UK fixed-line broadband performance, November 2013

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

Research Report

Publication date: 15 April 2014

Contents

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.[1] 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 broadband services.[2] 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[3], and the interests of consumers in respect to price, quality of service and value for money.[4]

The Act requires us to make arrangements to find out about the experiences of consumers using electronic communications services and the way they are provided, and we do this by carrying out research into these services.[5] 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.[6]

In order to understand the performance of UK fixed-line residential broadband connections, we commission research to identify the average download speeds that they deliver, along with a number of other metrics which determine the consumer experience of using broadband services. This is the tenth report into fixed-line residential broadband performance that Ofcom has published using data collected by research partner SamKnows Limited (SamKnows)[7] from a volunteer panel of UK residential broadband users.[8]

The present report sets out the findings from data collected during November 2013, during which 735 million test results were collected from a panel of 2,391 UK residential broadband users. We believe that the integrity of our technical methodology (set out in Annex 2), combined with the scale of data collection and the sophistication of the statistical analysis (set out in Annex 3), makes this research a very robust presentation of UK fixed-line broadband speeds.

Fixed broadband performance is an issue for many consumers, and Ofcom research conducted in Q1 2013 suggested that 11% of fixed broadband users were 'very' or 'fairly' dissatisfied with the speed of their connection. Likewise, while 81% 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 (88%).

Using this report

While Sections 1 and 2 of this report look at broadband 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)

[1] Section 3(1) of the Act
2 Section 3(2)(b)
3 Section 3(4)(a) and (e)
4 Section 3(5)
5 Section 14
6 Section 15
7 http://www.samknows.com/broadband
8 Previous reports are available on the Ofcom website at http://stakeholders.ofcom.org.uk/market-data-research/other/telecoms-research/broadband-speeds/?a=0.

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 typically marketed, often expressed as 'up to' xMbit/s (megabits per second).

- The '**average actual throughput**' speed, or '**average speed**' represents the average speed that a consumer actually receives, which drives the speed at which files can be uploaded 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.

Anomalous *BT Infinity* test results in May 2012

A number of *BT Infinity* fibre-to-the-cabinet (FTTC) panellists' measurement units recorded anomalous results during May 2012, with download speeds falling to less than 1Mbit/s at certain times. BT found that the low speeds recorded were due to a software problem with some of its Home Hub routers, which has now been resolved. Where we show May 2012 data in this report, we include the test results from those BT panellists whose measurement units recorded anomalous results. May 2012 figures which exclude the test results of the affected BT FTTC panellists can be found as footnotes in August 2012 Ofcom *UK fixed-line broadband performance* report, which can be accessed at:

http://stakeholders.ofcom.org.uk/market-data-research/other/telecoms-research/broadband-speeds/broadband-speeds-may2012/

Structure of 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; and

- Annex 4 contains the glossary of terms.

