97% for Sky's 'up to' 38Mbit/s FTTC package.

All of the FTTC packages included in the report are provided over the BT copper line from the local exchange/street cabinet to the end-user's home, and use BT controlled VDSL systems. This means that it is unlikely that you will see a substantial increase in the speed of

your service by switching from one FTTC package to another unless the speed of your existing service is being limited by factors within your ISP's control, such as network congestion.

Figure 1.26 Maximum, average and peak-time download speeds for ISP packages 'up to' 30Mbit/s and above: November 2015



Source: SamKnows measurement data for all panel members with a connection in November 2015. Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC (2) Data for FTTC operators has been weighted to the FTTC national max attainable speed profile (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean.

Figure 1.27 summarises the statistically significant differences between the download performances of ISP packages 'up to' 30Mbit/s and above included in our research in November 2015.

Figure 1.27 Significant differences between maximum, average and peak-time download speeds for ISP packages 'up to' 30Mbit/s and above: November 2015

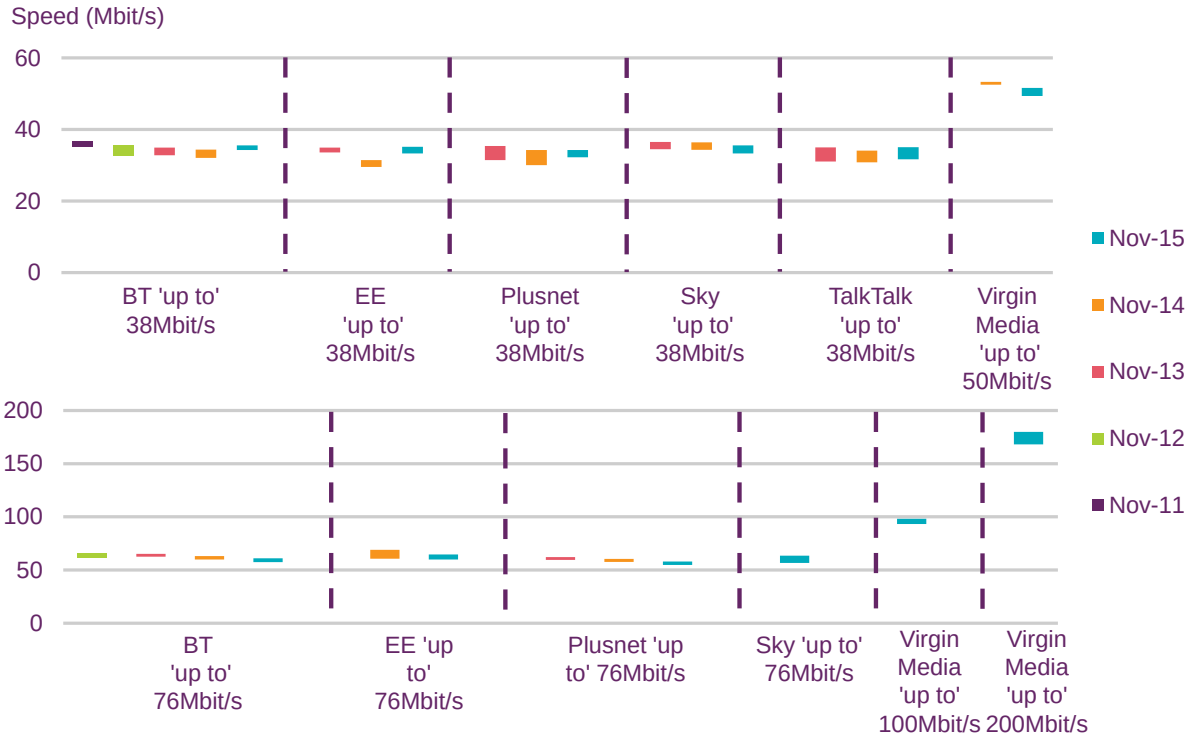
	Maximum	24 hours	8-10pm weekday
ISP package	Is faster than...	Is faster than...	Is faster than...
Virgin Media 200	Virgin Media 100, EE 76, Sky 76, BT 76, Plusnet 76, Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38	Virgin Media 100, EE 76, Sky 76, BT 76, Plusnet 76, Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38	Virgin Media 100, EE 76, Sky 76, BT 76, Plusnet 76, Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38
Virgin Media 100	EE 76, Sky 76, BT 76, Plusnet 76, Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38	EE 76, Sky 76, BT 76, Plusnet 76, Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38	EE 76, Sky 76, BT 76, Plusnet 76, Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38
EE 76	Plusnet 76*, Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38	Plusnet 76, Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38	Plusnet 76*, Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38
Sky 76	Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38	Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38	Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38
Plusnet 76	Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38	Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38	Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38
BT 76	Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38	Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38	Virgin Media 50, BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38
Virgin Media 50	BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38	BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38	BT 38, Sky 38, EE 38, TalkTalk 38, Plusnet 38
BT 38	No differences	Plusnet 38*	No differences

Source: Ofcom
*Notes: Significant differences to 95% confidence level; *difference is not significant to a 99% level of confidence*

5.5 Average download speeds for ISP packages 'up to' 30Mbit/s and above: November 2011 to November 2015

Figure 1.28 shows the average download speeds recorded for the 'up to' 30Mbit/s and above ISP packages covered in this report over various time periods. Speeds for packages 'up to' 30Mbit/s and above have remained relatively steady over the period shown.

Figure 1.28 Average download speeds for ISP packages 'up to' 30Mbit/s and above: November 2011 to November 2015



Source: SamKnows measurement data for all panel members with a connection in November 2015. Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC (2) Data for FTTC operators has been weighted to the FTTC national max attainable speed profile (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean.

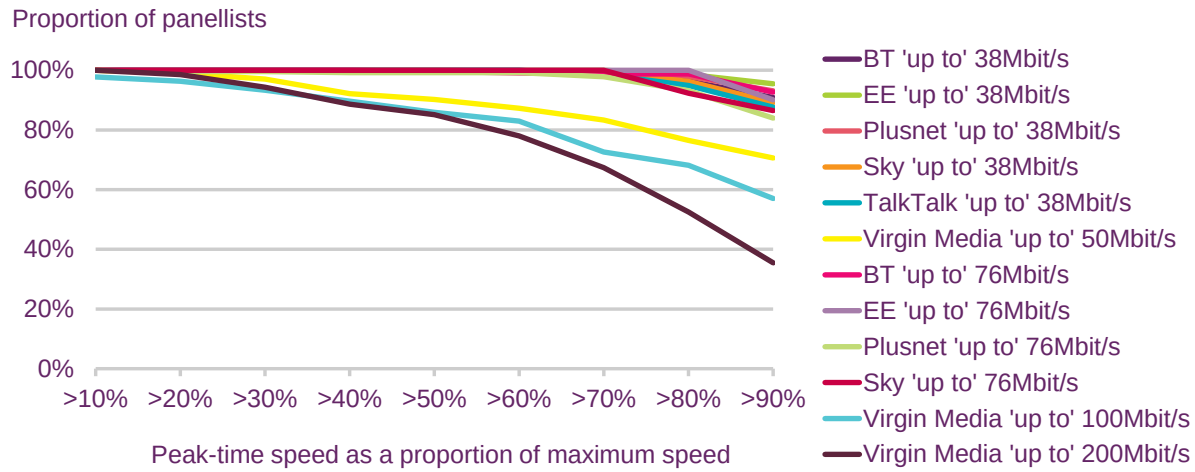
5.6 Distribution of average peak-time speed as a proportion of maximum speed for ISP packages 'up to' 30Mbit/s and above: November 2015

Figure 1.29 shows the analysis of the distribution of panellists with a headline speed of 'up to' 30Mbit/s and above, in terms of average speeds, during the 8pm to 10pm weekday peak-time period, as a proportion of average maximum speeds. As before, in this analysis, higher lines represent better performance.

Figure 1.29 shows that the best performing package, in terms of peak-time performance, was EE's FTTC 'up to' 38Mbit/s package, for which 95% of panellists received 90% or more of their connections' maximum speed at peak time in November 2015. Virgin Media's 'up to' 200Mbit/s package performed the least well of the packages, with just 35% of panellists receiving average peak-time speeds higher than 90% of their maximum speed during the 8pm to 10pm weekday peak-time period, in November 2015. Virgin Media's maximum speeds can exceed headline speeds, and for Virgin Media's 50Mbit/s, 100Mbit/s and 200Mbit/s packages, 75%, 64% and 44% of customers received 90% or more of their headline speeds respectively.

The 'up to' 76Mbit/s FTTC packages included in the analysis varied in performance, with 84% of Plusnet's 'up to' 76Mbit/s panellists receiving more than 90% of their maximum speed at peak times, compared to 93% for BT's.

Figure 1.29 Distribution of average peak-time speed as a proportion of maximum speed for ISP packages 'up to' 30Mbit/s and above: November 2015



Source: SamKnows measurement data for all panel members with a connection in November 2015.

Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC (2) Data for FTTC operators has been weighted to the FTTC national max attainable speed profile (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean.

5.7 Summary of average download speeds of all ISP packages

Figure 1.30 summarises the average maximum, 24-hour and weekday peak-time download speeds achieved by all the ISP packages included in our research in November 2015. As previously, it shows the 95% confidence interval around the mean. This is not necessarily the average speed achieved across all UK customers using each package, but we can say that at the 95% confidence level the average speed of these packages falls within the stated range.

Figure 1.30 Summary of average download speed, by ISP package: November 2015

	Average download speed during period		
Package	Maximum	24 hours	8-10pm weekdays
BT ADSL2+	9.5Mbit/s to 11.8Mbit/s	8.9Mbit/s to 11.1Mbit/s	8.8Mbit/s to 11.0Mbit/s
EE ADSL2+	9.6Mbit/s to 12.1Mbit/s	8.9Mbit/s to 11.5Mbit/s	8.7Mbit/s to 11.3Mbit/s
KC ADSL2+	9.1Mbit/s to 11.0Mbit/s	8.1Mbit/s to 9.9Mbit/s	7.4Mbit/s to 9.5Mbit/s
Plusnet ADSL2+*	10.1Mbit/s to 11.7Mbit/s	9.3Mbit/s to 10.8Mbit/s	9.2Mbit/s to 10.7Mbit/s
Sky ADSL2+	9.5Mbit/s to 11.2Mbit/s	8.7Mbit/s to 10.4Mbit/s	8.6Mbit/s to 10.3Mbit/s
TalkTalk ADSL2+	8.1Mbit/s to 10.0Mbit/s	7.5 Mbit/s to 9.3Mbit/s	7.4Mbit/s to 9.2Mbit/s
BT 'up to' 38Mbit/s	35.3Mbit/s to 36.4Mbit/s	34.3Mbit/s to 35.5Mbit/s	33.8Mbit/s to 35.1Mbit/s
EE 'up to' 38Mbit/s	34.3Mbit/s to 36.1Mbit/s	33.3Mbit/s to 35.2Mbit/s	32.9Mbit/s to 34.8Mbit/s
Plusnet 'up to' 38Mbit/s	34.3Mbit/s to 36.3Mbit/s	32.3Mbit/s to 34.2Mbit/s	32.1Mbit/s to 34.0Mbit/s
Sky 'up to' 38Mbit/s	34.4Mbit/s to 36.4Mbit/s	33.3Mbit/s to 35.6Mbit/s	33.1Mbit/s to 35.4Mbit/s
TalkTalk 'up to' 38Mbit/s	32.9Mbit/s to 36.1Mbit/s	31.7Mbit/s to 35.1Mbit/s	31.3Mbit/s to 34.7Mbit/s
Virgin Media 'up to' 50Mbit/s	54.2Mbit/s to 54.3Mbit/s	49.4Mbit/s to 51.6Mbit/s	44.6Mbit/s to 49.1Mbit/s
BT 'up to' 76Mbit/s	59.5Mbit/s to 63.1Mbit/s	57.4Mbit/s to 61.1Mbit/s	56.9Mbit/s to 60.5Mbit/s
Plusnet 'up to' 76Mbit/s	58.3Mbit/s to 61.6Mbit/s	54.8Mbit/s to 58.1Mbit/s	53.8Mbit/s to 57.1Mbit/s
Sky 'up to' 76Mbit/s	58.3Mbit/s to 65.2Mbit/s	56.6Mbit/s to 63.5Mbit/s	55.6Mbit/s to 62.4Mbit/s
EE 'up to' 76Mbit/s	61.8Mbit/s to 66.4Mbit/s	59.9Mbit/s to 64.7Mbit/s	59.2Mbit/s to 64.0Mbit/s
Virgin Media 'up to' 100Mbit/s	105.8Mbit/s to 107.5Mbit/s	93.3Mbit/s to 98.2Mbit/s	81.6Mbit/s to 90.6Mbit/s
Virgin Media 'up to' 200Mbit/s	203.3Mbit/s to 209.5Mbit/s	168.0Mbit/s to 179.9Mbit/s	148.0Mbit/s to 164.4Mbit/s

Source: SamKnows measurement data for all panel members with a connection in November 2015. Panel base: 2,153 (BT ADSL2+, 96; BT38, 223; BT76, 205; EE ADSL2+, 73; EE38, 80; Kcom ADSL2+ 78; Plusnet ADSL2+, 148, Plusnet38, 107; Plusnet76, 212; Sky ADSL2+, 139; Sky38, 107; Sky76, 60; TalkTalk ADSL2+, 108; TalkTalk 38, 53; Virgin Media 50, 102; Virgin Media 100, 135 and Virgin Media 200, 141)
Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to distance from exchange; Data for FTTC operators has been weighted to max. attainable speed profile; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

5.8 Upload speeds

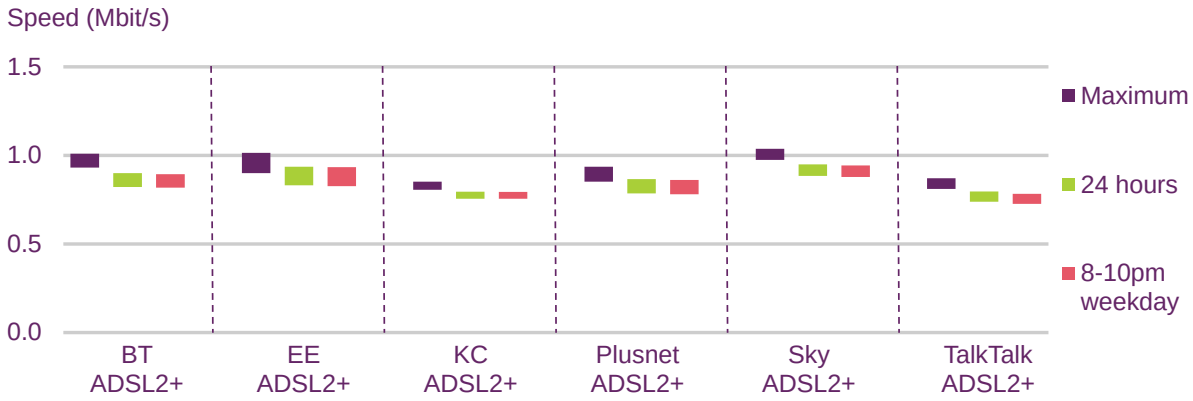
As mentioned previously, broadband connections work both ways, and have measurable download and upload speeds. Upload speeds are important for people who share large files or use real-time two-way communication, and for some online gaming. We therefore consider upload speeds in our research.

Maximum, average and peak-time upload speeds for ADSL2+ ISP packages

Our research shows that TalkTalk, Plusnet and KC's ADSL services had 24-hour average upload speeds of 0.8Mbit/s compared to 0.9Mbit/s or 1.0Mbit/s for all of the other ADSL2+ packages included in our research (Figure 1.31). BT, Sky and EE's ADSL2+ packages were all faster than TalkTalk's and KC's ADSL2+ packages in terms of their average 24-hour and peak-time upload speeds in November 2015, and KC's in terms of their average maximum

speeds. Sky's ADSL2+ package was also faster than Plusnet's in terms of its average 24 hour speeds and in terms of maximum speeds.

Figure 1.31 Maximum, average and peak-time upload speeds for ADSL2+ ISP packages: November 2015



Source: SamKnows measurement data for all panel members with a connection in November 2015. Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC; (2) Includes on-net customers only for LLU operators (3) Data have been weighted to distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 1.32 summarises the statistically significant differences in the upload speed performance of the ADSL2+ ISP packages covered in our research.

Figure 1.32 Significant differences between maximum, average and peak-time upload speeds for ADSL2+ ISP packages: November 2015

	Maximum	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**	**Is faster than...**
Sky ADSL2+	Plusnet ADSL2+, KC ADSL2+	Plusnet ADSL2+*, KC ADSL2+, TalkTalk ADSL2+	KC ADSL2+, TalkTalk ADSL2+
EE ADSL2+	KC ADSL2+	KC ADSL2+, TalkTalk ADSL2+	KC ADSL2+, TalkTalk ADSL2+
BT ADSL2+	KC ADSL2+	KC ADSL2+, TalkTalk ADSL2+	KC ADSL2+, TalkTalk ADSL2+
Plusnet ADSL2+	KC ADSL2+*	No differences	No differences
TalkTalk ADSL2+	BT ADSL2+*, EE ADSL2+*, Plusnet ADSL2+, KC ADSL2+	No differences	No differences
KC ADSL2+	No differences	No differences	No differences

Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

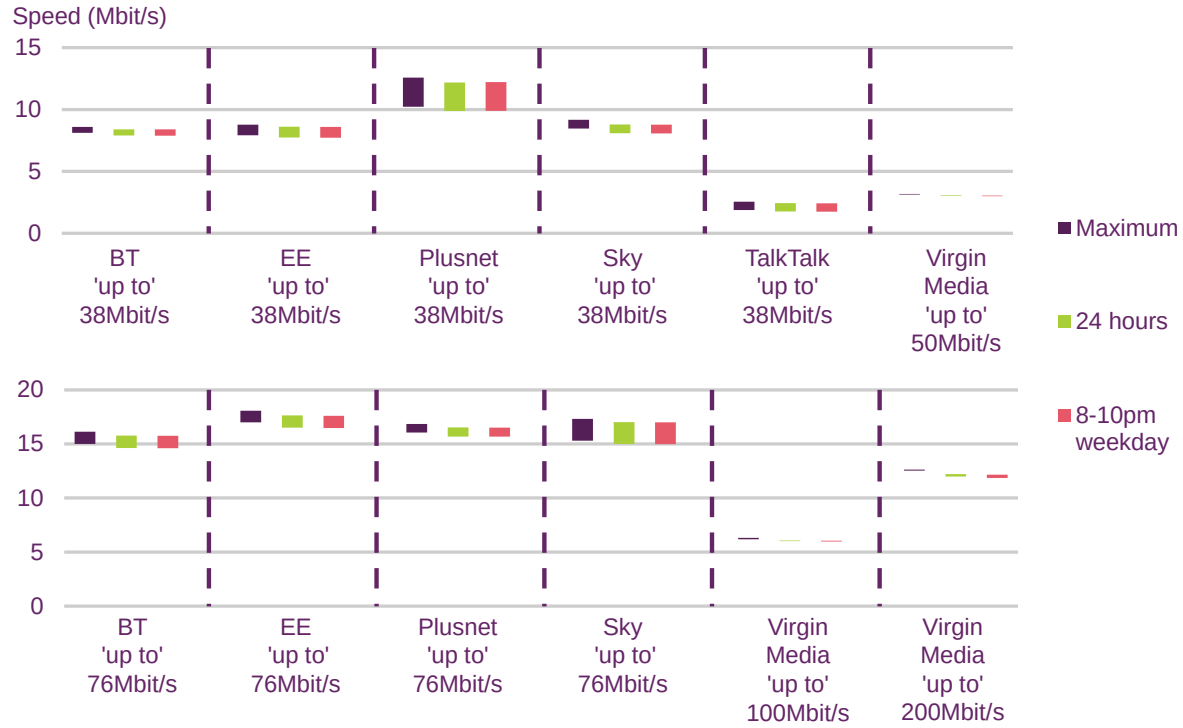
Maximum, average and peak-time upload speeds for ISP packages with a headline download speed of 'up to' 30Mbit/s and above

Among the ISP packages included in this report with a headline download speed of 'up to' 30Mbit/s and above, EE's, Plusnet's, Sky's and BT's 'up to' 76Mbit/s FTTC packages had the fastest upload speeds in terms of maximum, 24-hour average and peak-time upload speeds in November 2015. The average 24-hour upload speeds of these services were

17.1Mbit/s, 16.1Mbit/s,16.0Mbit/s and 15.2Mbit/s respectively, compared to averages ranging from 2.1Mbit/s to 11.0Mbit/s among the 'up to' 38Mbit/s FTTC services shown below.

In November 2015, the 24-hour average upload speed of the three Virgin Media cable broadband services shown below ranged from 3.0Mbit/s for the 'up to' 50Mbit/s service to 12.1Mbit/s for the 'up to' 200Mbit/s service. Average peak-time upload speeds as a proportion of the average maximum upload speeds ranged from 94% (for TalkTalk's 'up to 38Mbit/s FTTC service) to 98% for EE's 'up to' 38Mbit/s FTTC service and BT, Plusnet and Sky's 'up to' 76Mbit/s FTTC services.

Figure 1.33 Maximum, average and peak-time upload speeds for ISP packages 'up to' 30Mbit/s and above: November 2015



Source: SamKnows measurement data for all panel members with a connection in November 2015. Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC (2) Data for FTTC operators has been weighted to the FTTC national max attainable speed profile (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean.

Figure 1.34 summarises the statistically significant differences between the upload performances of ISP packages 'up to' 30Mbit/s and above included in our research in November 2015.

Figure 1.34 Significant differences between maximum, average and peak-time upload speeds for ISP packages 'up to' 30Mbit/s and above: November 2015

	Maximum	24 hours	8-10pm weekday
ISP package	Is faster than...	Is faster than...	Is faster than...
EE 76	Plusnet 76*, BT 76, Virgin Media 200, Plusnet 38, Sky 38, BT 38, EE 38, Virgin Media 100, Virgin Media 50, TalkTalk 38	BT 76, Virgin Media 200, Plusnet 38, Sky 38, EE 38, BT 38, Virgin Media 100, Virgin Media 50, TalkTalk 38	BT 76, Virgin Media 200, Plusnet 38, Sky 38, EE 38, BT 38, Virgin Media 100, Virgin Media 50, TalkTalk 38
Sky 76	Virgin Media 200, Plusnet 38, Sky 38, BT 38, EE 38, Virgin Media 100, Virgin Media 50, TalkTalk 38	Virgin Media 200, Plusnet 38, Sky 38, EE 38, BT 38, Virgin Media 100, Virgin Media 50, TalkTalk 38	Virgin Media 200, Plusnet 38, Sky 38, EE 38, BT 38, Virgin Media 100, Virgin Media 50, TalkTalk 38
Plusnet 76	Virgin Media 200, Plusnet 38, Sky 38, BT 38, EE 38, Virgin Media 100, Virgin Media 50, TalkTalk 38	Virgin Media 200, Plusnet 38, Sky 38, EE 38, BT 38, Virgin Media 100, Virgin Media 50, TalkTalk 38	Virgin Media 200, Plusnet 38, Sky 38, EE 38, BT 38, Virgin Media 100, Virgin Media 50, TalkTalk 38
BT 76	Virgin Media 200, Plusnet 38, Sky 38, BT 38, EE 38, Virgin Media 100, Virgin Media 50, TalkTalk 38	Virgin Media 200, Plusnet 38, Sky 38, EE 38, BT 38, Virgin Media 100, Virgin Media 50, TalkTalk 38	Virgin Media 200, Plusnet 38, Sky 38, EE 38, BT 38, Virgin Media 100, Virgin Media 50, TalkTalk 38
Virgin Media 200	Sky 38, BT 38, EE 38, Virgin Media 100, Virgin Media 50, TalkTalk 38	Sky 38, EE 38, BT 38, Virgin Media 100, Virgin Media 50, TalkTalk 38	Sky 38, EE 38, BT 38, Virgin Media 100, Virgin Media 50, TalkTalk 38
Plusnet 38	Sky 38, BT 38, EE 38, Virgin Media 100, Virgin Media 50, TalkTalk 38	Sky 38, EE 38, BT 38, Virgin Media 100, Virgin Media 50, TalkTalk 38	Sky 38, EE 38, BT 38, Virgin Media 100, Virgin Media 50, TalkTalk 38
Sky 38	Virgin Media 100, Virgin Media 50, TalkTalk 38	Virgin Media 100, Virgin Media 50, TalkTalk 38	Virgin Media 100, Virgin Media 50, TalkTalk 38
BT 38	Virgin Media 100, Virgin Media 50, TalkTalk 38	Virgin Media 100, Virgin Media 50, TalkTalk 38	Virgin Media 100, Virgin Media 50, TalkTalk 38
EE 38	Virgin Media 100, Virgin Media 50, TalkTalk 38	Virgin Media 100, Virgin Media 50, TalkTalk 38	Virgin Media 100, Virgin Media 50, TalkTalk 38
Virgin Media 100	Virgin Media 50, TalkTalk 38	Virgin Media 50, TalkTalk 38	Virgin Media 50, TalkTalk 38
Virgin Media 50	TalkTalk 38	TalkTalk 38	TalkTalk 38

Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence.*

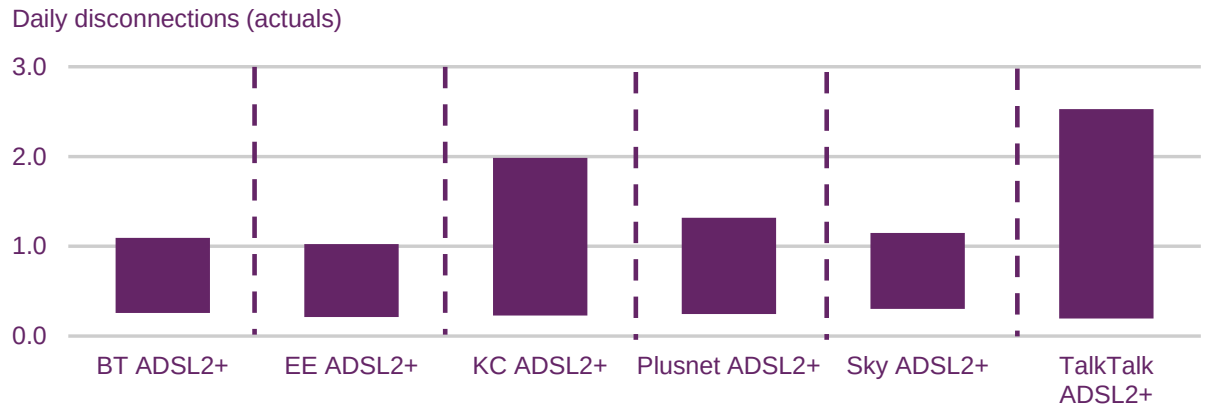
5.9 Average daily disconnections

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.

Daily disconnections for ADSL2+ services

There were no significant differences between the comparator ADSL2+ packages in terms of average actual daily disconnections (Figure 1.35). The average number of actual daily disconnections in November 2015 ranged from 0.6 for EE's ADSL2+ services to 1.4 for TalkTalk's ADSL2+ package.

Figure 1.35 Average daily disconnections (30 seconds or longer) for ADSL2+ ISP packages: November 2015
(Lower values indicate better performance)

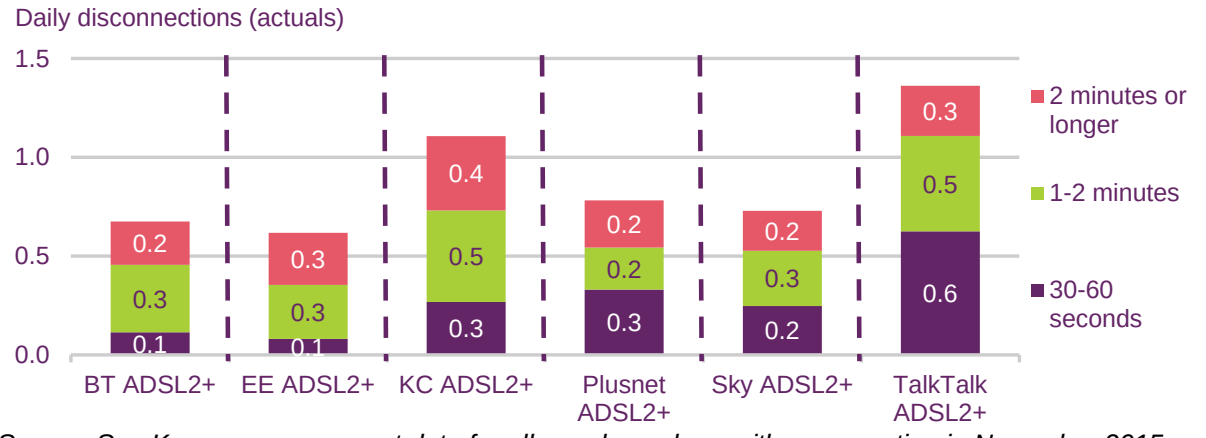


Source: SamKnows measurement data for all panel members with a connection in November 2015.
Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC; (2) Includes on-net customers only for LLU operators (3) Data have been weighted to distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.
(6) Note that better performance is indicated by lower values.

There were no statistically significant differences between the numbers of actual daily disconnections of different ADSL2+ ISP packages included in our research in November 2015.

Figure 1.36 shows the split of disconnections across ADSL2+ packages, by length, in November 2015. KC's ADSL2+ service had the highest number or disconnections of two minutes or longer (0.4 on average per day), while TalkTalk's ADSL2+ package had the highest number of actual disconnections between 30 and 60 seconds in November 2015 (0.6).

Figure 1.36 Split of disconnections longer than 30 seconds, by duration, for ADSL2+ ISP packages: November 2015

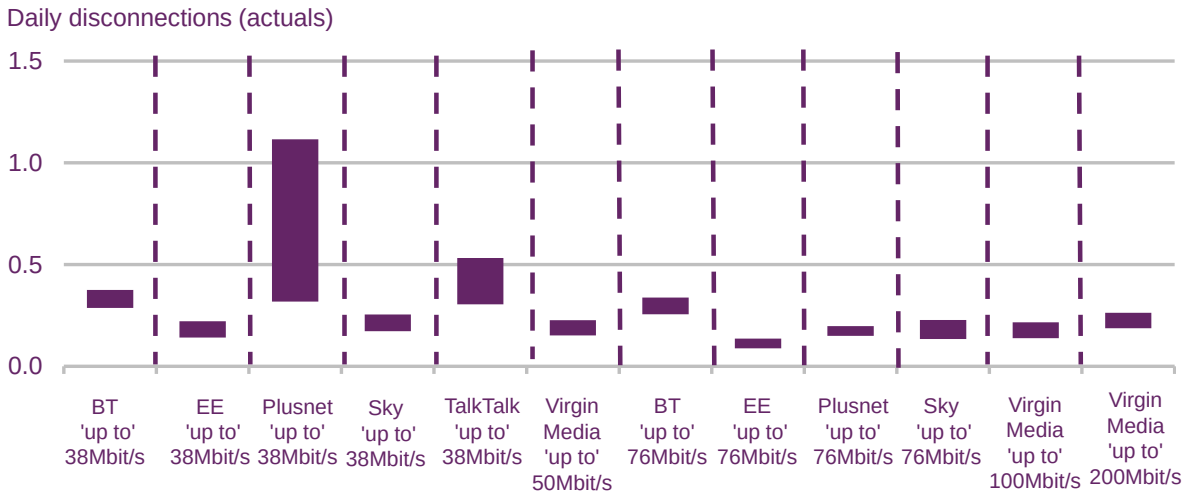


Source: SamKnows measurement data for all panel members with a connection in November 2015.
Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC; (2) Includes on-net customers only for LLU operators (3) Data have been weighted to distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.
(6) Note that better performance is indicated by shorter times (i.e. lower values).