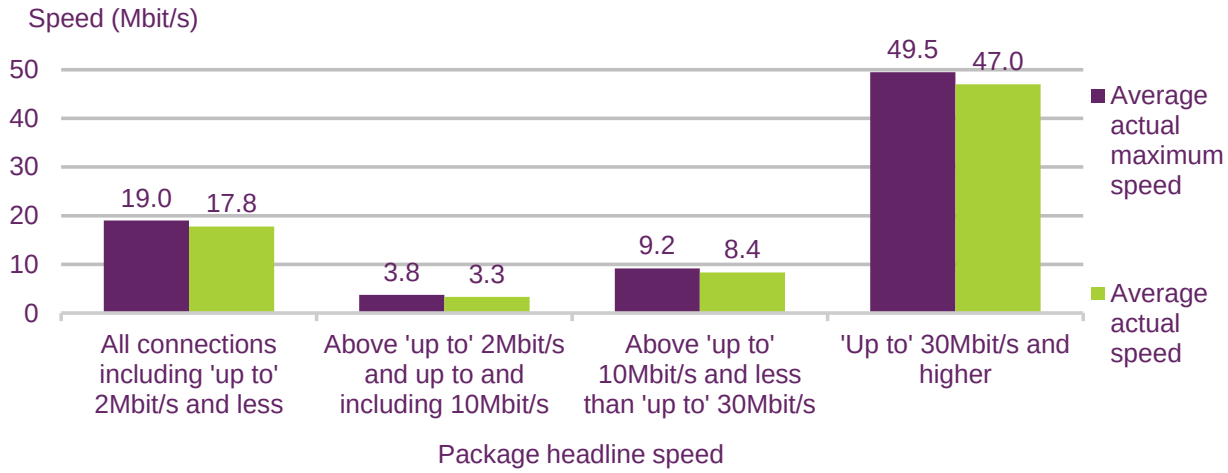
Section 1

Overview of UK fixed broadband speeds

The average fixed broadband download speed reached 17.8Mbit/s in November 2013

Our research found that the average actual speed for UK fixed-line residential broadband connections in November 2013 was 17.8Mbit/s (Figure 1.1). The average actual speed of superfast fixed broadband connections (i.e. those with a headline speed of 'up to' 30Mbit/s or higher) was 47.0 Mbit/s, which was over five times the average actual speed of connections above 'up to' 10Mbit/s and less than 'up to' 30Mbit/s (8.4Mbit/s). The average speed for connections above 'up to' 2Mbit/s up to and including 10Mbit/s was 3.3Mbit/s, less than a tenth of the average speed for superfast connections.

Figure 1.1 Average UK broadband speeds: November 2013



Source: SamKnows measurement data for all panel members with a connection in November 2013
Panel Base: 985
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, the last data collected for these packages was in April 2009 and this data has been factored in, in proportion to share of all connections in November 2013; (3) Data collected from multi-thread download speed tests; (4) 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.

Average broadband speeds increased by 3.1Mbit/s in the six months to November 2013

Average actual fixed broadband download speeds continued to increase in the six months to November 2013. The average actual speed across all residential connections was 17.8Mbit/s, which was 3.1Mbit/s faster than that recorded six months previously and 48% higher than the 12.0Mbit/s average speed recorded in November 2012. Sufficient sample sizes were not available among our panel for connections with headline speeds of 'up to' 2Mbit/s and less because of the current low market share of these connections (less than 0.1% of the total in November 2013), so the performance of these connections is not

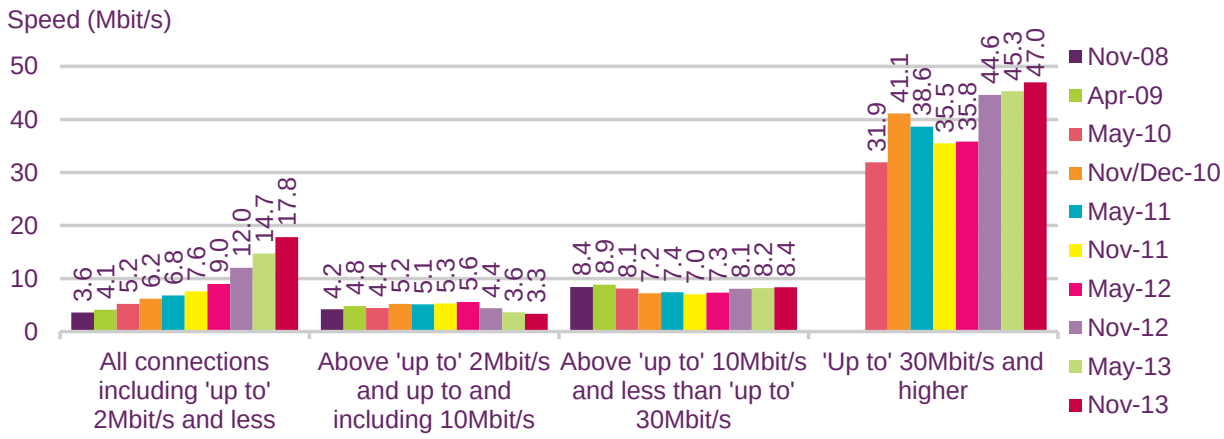
analysed in detail. However, connections with a headline speed of 'up to' 2Mbit/s or less are included in Figure 1.2 to accurately reflect average actual speeds across all connections.