Daily disconnections for ‘up to’ 30Mbit/s connections

Among ‘up to’ 30Mbit/s and above ISP packages, TalkTalk’s ‘up to’ 38Mbit/s packages had more actual daily disconnects than Virgin Media’s ‘up to’ 50Mbit/s, 100Mbit/s and 200Mbit/s packages, Sky, Plusnet and EE's 'up to’ 76Mbit/s packages and EE and Sky’s ‘up to’ 38Mbit/s packages (at the 95% confidence level).

Figure 1.37 Average daily disconnections of 30 seconds or longer for ISP packages ‘up to’ 30Mbit/s and above: November 2015 (Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in November 2015. Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC (2) Data for FTTC operators has been weighted to the FTTC national max attainable speed profile (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean. (5) Note that better performance is indicated by lower values.

Figure 1.38 summarises the statistically significant differences between the numbers of actual daily disconnections of ‘up to’ 30Mbit/s and above packages included in our research in November 2015.

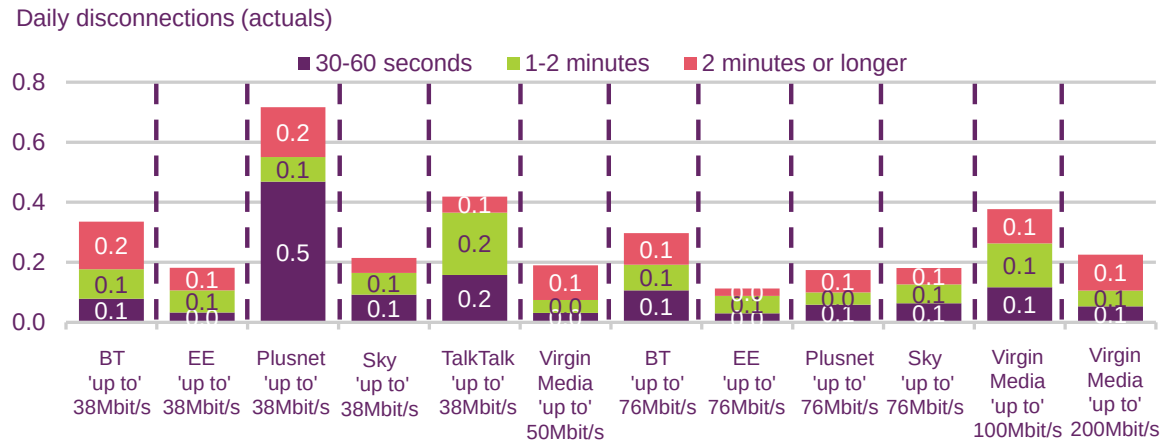
Figure 1.38 Significant differences, at the 95% confidence level, between average actual daily disconnections for ISP packages ‘up to’ 30Mbit/s and above: November 2015

	24 hours
ISP package	**Is better than...**
EE 76	Plusnet 38, TalkTalk 38
Plusnet 76	TalkTalk 38
Sky 76	TalkTalk 38
EE 38	TalkTalk 38
Virgin Media 50	TalkTalk 38
Sky 38	TalkTalk 38*
Virgin Media 200	TalkTalk 38
Virgin Media 100	TalkTalk 38

Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

Figure 1.39 shows the split of disconnections across ‘up to’ 30Mbit/s and above packages, by length, in November 2015. Plusnet’s ‘up to’ 38Mbit/s package had the most disconnections between 30 and 60 seconds in length (an average of 0.5 disconnections per day).

Figure 1.39 Level of disconnections longer than 30 seconds for ISP packages with headline speed ‘up to’ 30Mbit/s or above: November 2015



Source: SamKnows measurement data for all panel members with a connection in November 2015. Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC (2) Data for FTTC operators has been weighted to the FTTC national max attainable speed profile (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean. (5) Note that better performance is indicated by lower values.

Section 6

Other metrics affecting performance

There are a number of other metrics which can be used to evaluate the performance of fixed-line broadband services. The most important of these are outlined below in Figure 2.1. As the technologies and providers which deliver the highest download speeds do not necessarily deliver the best performance on other metrics, it is important that consumers also consider other sets of performance measurements to understand the overall performance of individual ISP packages. In this section we compare the performance of different ISP packages with respect to these metrics.

Figure 2.1 Summary of additional metrics covered in the research

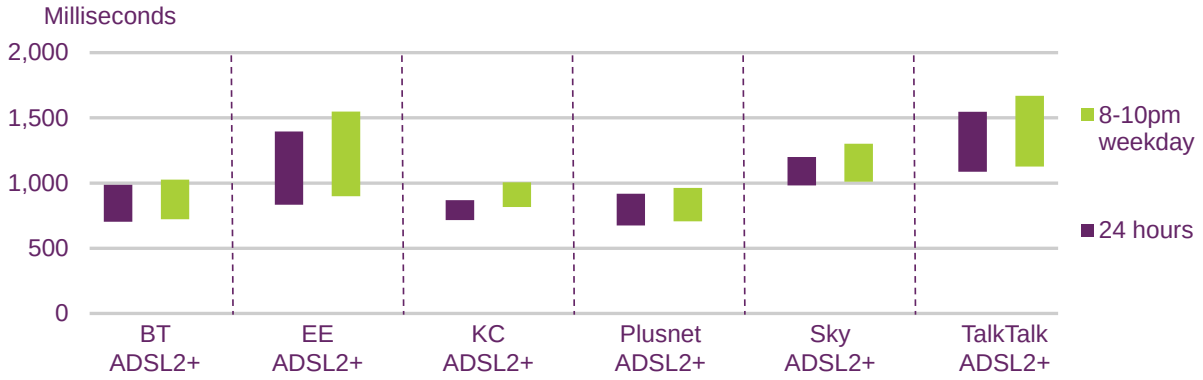
Variable	Definition and importance
Web browsing speed	**The time taken to fetch the main HTML and assets (text, basic code and content files) from a webpage** *Dependent on download speeds, latency and DNS resolution times*
Latency	**The time it takes a packet of data to travel to a third-party server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

Source: Ofcom

Web browsing

In order 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. Note that in Figure 2.2 and Figure 2.4 better performance is shown by lower bars.

Figure 2.2 Average and peak-time loading of web pages for ADSL2+ ISP packages: November 2015
(Lower values indicate better performance)



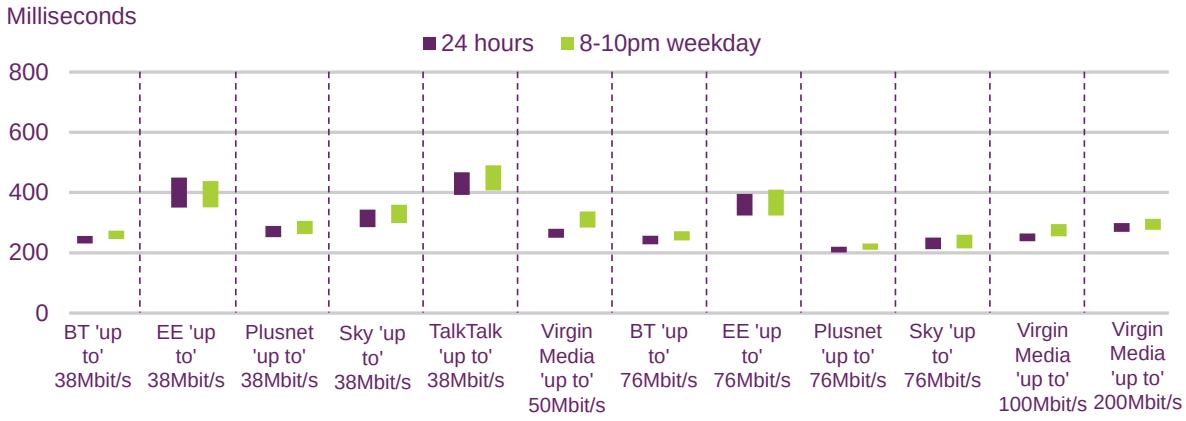
Source: SamKnows measurement data for all panel members with a connection in November 2015.
Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC; (2) Includes on-net customers only for LLU operators (3) Data have been weighted to distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.
(6) Note that better performance is indicated by shorter times (i.e. lower values).

Figure 2.3 Significant differences, at the 95% confidence level, between average and peak-time loading of web pages for ADSL2+ ISP packages: November 2015

	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**
KC ADSL2+	Sky ADSL2+, TalkTalk ADSL2+	Sky ADSL2+*, TalkTalk ADSL2+
Plusnet ADSL2+	Sky ADSL2+*, TalkTalk ADSL2+	Sky ADSL2+*, TalkTalk ADSL2+
BT ADSL2+	TalkTalk ADSL2+*	TalkTalk ADSL2+*
Sky ADSL2+	No differences	No differences
EE ADSL2+	No differences	No differences
TalkTalk ADSL2+	No differences	No differences

Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

Figure 2.4 Average and peak-time loading of web pages for ISP packages 'up to' 30Mbit/s and above: November 2015
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in November 2015.
Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC (2) Data for FTTC operators has been weighted to the FTTC national max attainable speed profile (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean. (5) Note that better performance is indicated by lower values.

Figure 2.5 Significant differences, at the 95% confidence level, between average and peak-time loading of web pages for ISP packages 'up to' 30Mbit/s and above: November 2015

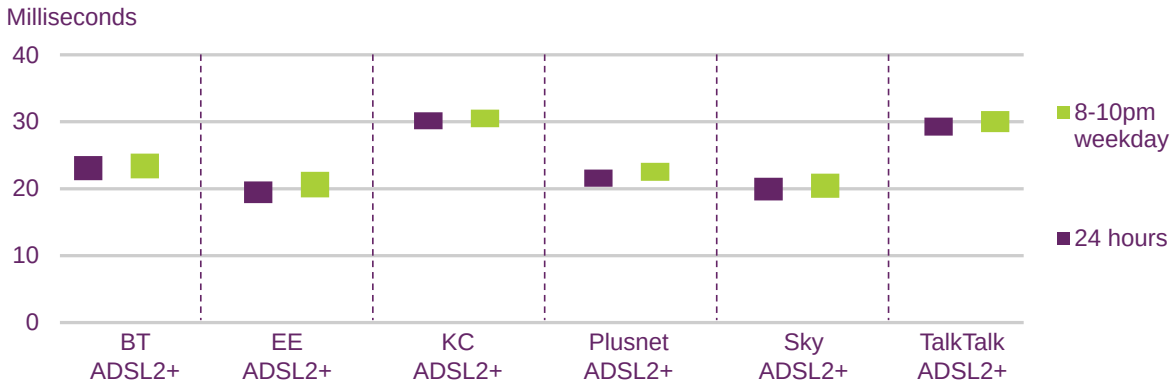
	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**
Plusnet 76	BT 76*, BT 38*, Virgin Media 100, Virgin Media 50, Plusnet 38, Virgin Media 200, Sky 38, EE 76, EE 38, TalkTalk 38	BT 76, BT 38, Plusnet 38, Virgin Media 100, Virgin Media 200, Virgin Media 50, Sky 38, EE 76, EE 38, TalkTalk 38
Sky 76	Plusnet 38*, Virgin Media 200, Sky 38, EE 76, EE 38, TalkTalk 38	Virgin Media 200, Virgin Media 50, Sky 38, EE 76, EE 38, TalkTalk 38
BT 76	Virgin Media 200, Sky 38, EE 76, EE 38, TalkTalk 38	Virgin Media 50*, Sky 38, EE 76, EE 38, TalkTalk 38
BT 38	Virgin Media 200, Sky 38, EE 76, EE 38, TalkTalk 38	Virgin Media 50*, Sky 38, EE 76, EE 38, TalkTalk 38
Virgin Media 100	Virgin Media 200*, Sky 38, EE 76, EE 38, TalkTalk 38	Sky 38*, EE 76, EE 38, TalkTalk 38
Virgin Media 50	Sky 38*, EE 76, EE 38, TalkTalk 38	EE 38*, TalkTalk 38
Plusnet 38	EE 76, EE 38, TalkTalk 38	EE 76*, EE 38, TalkTalk 38
Virgin Media 200	EE 76, EE 38, TalkTalk 38	EE 76*, EE 38, TalkTalk 38
Sky 38	EE 38*, TalkTalk 38	TalkTalk 38
EE 76	No differences	No differences
EE 38	No differences	No differences
TalkTalk 38	No differences	No differences

Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

Latency

Latency is the time that it takes for a single packet of data to travel from a user's PC 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. In Figure 2.6 and Figure 2.8 lower bars indicate better performance.

Figure 2.6 Average and peak-time latency for ADSL2+ ISP packages: November 2015
(Lower values indicate better performance)



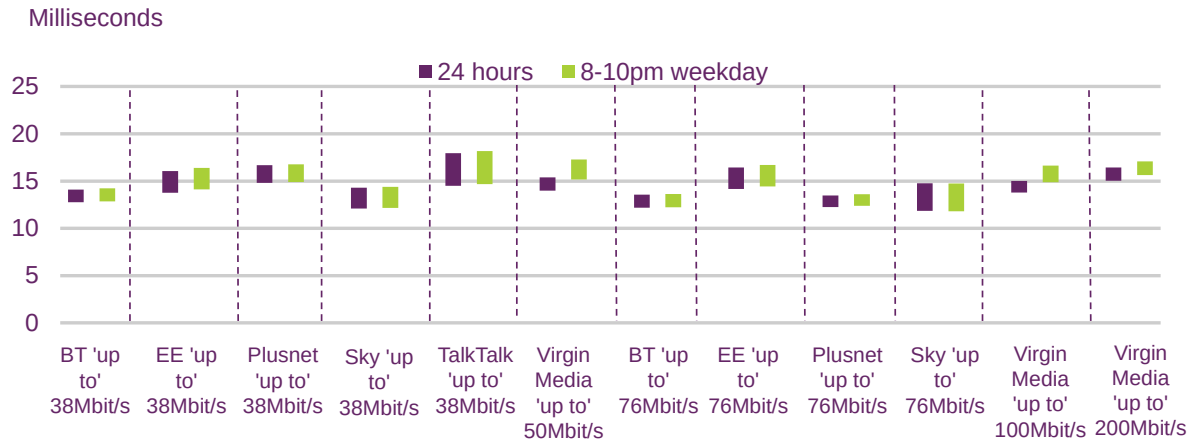
Source: SamKnows measurement data for all panel members with a connection in November 2015.
Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC; (2) Includes on-net customers only for LLU operators (3) Data have been weighted to distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.
(6) Note that better performance is indicated by shorter times (i.e. lower values).

Figure 2.7 Significant differences, at the 95% confidence level, between average and peak-time latency for ADSL2+ ISP packages: November 2015

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
EE ADSL2+	BT ADSL2+*, TalkTalk ADSL2+, KC ADSL2+	TalkTalk ADSL2+, KC ADSL2+
Sky ADSL2+	TalkTalk ADSL2+, KC ADSL2+	TalkTalk ADSL2+, KC ADSL2+
Plusnet ADSL2+	TalkTalk ADSL2+, KC ADSL2+	TalkTalk ADSL2+, KC ADSL2+
BT ADSL2+	TalkTalk ADSL2+, KC ADSL2+	TalkTalk ADSL2+, KC ADSL2+

Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

Figure 2.8 Average and peak-time latency for ISP packages 'up to' 30Mbit/s and above: November 2015
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in November 2015.
Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC (2) Data for FTTC operators has been weighted to the FTTC national max attainable speed profile (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean. (5) Note that better performance is indicated by lower values.

Figure 2.9 Significant differences, at the 95% confidence level, between average and peak-time latency for ISP packages 'up to' 30Mbit/s and above: November 2015

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
Plusnet 76	Virgin Media 100*, EE 38*, Virgin Media 50, EE 76, TalkTalk 38, Plusnet 38, Virgin Media 200	EE 38*, EE 76, Virgin Media 100, Plusnet 38, Virgin Media 50, Virgin Media 200, TalkTalk 38
BT 76	Virgin Media 100*, EE 38*, Virgin Media 50*, EE 76*, TalkTalk 38*, Plusnet 38, Virgin Media 200	EE 38*, EE 76, Virgin Media 100, Plusnet 38, Virgin Media 50, Virgin Media 200, TalkTalk 38
Sky 38	TalkTalk 38*, Plusnet 38*, Virgin Media 200	EE 76*, Virgin Media 100*, Plusnet 38*, Virgin Media 50*, Virgin Media 200, TalkTalk 38*
Sky 76	Plusnet 38*, Virgin Media 200	Virgin Media 100*, Plusnet 38*, Virgin Media 50*, Virgin Media 200
BT 38	TalkTalk 38*, Plusnet 38*, Virgin Media 200	EE 76*, Virgin Media 100, Plusnet 38, Virgin Media 50, Virgin Media 200, TalkTalk 38*
Virgin Media 100	Virgin Media 200*	No difference

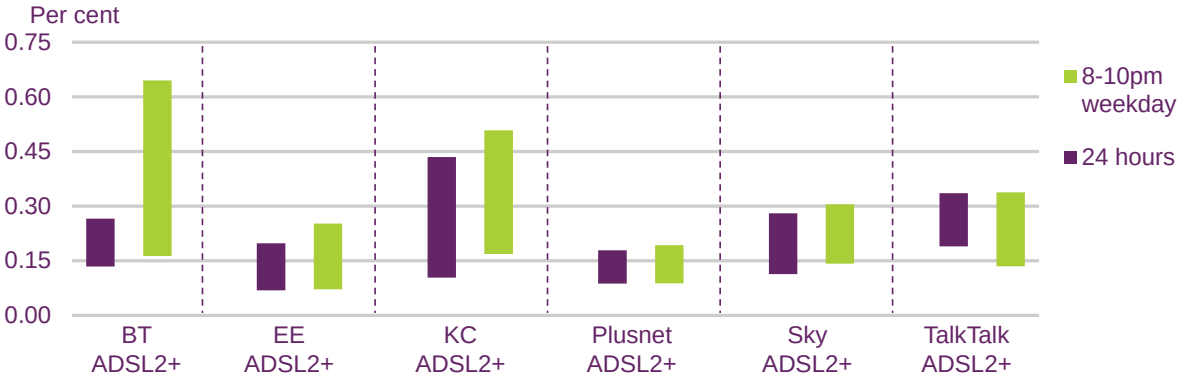
Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

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). Note that in Figure 2.10 and Figure 2.12 better performance equates to lower packet loss, which is indicated by lower bars.

Figure 2.10 Average and peak-time packet loss for ADSL2+ ISP packages: November 2015
(Lower values indicate better performance)



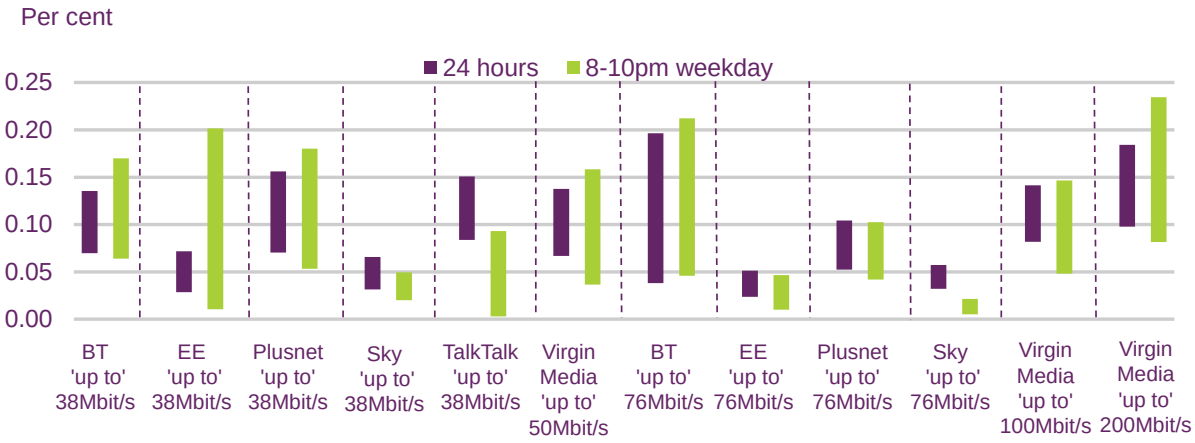
Source: SamKnows measurement data for all panel members with a connection in November 2015.
Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC; (2) Includes on-net customers only for LLU operators (3) Data have been weighted to distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.
(6) Note that better performance is indicated by lower values.

Figure 2.11 Significant differences, at the 95% confidence level, between average and peak-time packet loss for ADSL2+ ISP packages: November 2015

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
Plusnet ADSL2+	TalkTalk ADSL2+	No difference

Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

Figure 2.12 Average and peak-time packet loss for ISP packages 'up to' 30Mbit/s and above: November 2015
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in November 2015.
Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC (2) Data for FTTC operators has been weighted to the FTTC national max attainable speed profile (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean. (5) Note that better performance is indicated by lower values.

Figure 2.13 Significant differences, at the 95% confidence level, between average and peak-time packet loss for ISP packages 'up to' 30Mbit/s and above: November 2015

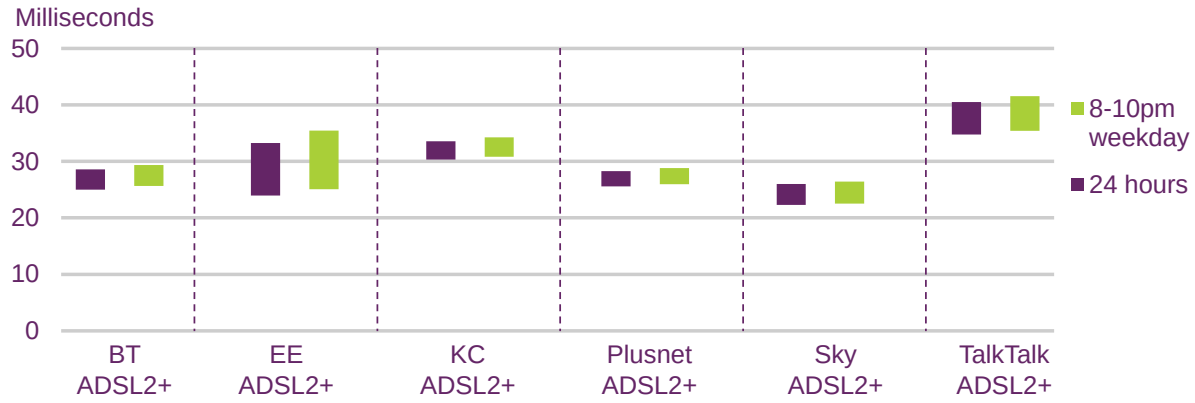
	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
EE 38	TalkTalk 38*, Virgin Media 100*, Virgin Media 200*	No differences
Sky 76	Plusnet 38*, BT 38*, Virgin Media 50*, TalkTalk 38, Virgin Media 100, Virgin Media 200	Sky 38*, Virgin Media 50*, Plusnet 76, BT 76*, Virgin Media 100, BT 38, Plusnet 38, Virgin Media 200
Sky 38	Plusnet 38*, BT 38*, Virgin Media 50*, TalkTalk 38, Virgin Media 100, Virgin Media 200	BT 38*, Plusnet 38*, Virgin Media 200
EE 76	No differences	BT 76*, Virgin Media 100*, BT 38*, Plusnet 38*, Virgin Media 200

Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

DNS resolution

DNS (the domain name service) plays a crucial part in the way the internet operates. This protocol translates domain names (such as ofcom.org.uk) into the IP addresses that are used to route traffic (e.g. 194.33.179.25) Every ISP maintains its own DNS servers through which customers computers issue queries to translate names into IP addresses. When these services fail or operate slowly, web browsing and other online activities suffer. A slow DNS does not affect download speed, but can severely affect the responsiveness of the internet while browsing. Note that in Figure 2.14 and Figure 2.16 better performance equates to faster resolution times, which are indicated by lower bars.

Figure 2.14 Average and peak-time DNS resolution time for ADSL2+ ISP packages: November 2015
(Lower values indicate better performance)



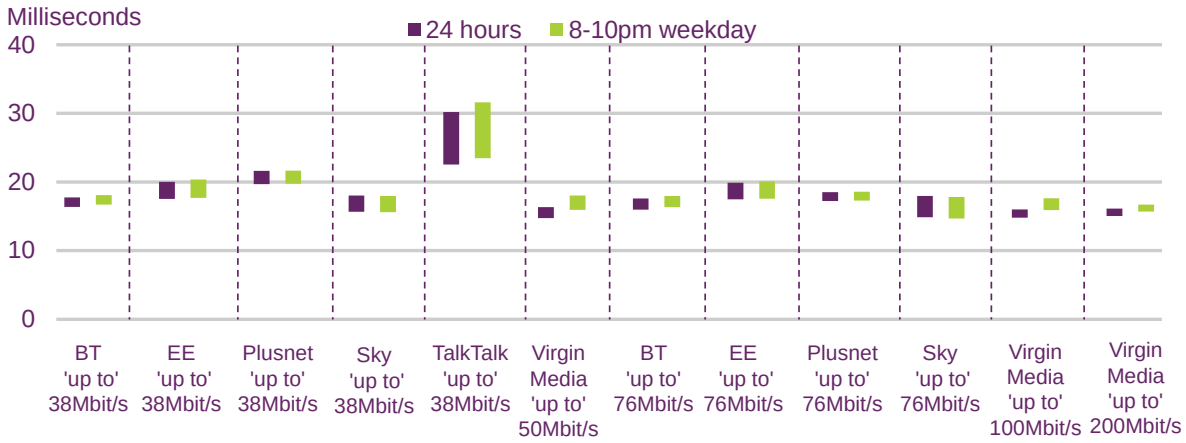
Source: SamKnows measurement data for all panel members with a connection in November 2015.
Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC; (2) Includes on-net customers only for LLU operators (3) Data have been weighted to distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.
(6) Note that better performance is indicated by lower values.

Figure 2.15 Significant differences, at the 95% confidence level, between average and peak-time DNS resolution time for ADSL2+ ISP packages: November 2015

	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**
BT ADSL2+	KC ADSL2+, TalkTalk ADSL2+	KC ADSL2+, TalkTalk ADSL2+
Plusnet ADSL2+	KC ADSL2+, TalkTalk ADSL2+	KC ADSL2+, TalkTalk ADSL2+
KC ADSL2+	TalkTalk ADSL2+*	TalkTalk ADSL2+*
Sky ADSL2+	KC ADSL2+, TalkTalk ADSL2+	KC ADSL2+, TalkTalk ADSL2+
EE ADSL2+	TalkTalk ADSL2+*	TalkTalk ADSL2+*

Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

Figure 2.16 Average and peak-time DNS resolution time for ISP packages 'up to' 30Mbit/s and above: November 2015
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in November 2015.
Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC (2) Data for FTTC operators has been weighted to the FTTC national max attainable speed profile (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean. (5) Note that better performance is indicated by lower values.

Figure 2.17 Significant differences, at the 95% confidence level, between average and peak-time DNS resolution time for ISP packages 'up to' 30Mbit/s and above: November 2015

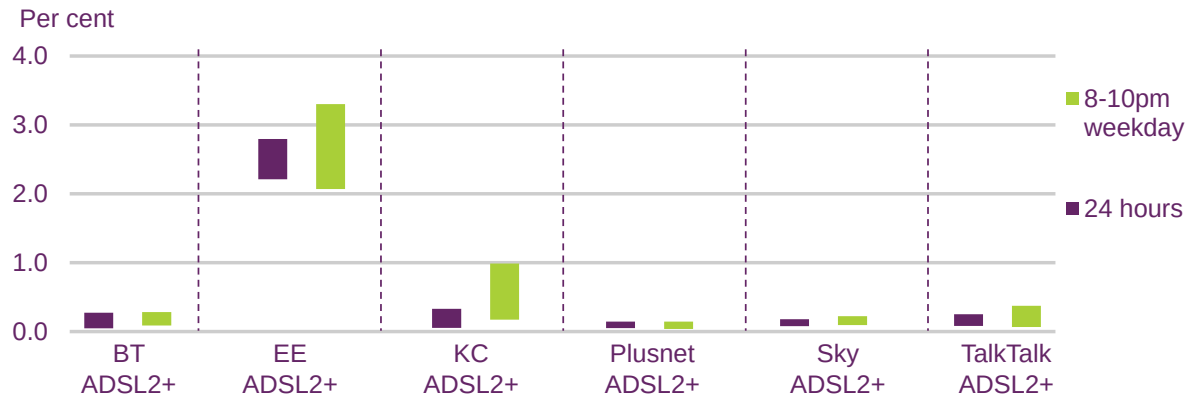
	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**
Virgin Media 100	BT 38*, Plusnet 76, EE 76, EE 38, Plusnet 38, TalkTalk 38	Plusnet 38, TalkTalk 38
Virgin Media 50	BT 38*, Plusnet 76, EE 76, EE 38, Plusnet 38, TalkTalk 38	Plusnet 38, TalkTalk 38
Virgin Media 200	BT 38*, Plusnet 76, EE 76, EE 38, Plusnet 38, TalkTalk 38	BT 38*, Plusnet 76, EE 76, EE 38, Plusnet 38, TalkTalk 38
Sky 76	Plusnet 38, TalkTalk 38	Plusnet 38, TalkTalk 38
Sky 38	Plusnet 38, TalkTalk 38	Plusnet 38, TalkTalk 38
BT 76	Plusnet 38, TalkTalk 38	Plusnet 38, TalkTalk 38
BT 38	Plusnet 38, TalkTalk 38	Plusnet 38, TalkTalk 38
Plusnet 76	Plusnet 38, TalkTalk 38	Plusnet 38, TalkTalk 38
EE 76	TalkTalk 38	TalkTalk 38
EE 38	TalkTalk 38*	TalkTalk 38
Plusnet 38	TalkTalk 38*	TalkTalk 38

Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 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. Note that in Figure 2.18 and Figure 2.20 better performance equates to short times, which are indicated by lower bars.

Figure 2.18 Average and peak-time DNS failure rates for ADSL2+ ISP packages: November 2015
(Lower values indicate better performance)



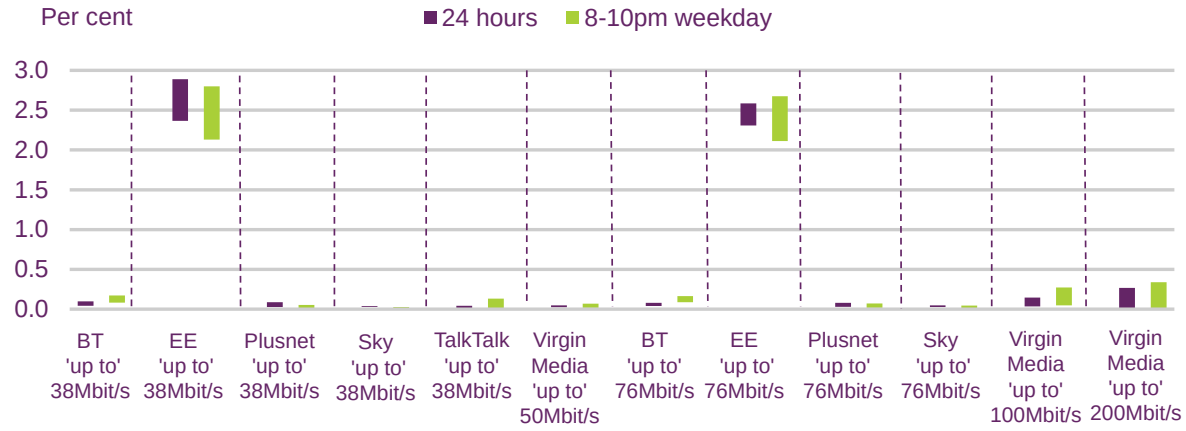
Source: SamKnows measurement data for all panel members with a connection in November 2015.
Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC; (2) Includes on-net customers only for LLU operators (3) Data have been weighted to distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.
(6) Note that better performance is indicated by lower values.