Average actual download speeds increased for every category compared, except for connections above 'up to' 2Mbit/s and up to and including 10Mbit/s, where speeds fell by 0.3Mbit/s between May and November 2013. The likely main driver of the fall in average speed recorded for this category is Virgin Media's 'double speeds' upgrade programme, whereby Virgin Media 'up to' 10Mbit/s cable customers have been upgraded onto 'up to' 20Mbit/s or 'up to' 30Mbit/s services. 'Up to' 10Mbit/s cable customers typically had much higher average speeds than the ADSL1 connections which make up the majority of the other connections included in this category, so it is probable that the removal of cable connections from the category has led to a fall in its average speeds.

The average download speed for connections above 'up to' 10Mbit/s and less than 'up to' 30Mbit/s slightly increased, by 0.2Mbit/s to 8.4Mbit/s, between May 2013 and November 2013. Again, this is likely to be largely due to Virgin Media's speeds upgrade programme, which increased the number of connections which were 'up to' 20Mbit/s cable connections in this category, thus increasing the average speed of connections in this category (in November 2012 the average speed of an 'up to' 20Mbit/s cable connection was 18.9Mbit/s compared to 7.4Mbit/s for ADSL2+ connections with a headline speed above 'up to' 8Mbit/s).

Download speeds for connections 'up to' 30Mbit/s and higher increased by 1.7Mbit/s from 45.3Mbit/s in May 2013 to 47.0Mbit/s in November 2013. This increase is likely to be due to increased take-up of higher speed services, again partly driven by Virgin Media's 'double-speeds' upgrade programme, which was concluded in December 2013.

Figure 1.2 Average actual broadband speeds: November 2008 to November 2013



Source: SamKnows measurement data for all panel members

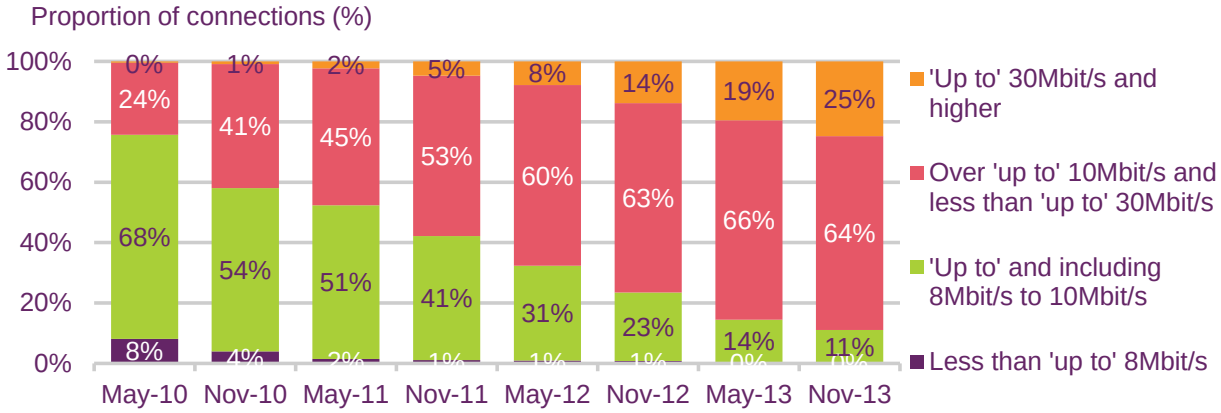
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers 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 2013; (3) Data collected from single-thread download speed tests prior to November/December 2010 and multi-thread download speed tests for November/December 2010 onwards; (4) 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.

A quarter of UK residential broadband connections had a headline speed of 'up to' 30Mbit/s or higher in November 2013

The proportion of residential fixed broadband connections that had a headline speed of 'up to' 30Mbit/s or higher in November 2013 was 25%, meaning that a quarter of residential broadband connections in the UK are considered to be superfast. This represented an increase of five percentage points from May 2013, when 19% of connections had a headline speed of 'up to' 30Mbit/s or higher. We consider the increased take-up of superfast connections to be a key factor driving the increase in average actual speeds across all connections.

The proportion of connections that were over 'up to' 10Mbit/s and less than 'up to' 30Mbit/s in November 2013 was 64%, a decrease of two percentage points on the previous six months, suggesting that consumers are upgrading from these connections to superfast services. The proportion of connections that were 'up to' and including 8Mbit/s to 10Mbit/s fell by three percentage points in November 2013 to 11%, while for the second successive reporting period, connections with a headline speed of less than 'up to' 8Mbit/s accounted for less than one per cent of connections.

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)
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.

The average speed of cable connections increased by 5.3Mbit/s in the six months to November 2013

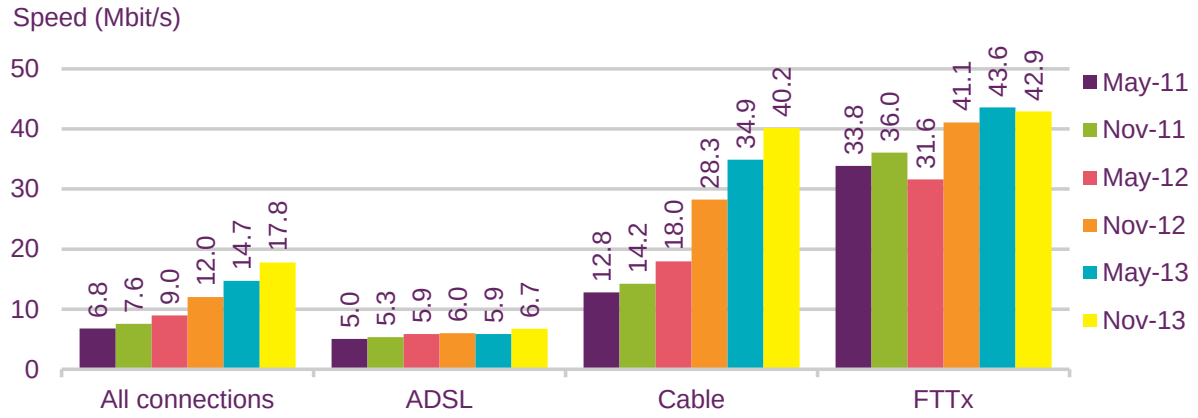
The average download speed of residential cable broadband connections was 40.2Mbit/s in November 2013 compared to 34.9Mbit/s in May 2013, an increase of 5.3Mbit/s over six months. This increase is likely to have been driven by Virgin Media's now completed 'double speeds' upgrade programme, which took place over the course of 2013, and contributed to average download speeds over cable connections being only 2.7Mbit/s lower than those over FTTx[9] connections in November 2013, compared to a difference of 8.8Mbit/s in May 2013.

Although panellists with fibre connections had the fastest average speeds overall, the average speed of FTTx connections fell by 0.7Mbit/s between May and November 2013 to 42.9Mbit/s. This is likely to be partly due to the proportion of FTTx connections that were 'up to' 76Mbit/s (rather than 'up to' 38Mbit/s) falling slightly during the period, the first time that this has happened since the faster services launched.

[9] FTTx is 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.

Average ADSL speeds were 6.7Mbit/s in November 2013 compared to 5.9Mbit/s in May 2013, however, this increase was not statistically significant. We will continue to monitor the average actual download speeds for ADSL connections in future to determine whether this increase in ADSL download speeds continues and, if so, which factors are driving this.

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



Source: SamKnows measurement data for all panel members with a connection in November 2013
Panel Base: 985
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.

Average download speeds in urban areas were almost three times those in rural areas in November 2013

Average download speeds tend to be faster in urban areas than in rural areas. There are two main reasons for this: the first is that the average line length from the exchange to the end-user's premises tends to be longer in rural areas (which can result in increased signal loss and lower ADSL speeds) and the second is that the availability of technologies that are capable of providing superfast services, such as fibre and cable, tends to be lower in rural areas as ISPs tend to focus network rollout in urban areas so as to maximise their potential customer bases.