Figure 2.19 Significant differences, at the 95% confidence level, between average and peak-time DNS failure rates for ADSL2+ ISP packages: November 2015

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
Plusnet ADSL2+	EE ADSL2+	KC ADSL2+*, EE ADSL2+
Sky ADSL2+	EE ADSL2+	EE ADSL2+
BT ADSL2+	EE ADSL2+	EE ADSL2+
TalkTalk ADSL2+	EE ADSL2+	EE ADSL2+
KC ADSL2+	EE ADSL2+	EE ADSL2+

Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

Figure 2.20 Average and peak-time DNS failure rates for ISP packages 'up to' 30Mbit/s and above: November 2015
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in November 2015.
Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC (2) Data for FTTC operators has been weighted to the FTTC national max attainable speed profile (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean. (5) Note that better performance is indicated by lower values.

Figure 2.21 Significant differences, at the 95% confidence level, between average and peak-time DNS failure rates for ISP packages 'up to' 30Mbit/s and above: November 2015

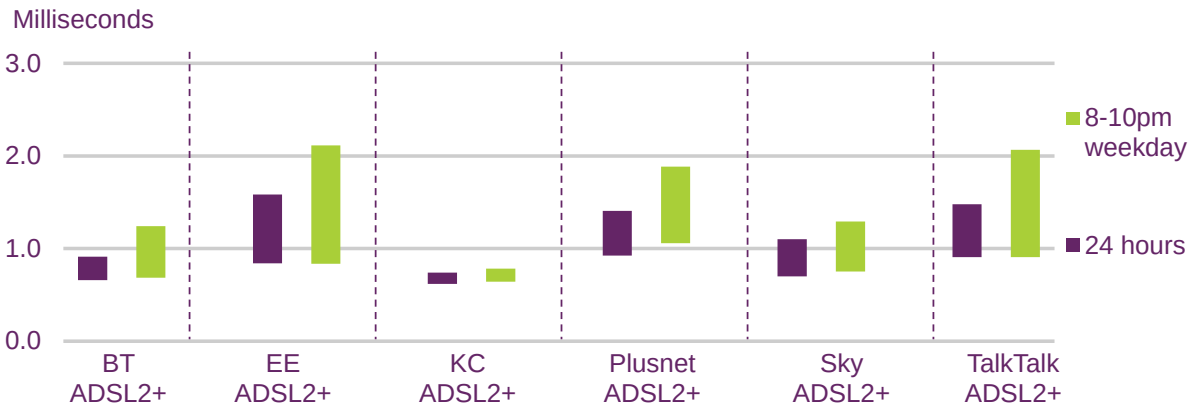
	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
TalkTalk 38	BT 38*, EE 76, EE 38	EE 76, EE 38
Sky 38	EE 76, EE 38	Virgin Media 100*, BT 38, BT 76, EE 76, EE 38
Sky 76	EE 76, EE 38	Virgin Media 100*, BT 38, BT 76, EE 76, EE 38
Virgin Media 50	EE 76, EE 38	EE 76, EE 38
Plusnet 76	EE 76, EE 38	EE 76, EE 38
Plusnet 38	EE 76, EE 38	BT 38, BT 76, EE 76, EE 38
BT 76	EE 76, EE 38	EE 76, EE 38
BT 38	EE 76, EE 38	EE 76, EE 38
Virgin Media 100	EE 76, EE 38	EE 76, EE 38
Virgin Media 200	EE 76, EE 38	EE 76, EE 38

Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

Jitter

'Jitter' is defined 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. Note that in Figure 2.22, Figure 2.24, Figure 2.26 and Figure 2.28 better performance equates to shorter times, which are indicated by lower bars.

Figure 2.22 Average and peak-time upstream jitter for ADSL2+ ISP packages: November 2015
(Lower values indicate better performance)



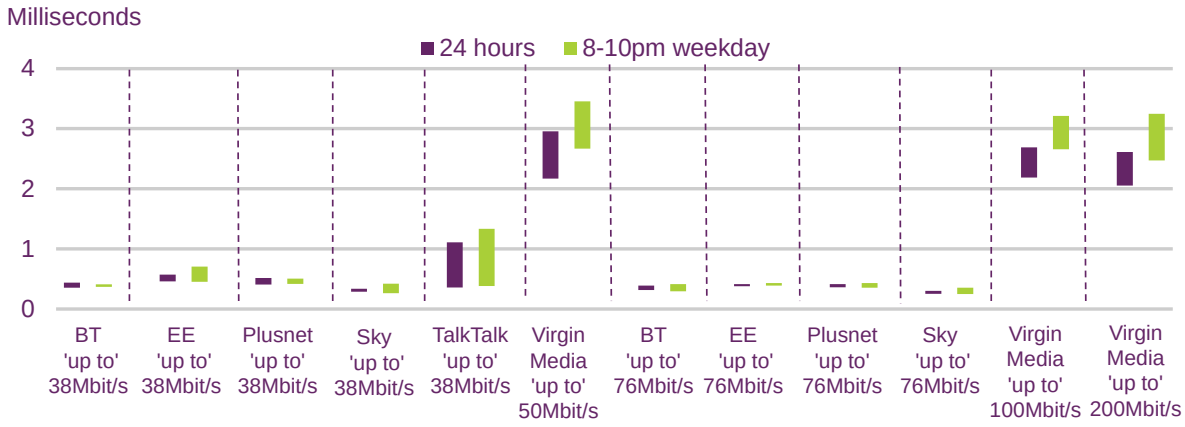
Source: SamKnows measurement data for all panel members with a connection in November 2015.
Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC; (2) Includes on-net customers only for LLU operators (3) Data have been weighted to distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.
(6) Note that better performance is indicated by lower values.

Figure 2.23 Significant differences, at the 95% confidence level, between average and peak-time upstream jitter for ADSL2+ ISP packages: November 2015

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
KC ADSL2+	TalkTalk ADSL2+, EE ADSL2+*, Plusnet ADSL2+	TalkTalk ADSL2+*, Plusnet ADSL2+
BT ADSL2+	Plusnet ADSL2+	No differences
Sky ADSL2+	No differences	No differences
Plusnet ADSL2+	No differences	No differences
TalkTalk ADSL2+	No differences	No differences
EE ADSL2+	No differences	No differences

Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

Figure 2.24 Average and peak-time upstream jitter for ISP packages 'up to 30Mbit/s and above: November 2015
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in November 2015. Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC (2) Data for FTTC operators has been weighted to the FTTC national max attainable speed profile (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean. (5) Note that better performance is indicated by lower values.

Figure 2.25 Significant differences, at the 95% confidence level, between average and peak-time upstream jitter for ISP packages 'up to' 30Mbit/s and above: November 2015

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
Sky 76	BT 76*, TT 38*, BT 38, Plusnet 76, Plusnet 38, EE 38, Virgin Media 200, Virgin Media 100, Virgin Media 50	BT 38*, EE 76, TT 38*, Plusnet 38, EE 38, Virgin Media 200, Virgin Media 100, Virgin Media 50
Sky 38	TT 38*, BT 38*, Plusnet 76, Plusnet 38, EE 38, Virgin Media 200, Virgin Media 100, Virgin Media 50	EE 38*, Virgin Media 200, Virgin Media 100, Virgin Media 50
BT 76	Plusnet 38*, EE 38, Virgin Media 200, Virgin Media 100, Virgin Media 50	Plusnet 38*, EE 38*, Virgin Media 200, Virgin Media 100, Virgin Media 50
Plusnet 76	EE 38, Virgin Media 200, Virgin Media 100, Virgin Media 50	EE 38*, Virgin Media 200, Virgin Media 100, Virgin Media 50
EE 76	Virgin Media 200, Virgin Media 100, Virgin Media 50	Virgin Media 200, Virgin Media 100, Virgin Media 50
BT 38	Virgin Media 200, Virgin Media 100, Virgin Media 50	Plusnet 38*, EE 38*, Virgin Media 200, Virgin Media 100, Virgin Media 50
Plusnet 38	Virgin Media 200, Virgin Media 100, Virgin Media 50	Virgin Media 200, Virgin Media 100, Virgin Media 50
EE 38	Virgin Media 200, Virgin Media 100, Virgin Media 50	Virgin Media 200, Virgin Media 100, Virgin Media 50
TalkTalk 38	Virgin Media 200, Virgin Media 100, Virgin Media 50	Virgin Media 200, Virgin Media 100, Virgin Media 50

Source: Ofcom

*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

Figure 2.26 Average and peak-time downstream jitter for ADSL2+ ISP packages: November 2015
(Lower values indicate better performance)

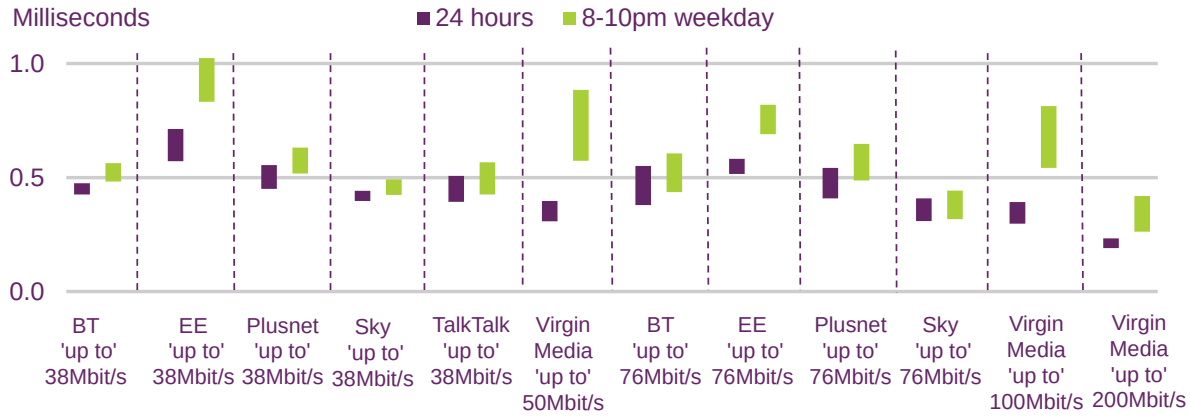
Source: SamKnows measurement data for all panel members with a connection in November 2015.
Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC; (2) Includes on-net customers only for LLU operators (3) Data have been weighted to distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.
(6) Note that better performance is indicated by lower values.

Figure 2.27 Significant differences, at the 95% confidence level, between average and peak-time downstream jitter for ADSL2+ packages: November 2015

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
KC ADSL2+	Plusnet ADSL2+*, Sky ADSL2+*, TalkTalk ADSL2+*, EE ADSL2+	TalkTalk ADSL2+*, Sky ADSL2+*, Plusnet ADSL2+, EE ADSL2+
BT ADSL2+	EE ADSL2+	EE ADSL2+

Source: Ofcom
*Notes: No other differences were statistically significant; * difference not significant to a 99% level of confidence*

Figure 2.28 Average and peak-time downstream jitter for ISP packages 'up to' 30Mbit/s and above: November 2015
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in November 2015.
Notes: (1) Includes only customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC (2) Data for FTTC operators has been weighted to the FTTC national max attainable speed profile (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean. (5) Note that better performance is indicated by lower values.

Figure 2.29 Significant differences, at the 95% confidence level, between average and peak-time downstream jitter for ISP packages 'up to' 30Mbit/s and above: November 2015

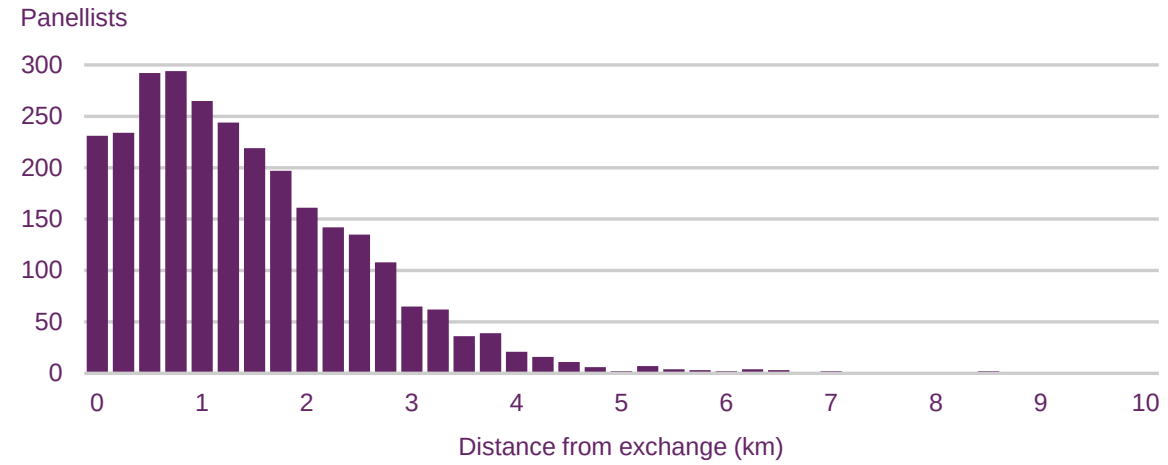
	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
Virgin Media 200	Virgin Media 100, Virgin Media 50, Sky 76, BT 76, TalkTalk 38, Sky 38, BT 38, Plusnet 76, Plusnet 38, EE 76, EE 38	Sky 38*, TT 38*, BT 76*, BT 38, Plusnet 76, Plusnet 38, Virgin Media 100, Virgin Media 50, EE 76, EE 38
Virgin Media 100	TalkTalk 38*, Sky 38*, BT 38, Plusnet 76*, Plusnet 38, EE 76, EE 38	EE 38
Virgin Media 50	Sky 38*, BT 38, Plusnet 76*, Plusnet 38, EE 76, EE 38	No differences
Sky 76	BT 38*, Plusnet 76*, Plusnet 38, EE 76, EE 38	BT 38, Plusnet 76, Plusnet 38*, Virgin Media 100, Virgin Media 50, EE 76, EE 38
Sky 38	Plusnet 38*, EE 76, EE 38	Plusnet 38*, Virgin Media 100, Virgin Media 50, EE 76, EE 38
BT 76	EE 76, EE 38	EE 76, EE 38
TalkTalk 38	EE 76*, EE 38	Virgin Media 50*, EE 76, EE 38
BT 38	EE 76, EE 38	Virgin Media 50*, EE 76, EE 38
Plusnet 76	EE 38*	EE 76*, EE 38
Plusnet 38	EE 38*	EE 76, EE 38

Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

Annex 1

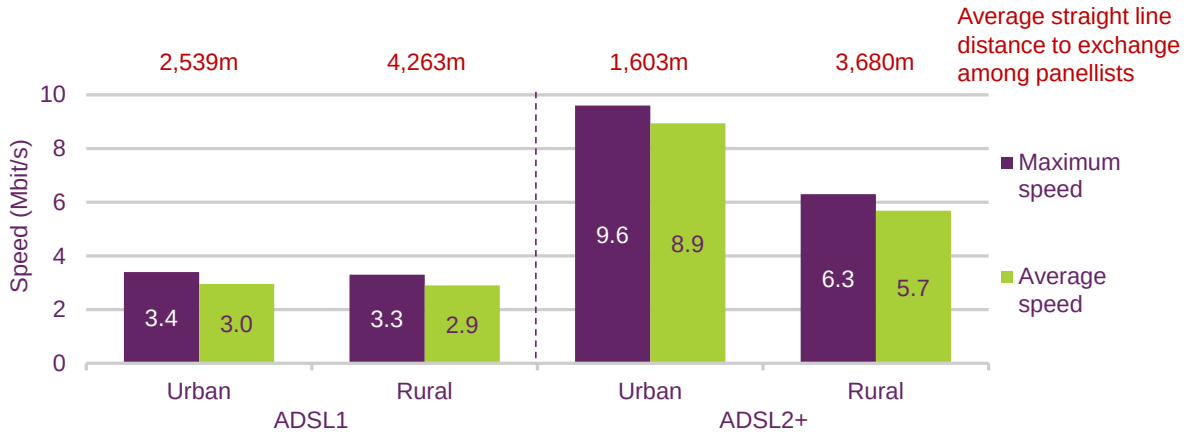
Additional analysis

Figure 3.1 Distribution of panellists, by distance from exchange



Source: Ofcom, using data supplied by SamKnows

Figure 3.2 Average and maximum download speeds for ADSL broadband connections in rural and urban areas: November 2015

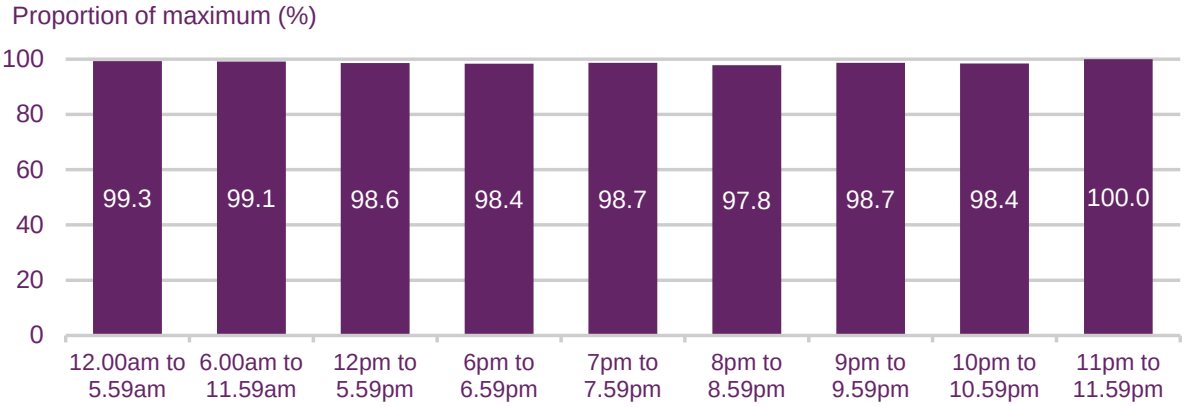


Source: SamKnows measurement data for all panel members with a connection in November 2015, Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, FTTC max attainable speed and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests

Figure 3.3 Average and maximum download speeds, by geographic market: November 2015

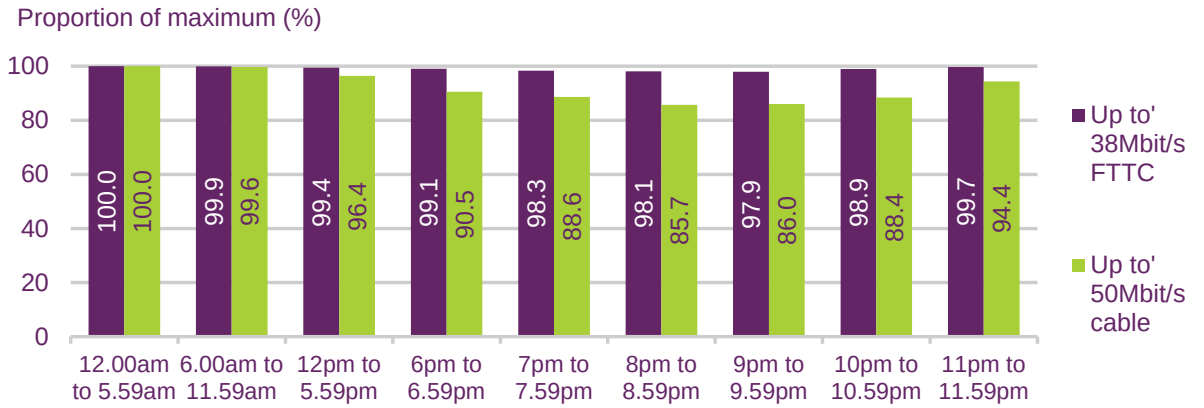
Source: SamKnows measurement data for all panel members with a connection in November 2015. Panel base: 1181
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in November 2015 and an estimated split between rural and urban areas; (3) Data collected from multi-thread download speed tests.

Figure 3.4 Average download speed as a proportion of maximum speed by time of day for ADSL2+ ISP packages: November 2015



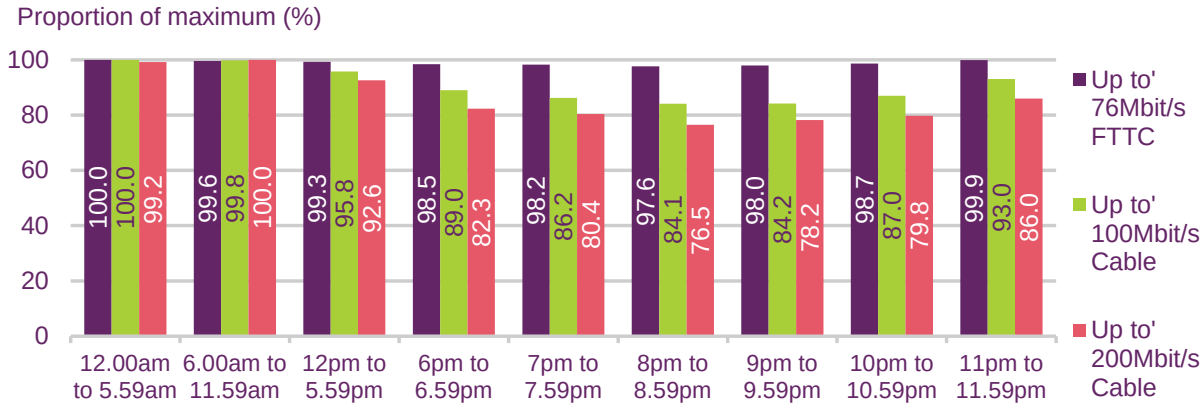
Source: SamKnows measurement data for all panel members with a connection in November 2015.
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK ADSL2+ residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 3.5 Average download speed as a proportion of maximum speed, by time of day for 'up to' 38Mbit/s and 'up to 50Mbit/s ISP packages: November 2015



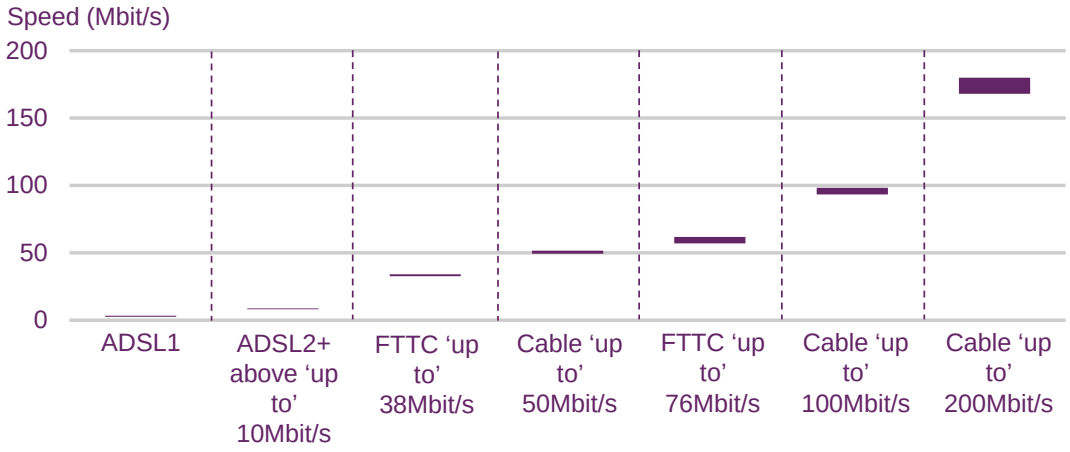
Source: SamKnows measurement data for all panel members with a connection in November 2015. Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK 'up to' 30Mbit/s cable and 'up to' 38Mbit/s FTTC residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 3.6 Average download speeds as a proportion of maximum speed, by time of day, for 'up to' 76Mbit/s, 'up to' 100Mbit/s and 'up to' 152Mbit/s ISP packages: November 2015



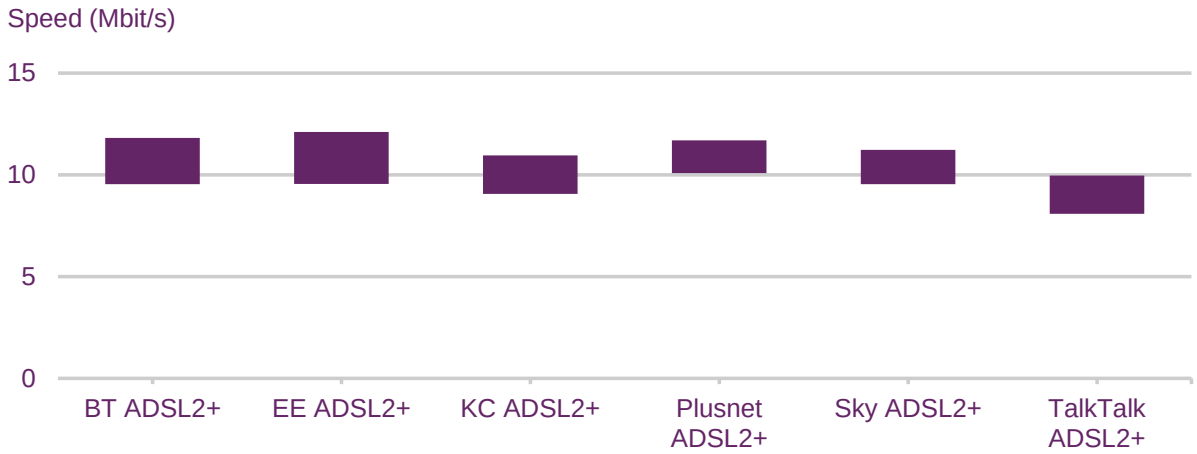
Source: SamKnows measurement data for all panel members with a connection in November 2015. Notes: (1) Data have been weighted by ISP package, rural/urban and geographic market classification to ensure that they are representative of UK 'up to' 60Mbit/s cable, 'up to' 76Mbit/s FTTC and 'up to' 100Mbit/s cable residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 3.7 Average download speeds, by technology and headline speed: November 2015



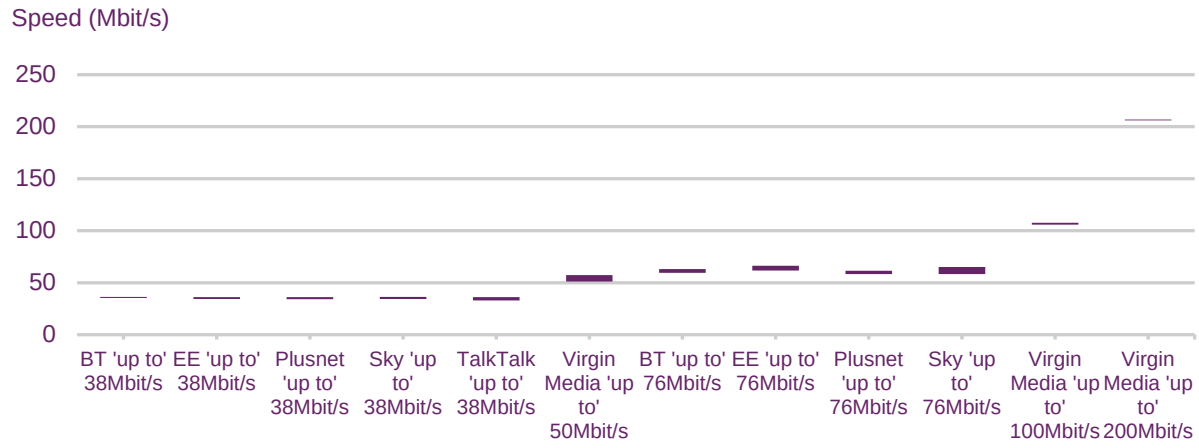
Source: SamKnows measurement data for all panel members with a connection in November 2015. Panel base: 1181
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in November 2014; (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean.

Figure 3.8 Maximum download speeds for ADSL2+ ISP packages: November 2015



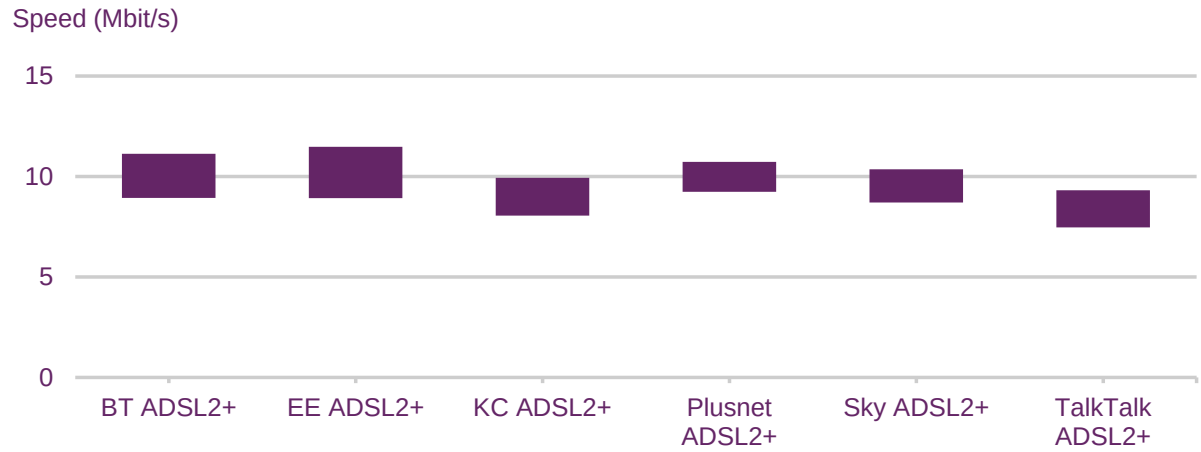
Source: SamKnows measurement data for all panel members with a connection in November 2015.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in geographic markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 3.9 Maximum download speeds for ISP packages 'up to' 30Mbit/s and above: November 2015



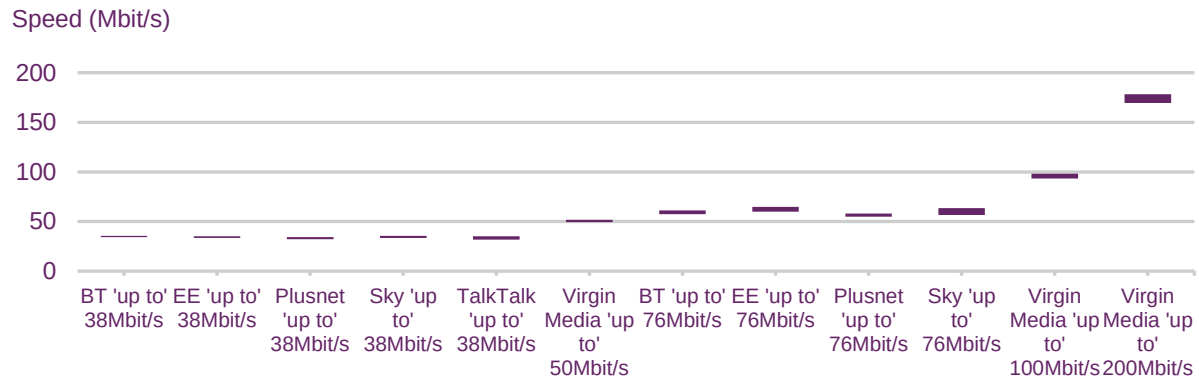
Source: SamKnows measurement data for all panel members with a connection in November 2015. Notes: (1) Includes only ADSL customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 3.10 Average download speeds for ADSL2+ ISP packages, 24 hours: November 2015



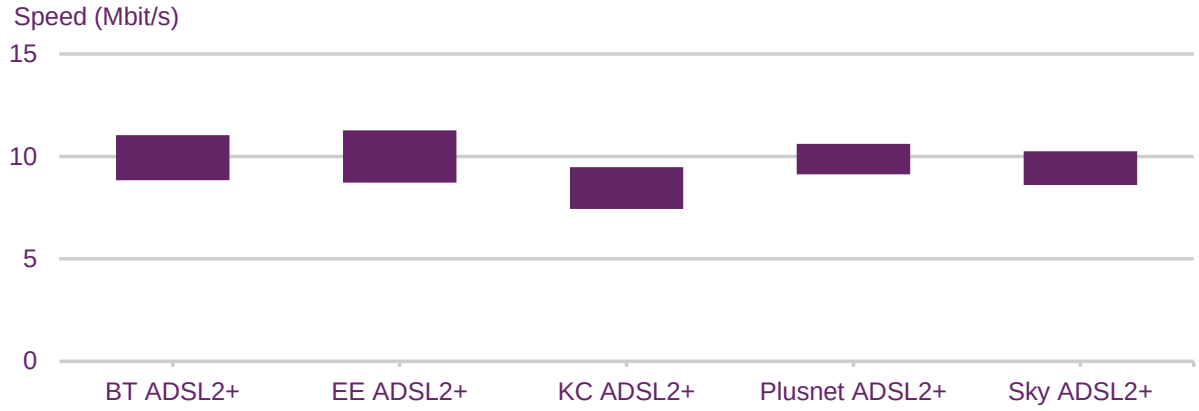
Source: SamKnows measurement data for all panel members with a connection in November 2015 Notes: (1) Includes only ADSL customers within 5km of the exchange and in geographic markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

Figure 3.11 Average download speeds for ISP packages 'up to' 30Mbit/s and above, 24 hours: November 2015



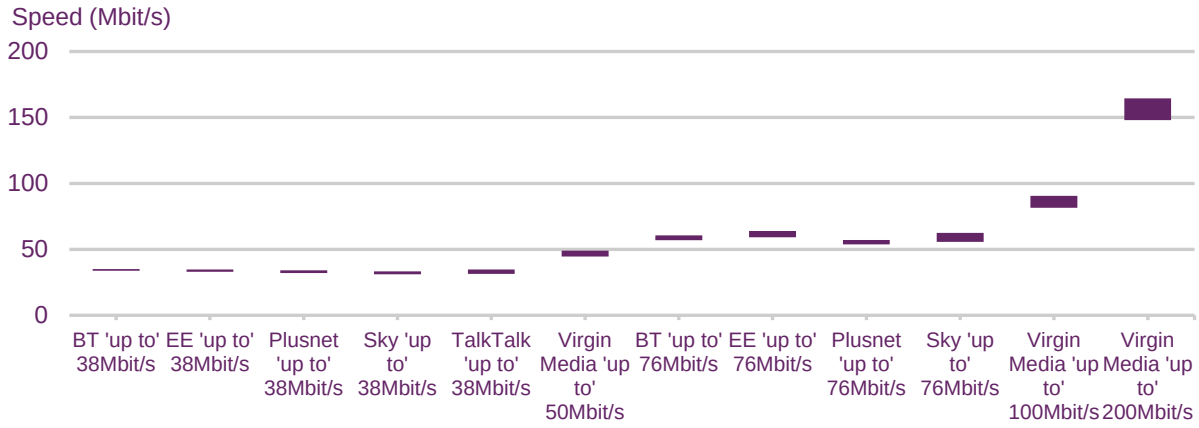
Source: SamKnows measurement data for all panel members with a connection in November 2015 Notes: (1) Includes only ADSL customers within 5km of the exchange and in geographic markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 3.12 Average download speeds for ADSL2+ ISP packages, 8pm to 10pm weekdays: November 2015



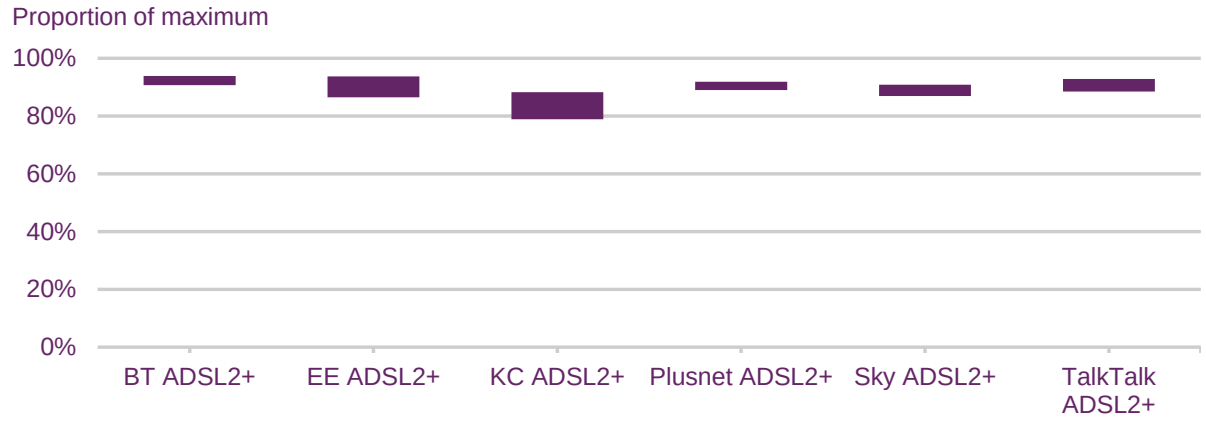
Source: SamKnows measurement data for all panel members with a connection in November 2015. Notes: (1) Includes only ADSL customers within 5km of the exchange and in geographic markets 2 and 3 and in the Kingston upon Hull area for KC; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 3.13 Average download speeds for 'up to' 30Mbit/s and above packages, 8pm to 10pm weekdays: November 2015



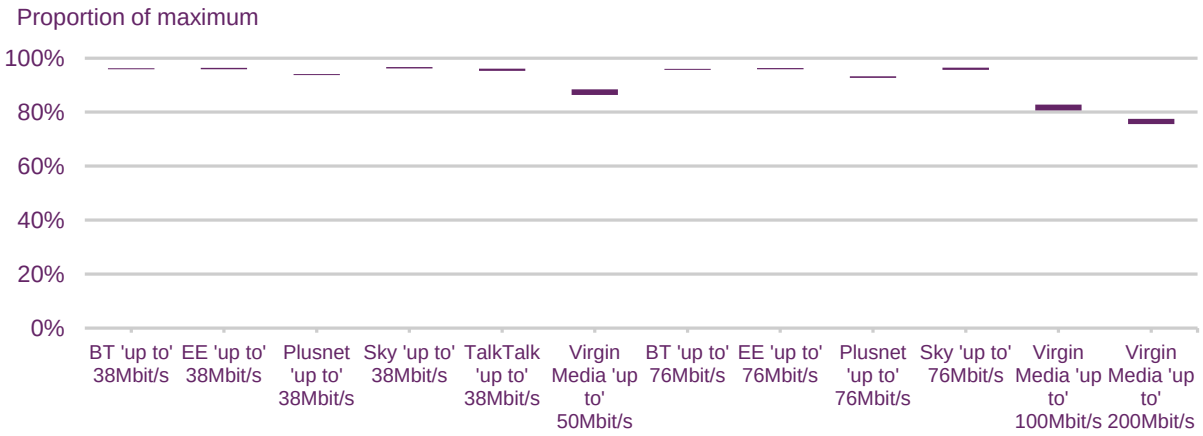
Source: SamKnows measurement data for all panel members with a connection in November 2015. Notes: (1) Includes only ADSL customers within 5km of the exchange and in geographic markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5)The range shown represents a 95% confidence interval around the mean.

Figure 3.14 Peak-time (8pm to 10pm weekday) speeds as a proportion of maximum speeds for ADSL2+ ISP packages: November 2015



Source: SamKnows measurement data for all panel members with a connection in November 2015. Notes: (1) Includes only ADSL customers within 5km of the exchange and in geographic markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

Figure 3.15 Peak-time (8pm to 10pm weekday) speeds as a proportion of maximum speeds for ISP packages 'up to' 30Mbit/s and above: November 2015



Source: SamKnows measurement data for all panel members with a connection in November 2015
Notes: (1) Only includes ADSL customers within 5km of the exchange and in geographic markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

Annex 2

Technical and research methodologies

Technical methodologies

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

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

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

It should be noted that 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 also 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 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 determined the maximum speed the line can support.

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

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

Expires: 0

Pragma: no-cache

Upload tests are performed for a fixed duration of 10 seconds for connections without data caps or those with an upload speed of 20Mbit/s or faster. For those with data caps, upload tests were performed using 3 x 1MB files with a similar initial lead-in period to that used for download tests. Connections with upload speeds faster than 10Mbit/s will transfer an increased amount during the upstream throughput test. This amount is up to 6MB. Six speed-test servers are deployed in a range of different data centres in and immediately around London to handle the traffic. 12Gbit/s of capacity is shared between these servers. Each server is monitored for excessive network load and 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 utilised 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. Furthermore, 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 was 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 YouTube video streaming performance

The YouTube test is an application-specific test, supporting the streaming of video and audio content from YouTube using their protocols and codecs.

The test begins by seeking out the most popular video in the user's country. This is achieved by fetching a list of the most popular YouTube videos from a central SamKnows server. The

central list of videos is refreshed once every 12 hours using the YouTube API. SamKnows filter for videos that are at least 60 seconds in length and have an HD quality variant. Note that by interacting with the YouTube API from a central location it can be ensured that every probe is delivered the same list of videos.

The test running on the probe will now fetch the YouTube web page for the most popular video, and parse the Javascript contained within the page. Within this Javascript is held a list of all of the encodings of the video in question and the content server hostname. By making this request from the probe we ensure that the test is receiving the same content server as the user would if they were using a desktop computer on the same connection.

The test then connects to the content server and begins streaming the video and audio. The test parses video frames as it goes, capturing the timestamp contained within each video frame. After each frame SamKnows sample how much realtime has elapsed versus video time. If video time > realtime at a sample period, then an underrun has not occurred. Otherwise, one has occurred.

The test downloads 10 seconds of audio and video at a time and runs once 12am-6am, once 6am-12pm, once 12pm-6pm and every other hour 6-12am.

In its default mode of operation the test will capture the ‘bitrate that can be reliably streamed’ on the user’s connection. This is achieved through the following process:

1. Find the fastest recent speedtest result that the probe has completed.

2. As described above, fetch the list of YouTube videos, find the most popular one, and then select the highest bitrate encoding which is less than the fastest speedtest result found in step 1.

3. Attempt to stream this video, for a fixed duration of 10 seconds of realtime. If successful, then the “bitrate reliably streamed” for this instance is the bitrate that we just fetched.

4. However, if a stall event occurs, then we immediately abort the test and retry at the next lower bitrate.

5. If we find a bitrate that we can stream without a stall event occurring then that bitrate is our “bitrate reliably streamed” for this instance.

6. However, if we encounter stalls for every bitrate, then the “bitrate reliably streamed” is zero.

The test captures the ‘bitrate reliably streamed’ (the highest quality video that can be streamed without rebuffering events) and the video startup delay.

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 with 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 which Netflix server this user's IP address would normally be served content from. 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 attempt 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's 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 then have the ability to infer when a stall occurred (by examining when our simulated video stream has fallen behind realtime). The test currently simulates videos at bitrates of 235Kbps, 375Kbps, 560Kbps, 750Kbps, 1050Kbps, 1750Kbps, 2350Kbps, 3000Kbps, 4500Kbps, 6000Kbps and 15600Kbps.

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

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

Testing BBC iPlayer video streaming performance

The BBC iPlayer test is an application-specific test, supporting the streaming of video and audio content from iPlayer using their protocols and codecs.

The test begins by fetching a list of the most popular videos from an iPlayer XML API. The most popular video is chosen for playback, on the basis that this is most representative of what users will be watching at the time. Moreover, if there are iPlayer caches present in the ISP's network then this content is more likely to be cached there.

The XML manifest for this video is then fetched from the BBC's webservers. This contains paths to all of the different bitrates that this video is encoded at, and the different CDNs that serve them. At the time of writing BBC iPlayer uses multiple CDNs to serve content. By having the probe directly fetch the XML manifest we can ensure that any decisions the BBC make (e.g. "ISP X should always be served by CDN Y") are followed by our test. The test parses the XML manifest file, honouring the priority assigned to each CDN and building an ordered list of available bitrates.

At this point the test can begin to fetch video content from the content server. This is currently achieved over RTMP, mimicking the iPlayer web browser client. The test parses video frames as it goes, capturing the timestamp contained within each frame. After each frame we sample how much realtime has elapsed versus video time. If video time > realtime at a sample period, then an underrun has not occurred. Otherwise, one has occurred.

As with the YouTube and Netflix tests, the client is configured to start testing at the highest supportable bitrate and then step down if and when stalls occur. This allows the identification of 'bitrate reliably streamed'.

The test captures the 'bitrate reliably streamed' (the highest quality video that can be streamed without rebuffering events) 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 2,096 panellists who had a broadband monitoring unit connected to their routers in November 2013. Figure 3.16 sets out Ofcom's definitions of geographic broadband markets (based on the definitions for the wholesale broadband access (WBA) market[32]). 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 as a whole, 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 as a whole (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.

Figure 3.16 Ofcom definitions of geographic broadband markets

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

Source: Ofcom, including Review of the wholesale broadband access markets: Statement on market definition, market power determinations and remedies, December 2010 (http://stakeholders.ofcom.org.uk/binaries/consultations/wba/statement/wbastatement.pdf)

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

Note: The operators classed as Principal Operators were BT, Cable & Wireless Worldwide, O2, EE, Sky, TalkTalk and, in local exchange areas where cable coverage exceeded 65% of premises, Virgin Media

We have used statistical techniques to adjust our results to ensure that they are representative of the UK broadband population as a whole. 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.

All weightings applied have been developed by market research company Saville Rossiter-Base[33] and reviewed by Ofcom before use. David Saville of Saville Rossiter-Base also 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 3. 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[34].

[33] http://www.sr-b.co.uk/

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

Annex 3

Statistical methodology

Key statistical concepts used in this report

This report presents the findings from research which has involved the collection and interpretation of 75.3 million data points. It has been a complex process, both technically and statistically.

The glossary in Annex 4 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 by 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 again 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, technology (LLU, non-LLU and cable), 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 particular 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 normalising 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. Therefore we 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 therefore is a suitable proxy for measuring quality of the line.

- For this report, in the light of the proposed change of methodology in relation to FTTC services, Virgin Media cable services have been compared to tier 1 and tier 2 FTTC services, which are weighted by market share, market and rural/urban split. In practice, as most FTTC services are in market 3 and urban areas, the main impact from the weighting comes from combining different ISPs by market share.

- No weights are applied to Virgin cable packages as these circuits are not affected by distance from the exchange or supplier cabinets.

Sample size

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

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

A fourth round of recruitment occurred between May 2012 and November 2012 to maintain the existing panel (in particular KC ADSL2+ and Plusnet ADSL2+) and to enable reporting of additional high-speed packages (BT's 'up to' 76Mbit/s FTTC service and Virgin Media's 'up to' 60Mbit/s and 100Mbit/s services). In total 333 additional monitoring units were sent out.

A fifth round of recruitment took place between November 2012 and May 2013 to maintain the existing panel and to enable reporting of additional high-speed services – Plusnet's 'up to' 38Mbit/s and 'up to' 78Mbit/s packages and Virgin Media 'up to' 120Mbit/s service.