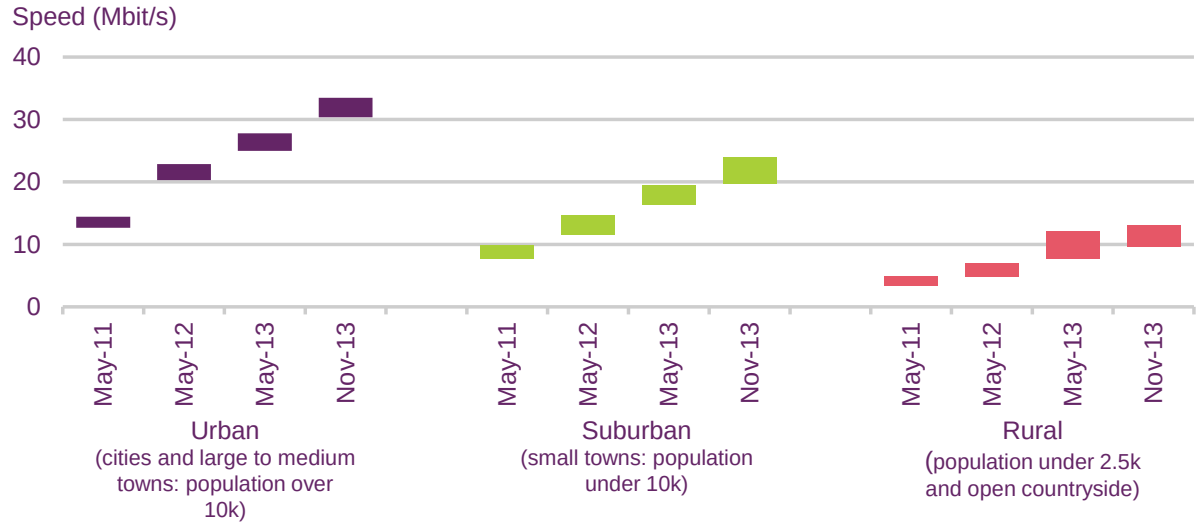
The average actual download speeds for UK urban, suburban and rural areas shown in Figure 1.5 below are calculated using a different statistical methodology to the UK-wide averages that appear elsewhere in this section of the report. While this methodology does enable us to compare download speeds by geographic area over time, the research is not explicitly designed to measure speeds by urbanity. As such, these results should be treated as being indicative only. Further details regarding the statistical methodologies used in this report are provided in Annex 3.

Our indicative analysis shows that the average download speed in urban areas increased by 21% to 31.9Mbit/s in November 2013, almost three times the estimated average download speed in rural areas (11.3Mbit/s). The average download speed in suburban areas in November 2013 was 21.8Mbits, an increase of 22% from May 2013. The increase in

download speeds in rural areas in the six months to November 2013 was not statistically significant. As such, the increase in speeds from 9.9Mbit/s to 11.3Mbit/s should be seen as indicative only.

There was a difference of 20.6Mbit/s between average download speeds in urban areas and those in rural areas in November 2013, up from 16.5Mbit/s in May 2013. As the availability and take-up of superfast services in urban areas rapidly increases, it is likely that the difference in average broadband speeds between urban and rural areas will temporarily grow. However, we expect that speeds will become more evenly matched across the UK as fibre broadband availability increases in rural areas.

Figure 1.5 Average download speeds for fixed broadband connections in urban, suburban and rural areas: May 2011 to November 2013



Source: SamKnows
Panel Base: 2011; Urban 999, Suburban 382, Rural 323; 2012 Urban 1099, Suburban 391, Rural 294; and 2013 May Urban 1362, Suburban 448, Rural 365; 2013 November Urban 746, Suburban 292; Rural 271
Notes: This analysis by urbanity uses a different weighting methodology to that employed in the rest of this section. This methodology is likely to overstate the results and calculation of an average UK download speed from this data would yield a figure of 25.3Mb/s, which is different to the figure shown elsewhere in this section. Further detail regarding the statistical methodology used is provided in Annex 3.

Average urban fibre broadband speeds were over 50% faster than those in rural areas in November 2013

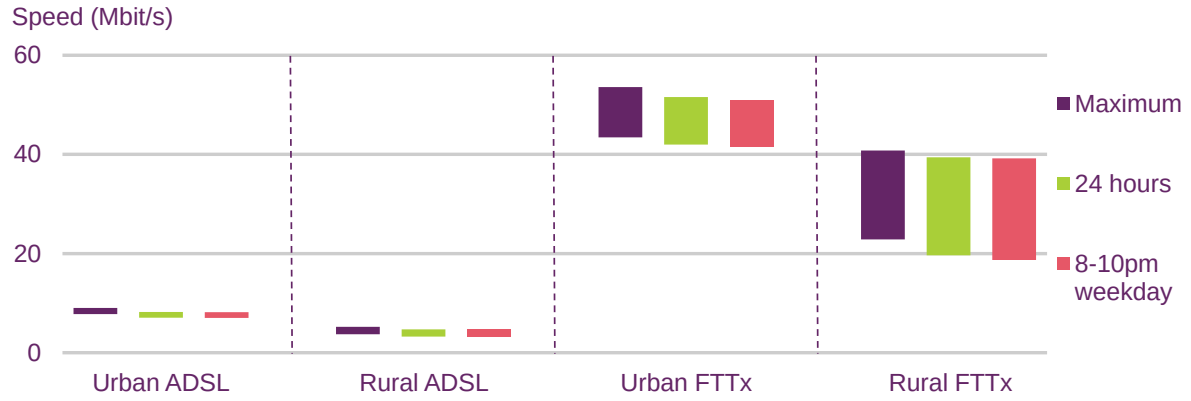
Our indicative analysis shows that average download speeds were faster in urban areas than rural areas on both ADSL and fibre connections in terms of the average maximum, 24-hour and 8pm to 10pm weekday peak-time speeds.

In November 2013, the average actual download speed over FTTx connections in urban areas was 46.8Mbit/s, 17.2Mbit/s faster than the average actual speed on FTTx connections in rural areas (29.5Mbit/s), although the rural FTTx figure is indicative only as it is based on a sample of just 17 rural FTTx panellists. Although average actual download speeds over FTTx connections were higher in urban areas than rural areas, average download speeds over rural fibre connections were over five times faster over than those on rural ADSL

connections (4.0Mbit/s), although once again the rural figures should be treated with caution due to small sample size. Average peak-time speeds on fibre connections in urban areas were 46.3Mbit/s, 95% of the average maximum download speed, while in rural areas (where figures are once again indicative due to small sample size) average peak-time speeds were 29.0Mbit/s, 91% of the average maximum.

Average actual download speeds on ADSL connections in urban areas were 7.6Mbit/s, almost most twice those in rural areas. The average peak-time download speed on ADSL connections in urban areas was also 7.6Mbit/s, 90% of the average maximum speed over this type of connection (8.4Mbit/s). In comparison, the average peak-time download speed on ADSL connections in rural areas was 3.9Mbit/s, 87% of the average maximum download speed.

Figure 1.6 Average actual urban and rural ADSL and FTTx download speeds



Source: SamKnows
Panel Base: Urban ADSL 420, rural ADSL 171, urban fibre 147, rural fibre 17.

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

Download speeds 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) on ISPs' networks (Figure 1.7). For all types of connections analysed, the peak-time speeds were lower than both the average maximum speed and the 24 hour average speed. In November 2013, the average 8pm to 10pm weekday peak-time download speed across all connections was 17.5Mbit/s, which was 92% of the 19.0Mbit/s average maximum speed and 98% of the 24 hour average.

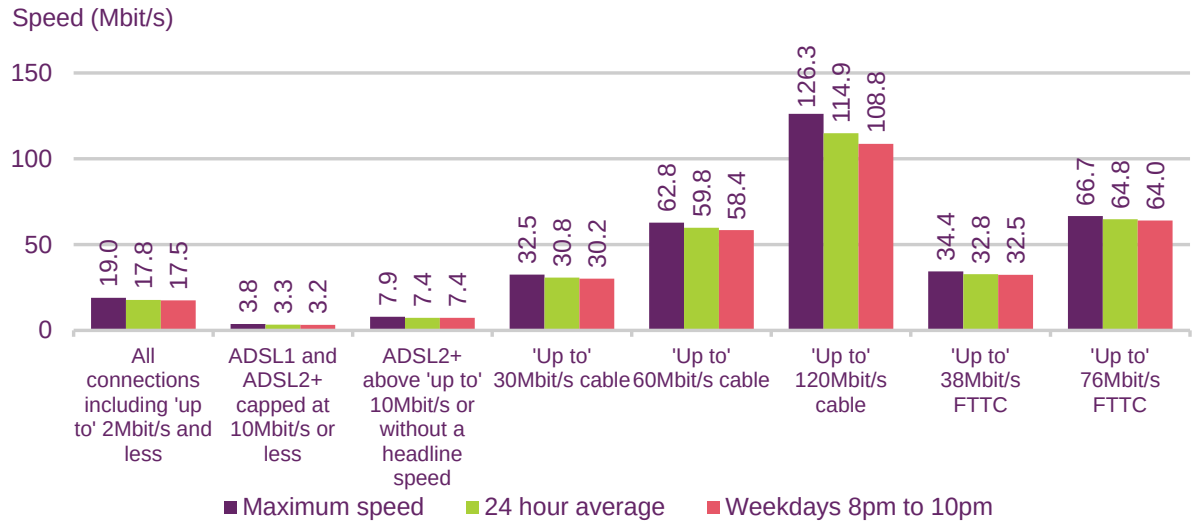
Cable connections 'up to' 120Mbit/s experienced the most variation between peak-time download speeds and maximum speeds. The peak-time download speed on 'up to' 120Mbit/s cable connections was 108.8Mbit/s, 86% of the average maximum speed and 95% of the 24 hour average over this type of connection. Cable connections 'up to' 30Mbit/s and 'up to' 60Mbit/s experienced less variation: the peak-time download speed on 'up to' 60Mbit/s cable connections was 58.4Mbit/s, 93% of the maximum speed and 98% of the 24 hour average. For 'up to' 30Mbit/s cable connections, the peak-time speed was 30.2Mbit/s, also 93% of the average maximum speed and 98% of the 24 hour average.