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

Between November 2014 and November 2015, a further 1109 boxes were sent out. The purpose of this recruitment was to rebalance the panel and allow better reporting of national rural and urban data. The panel is currently over-representative of the higher-speed packages, with 76% of the sample contributing less than 1 of a response towards the UK average. The current active panel also excludes customers with packages with headline speeds of 'up to' 2Mbit/s and less, because of the current low share of these connections (less than 0.1% of the total in November 2013). In our first round of research conducted between October 2008 and April 2009, we found that the speeds delivered by 'up to' 2Mbit/s and less packages were consistent over time and between providers. In this report we have excluded data from 'up to' 2Mbit/s and less packages due to their low market share

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

In total 4,736 measurement units have been despatched since October 2008. Of the 1,453 which are not providing data, 600 were phased out as not capable of reporting packages with speeds over 20Mbit/s. 3,142 of these were connected by panellists between 1st and 30th November 2014. Of these, 1,639 supplied data to the UK average, and 2151 to the named ISP package comparisons.

Figure 4.1 Panellist numbers

Sample set	Number
Total number of boxes dispatched	**4,736 (600 phased out)**
Total number of boxes connected	**3504**
Excluded because of missing data, (i.e. measurements)	313
Excluded as demographics not available	360
Excluded due to known issue with data	77
Other Exclusions to improve UK sample weighting (i.e. distance, market classification, region, ISP)	11
Total participants included in UK Analysis	**1639**
Total participants included in ISP Package Analysis	**2151**

All measurement data were collated and stored for analysis purposes as a monthly trimmed average of the measurements obtained for each respondent for the relevant time interval (e.g. 24 hours, 8 to 10pm weekday, 9am to 5pm Monday to Friday). Only panellists who provided a minimum of five valid measurements across all the download speeds tests for each time interval were included in the monthly analysis. A trimmed mean was used because, for a small proportion of respondents, the occasional test result was far in excess

of what was achievable on the line. The top 0.5% of results per respondents did not count towards the average.

The average number of measurements per respondent for the 24-hour multi-thread download speed tests in November 2015 was 390, from a theoretical maximum of 464 per respondent (i.e. if all panellists had their monitoring unit connected on 1st May and all scheduled tests were run - tests were not run when the monitoring unit detected concurrent use of the bandwidth).

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

Quotas were set before the exact LLU package market shares for LLU operators and the lines in geographic markets 2 and 3 for other providers were available, but results were weighted to be representative at national level. In order to recruit ISP packages to match specific quota criteria above, and to achieve 100-150 panellists per package, only ISP packages with over 250,000 subscribers in total were targeted, although we do include ISP packages with less than 250,000 subscribers where we are able to recruit sufficient panellists and where we believe a package is important enough to the future development of the market to warrant inclusion in the report.

Due to issues beyond our control, there were difficulties in recruiting specific geographies and packages for this report. Therefore in enable to allow robust reporting, we leased 432 panellists from SamKnow's wider UK panels. Their data will be used for this report but Ofcom seeks to recruit panellists unique to the Ofom panel to fill these gaps.

The results and analysis of the 3,142 panellists' measurement results were divided into two separate datasets, each weighted to targets.

National panel (over 'up to' 2Mbit/s packages): 1,639 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: 2,151 panellists. A subset of the national panel, consisting of panellists from geographic markets 2 and 3 only, panellists from LLU operators Sky and TalkTalk and cable provider Virgin Media were on-net only. There was a target of 100 valid panellists for each ISP package, but the criterion for inclusion in the reporting was an effective sample minimum of 50 valid panellists (those with a base of fewer than 75 should be treated with caution).

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

Sample weighting

There were two weighting classifications applied to the data:

- **National panel**. Weighting by ISP market and package shares by LLU/non-LLU connections supplied by ISPs as at November 2014, 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; and

- **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 (38 or 76 Mbit/s) and to the installation method – self or engineer install. BT openreach provided 4 curves – 38 Mbit/s self and engineer install and 76 Mbit/s self and engineer install.

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

- As mentioned previously, our measurement approach does not take into account 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 4.2 Variation of mean and variance, by distance band

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

Source: Ofcom

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

Assigning panellists to ISP and broadband package

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

Volunteer panellists (who registered at www.samknows.com/broadband/signup/ofcom) were required to provide their ISP, package name, headline speed and download limit from drop-down menus and/or text boxes provided in an online form. This was used as initial categorisation of potential candidates against the target quotas.

- The stated package name and headline speed (where they allowed identification of the correct ISP package) were used to assign panellists to an ISP package.

Volunteers who matched the sample criteria were screened by ISP package, and an average speed reading estimate was obtained to screen actual versus stated package. Those who were successfully screened were sent monitoring units.

- The stated ISP allocation was validated against IP address. When an IP address and stated ISP were inconsistent or missing, the volunteer was rejected. When an average speed measurement was outside the feasible range, the volunteer was flagged, and a monitoring unit box dispatched if sample required for the assessed package.

Once the volunteer correctly connected the monitoring unit and test measurements were received, straight-line distance from home to exchange and geographic market classification were added to the measurement data.

A further stage of ensuring that respondents were assigned to the correct ISP package took place before the analysis stage. Four steps were undertaken:

- The initial assumption was that the package assignment, recorded in the panel data file, was correct. However, the ISPs were asked to verify that respondents were on the correct package.

- However, those participants whose stated and measured package assignments or ISP were not consistent and could not be definitively reconciled were excluded from the comparison data. Only those panellists with an ADSL connection who were connected to an ADSL2+ enabled exchange were considered for the ‘up to’ 20Mbit/s and 24Mbit/s package allocation. The above modification (upload speed assignment) was necessary to identify those customers using ADSLMax on an ADSL2+ exchange.

Weighting to distance from exchange

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

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

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

Weighting fibre packages

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

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

Ofcom was presented with the choice of using a single curve for each speed which did discriminate between respondents with self and engineer installed lines or of using two curves which did discriminate on installation method. The rationale for using two curves per speed is that installation method is within the control of an operator and can an effect of achievable speeds. Normally, self-install delivers a lower speed than engineer install, As the purpose of the report is to reflect actual customer experience, this dfference in operator installation choice was felt to be worth retaining.

in the absence of detailed information for all operators as to the proportions of lines which are self and engineered installs, this has been allowed to “fall out” from the panel. If a respondent has a self-install line s/he will be fitted to the self-install curve and equally so for engineer-installed lines.

National panel

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

ISP package panel

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

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

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

Rural/urban comparison

For this analysis, an alternative weighting was used. All ADSL data was normalised to the UK distance-from-exchange profile of lines. The data were further weighted to the market share by technology in each year, but the percentage of each technology within area type was allowed to fall out of the data without adjustment. The different weighting used in this analysis results in a different UK average speed compared to the rest of the report and should be used only within this distinct piece of analysis.

Weighting methodology

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

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

Weighting efficiency

Overall, against the entire weighting framework, the national panel achieved a weighting efficiency of 44%. 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 4.3 National panel range of weights

Range	Count	Column N%
Less than 0.5	660	40%
0.5 to 1	506	31%
1 to 1.5	175	11%
1.5 to 2	100	6%
2 to 3	114	7%
3+	84	5%

Source: Ofcom

Overall, against the entire weight frame, the ISP package panel achieved a weighting efficiency of 82%. This is because Virgin Media cable packages are not weighted, as distance from exchange does not impair download speeds.

Figure 4.4 ISP package panel range of weights

Weights	Count	Column N %
Less than 0.5	132	6%
0.5 to 1	1023	48%
1 to 1.5	802	37%
1.5 to 2	157	7%
2+	33	2%

Source: Ofcom

Figure 4.5 Weighting efficiency, by ISP package

ISP package	Weighting efficiency
BT ADSL2+	57%
KC ADSL2+	64%
EE* ADSL2+	63%
Plusnet ADSL2+	59%
Sky ADSL2+	55%
TalkTalk ADSL2+	66%
BT 'up to' 38Mbit/s	83%
EE 'up to' 38Mbit/s	76%
Plusnet 'up to' 38Mbit/s	51%
Talk Talk “up to ‘38 Mbit/s”	79%
Sky 'up to' 38Mbit/s	44%
Virgin Media 'up to' 50Mbit/s	100%
BT 'up to' 76Mbit/s	81%
EE 'up to' 76Mbit/s	79%
Plusnet 'up to' 76Mbit/s	79%
Sky 'up to' 76Mbit/s	70%
Virgin Media 'up to' 100Mbit/s	100%
Virgin Media 'up to' 200 Mbit/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 4.6 Maximum download speeds for ADSL2+ ISP packages, weighted and unweighted figures: November 2015

Source: SamKnows measurement data for all panel members with a connection in November 2015. Panel base: 1639
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

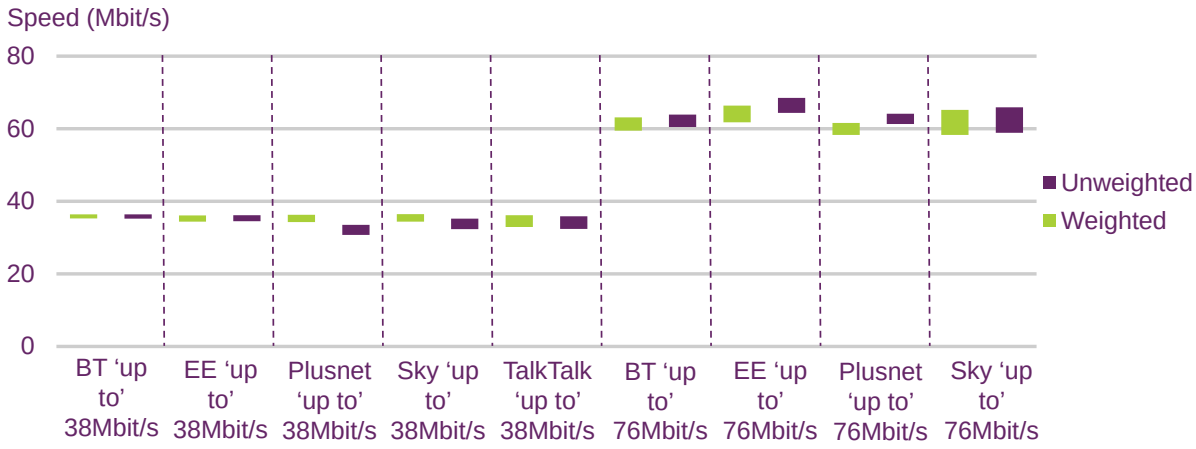
Figure 4.7 Average download speeds for ADSL2+ ISP packages, 24 hours, weighted and unweighted figures: November 2015

Source: SamKnows measurement data for all panel members with a connection in November 2015. Panel base: 1639
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 4.8 Peak-time download speeds for ADSL2+ ISP packages, 8pm to 10pm weekdays, weighted and unweighted figures: November 2015

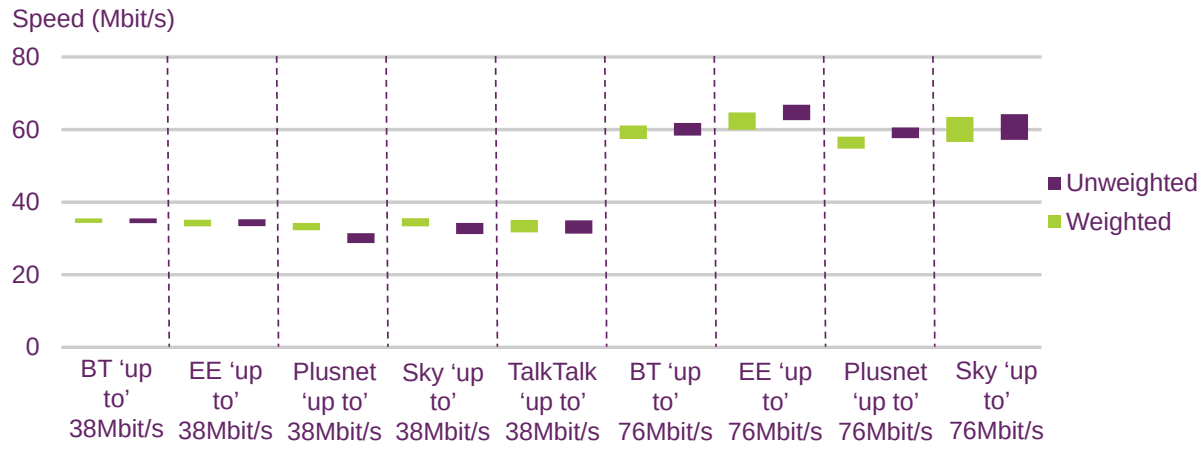
Source: SamKnows measurement data for all panel members with a connection in November 2015. Panel base: 1639
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 4.9 Maximum download speeds for FTTC ISP packages, weighted and unweighted figures: November 2015



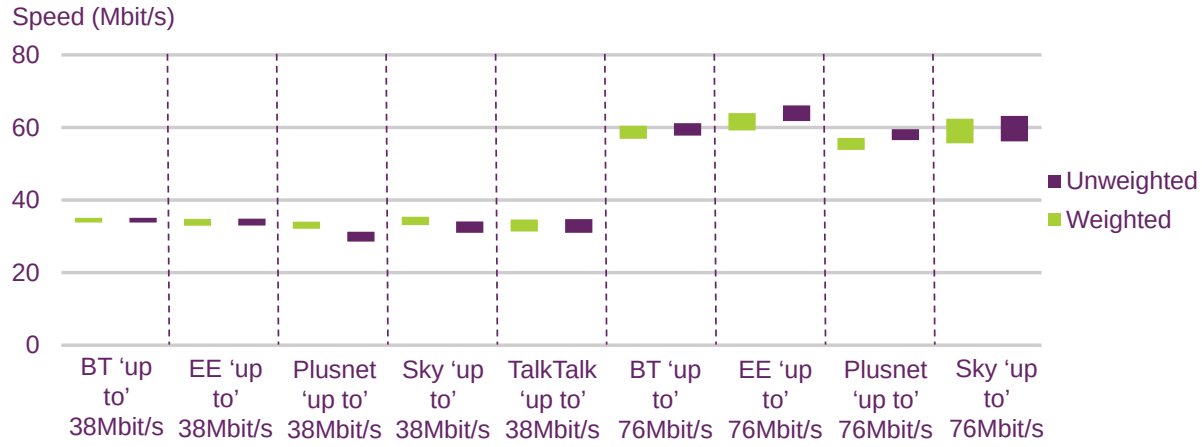
Source: SamKnows measurement data for all panel members with a connection in November 2015. Panel base: 1639
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 4.10 Average download speeds for FTTC ISP packages, weighted and unweighted figures: November 2015



Source: SamKnows measurement data for all panel members with a connection in November 2015. Panel base: 1639
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 4.11 Peak-time download speeds for FTTC ISP packages, 8pm to 10pm weekdays, weighted and unweighted figures: November 2015



Source: SamKnows measurement data for all panel members with a connection in November 2015. Panel base: 1639
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification, max attainable speed (FTTC) and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

Comparison of urban and rural speeds over time

Using Bluewave Geographic's Locale dataset, it is possible to segment all UK postcodes into one of seven urban-rural groupings. This dataset, widely used in market research design and sampling, allocates postcodes to a category based on their population density and how close the settlement they live within is to a larger one.. The seven groupings range from A

(large cities such as London and Birmingham), to G isolated rural areas such as the Western Isles and Dartmoor).

To simplify the analysis, the groupings have been banded together into three broad groups: urban (cities and large to medium towns: population over 10k), suburban (small towns) and rural (population less than 2.5k and in open countryside). This grouping enables us to compare rural, suburban and urban areas over time.

Annex 4

Glossary

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Multi-thread test: A test involving the download of two or more data files simultaneously - in the case of our research, three files (see Technical Methodology – Annex 2). 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.