FTTC connections were less affected by peak-time contention than cable connections. The peak-time download speed on 'up to' 38Mbit/s FTTC connections was 32.5Mbit/s, 94% of the average maximum speed and 99% of the 24 hour average, while the peak-time

download speed on ‘up to’ 76Mbit/s FTTC connections was 64.0Mbit/s, 96% of the average maximum speed and 99% of the 24 hour average.

For ADSL connections capped at 10Mbit/s or less, the peak-time download speed was 3.2Mbit/s, 86% of the average maximum speed and 98% of the 24 hour average, while peak-time download speeds on ADSL2+ connections above ‘up to’ 10Mbit/s were 93% of the maximum speed and the same as the 24 hour average.

Figure 1.7 Variations in download speed by time of day: November 2013

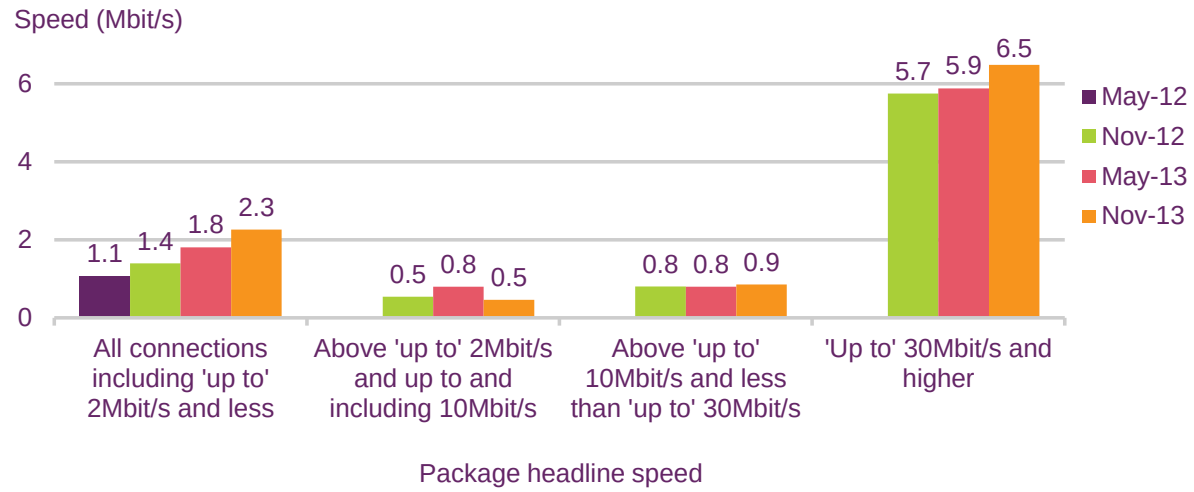


Source: SamKnows measurement data for all panel members with a connection in November 2013. Panel Base: 985
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of 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 2013; (3) Data collected from multi-thread download speed tests.

The average actual upload speed of a UK residential fixed-line broadband connection was 2.3Mbit/s in November 2013

While broadband advertising focuses on download speeds, upload speeds matter to those sharing large files, using real-time two-way video communications and for some online gaming. Our research shows that average actual upload speeds increased to 2.3Mbit/s in November 2013, an increase of 0.5Mbit/s compared to the 1.8Mbit/s recorded in May 2013. This increase is most likely driven by increased take-up of superfast services, which tend to have faster upload speeds than those provided over older technologies.

Figure 1.8 Average upload UK broadband speeds: November 2013



Source: SamKnows measurement data for all panel members with a connection in November 2013. Panel Base: 985
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 speed tests.

Section 2

Variations of speeds by internet service provider (ISP) package

Background

This section sets out the performance of individual ISP packages in terms of their connection speeds, comparing the average maximum, peak-time and 24-hour download and upload speeds of both ADSL2+ and superfast ISP packages. We also include analysis of how 11 individual panellists' average download speeds have changed since May 2010 to give some anecdotal evidence of some consumers' experiences of the UK fixed-line broadband market over this time period.

A key factor affecting 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. Therefore, to take into account the differing ISP customer profiles when we compare the performance of individual ADSL ISP packages in our *fixed-line broadband performance* reports, we 'normalise' the test result data by distance from the exchange to take into account differing ISP customer profiles. This enables like-for-like comparisons of performance across ADSL services. More information on the normalisation of ADSL ISP providers can be found in the statistical methodology in Annex 3 of this report.

Fibre-to-the-cabinet (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 available speeds over FTTC are therefore also affected by the length (and quality) of the wiring over which the data signal is transmitted. In previous reports we have not normalised FTTC test results to take into account differing ISP user profiles as we do with ADSL. However, as the rollout of FTTC reaches more rural areas there is a possibility that similar systematic biases may arise. We are currently working with BT Openreach and ISPs to assess whether it is appropriate to normalise FTTC test results and, if so, how this should be done.

While we do this, we have opted to omit individual FTTC service data from the ISP comparisons section of these reports, and instead include average figures across all 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC panellists, which are weighted to reflect the market shares of operators within each service. It is important to note that it is therefore not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

We hope to be able to resolve this issue before the next *fixed-line broadband performance* report, which will be based on tests run in May 2014, is published later this year.

Our ability to compare the performance of specific ISP packages is dependent on having sufficient panellists to allow meaningful statistical analysis. We were able to achieve sufficient panel sizes for the following ISP packages in November 2013 (listed in alphabetical order):

- BT Retail's ADSL2+ service;
- EE's ADSL2+ service;
- Karoo's ADSL2+ service;

- Plusnet's ADSL2+ service (note that although Plusnet is owned by BT, it was considered separately as parts of the network are different);
- Sky's on-net ADSL2+ service;
- TalkTalk's on-net ADSL2+ service; and
- Virgin Media's 'up to' 30Mbit/s, 'up to' 60Mbit/s and 'up to' 120Mbit/s cable services.

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

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 range 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 emphasise that these bars indicate the ***average (mean) performance***, not the range of performance delivered.

The sampling and statistical methodologies have been designed to enable us to report ISP package performance on a like-for-like basis. As mentioned previously, data for ADSL panellists have been normalised for distance from the local exchange, to ensure that there are no biases created by ISPs having customer bases with different distance profiles. For details, see the research methodology set out in Annex 2 and the statistical methodology set out in Annex 3.

ADSL2+ connections

The main variable when affecting the speeds delivered by ADSL2+ is the distance of the end-user's premises to the local exchange, over which the ISP has no control. Therefore when looking at the fixed-line broadband speeds in Figure 2.1 we have discounted those premises over 5km away from their local exchange to be able to more accurately evaluate the ISP's performance.

In November 2013, the proportion of average maximum speeds delivered during the weekday peak period ranged from 91% for EE to 94% for TalkTalk across the ADSL2+ ISP packages covered by our research. The only difference between the performance of the ADSL2+ ISP packages included in our research in November 2013 was that the average maximum download speed of Karoo's ADSL2+ service (11.5Mbit/s) was faster than the 9.3Mbit/s average maximum speed provided by TalkTalk's ADSL2+ service to a 95% level of confidence.

Figure 2.1 Maximum, average and peak-time download speeds for ADSL2+ ISP packages: November 2013

Source: SamKnows measurement data for all panel members with a connection in November 2013. Notes: (1) Includes only customers within 5km of the local exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data 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 2.2 summarises the statistically significant differences in the download speed performance of the ADSL2+ ISP packages covered in our research.

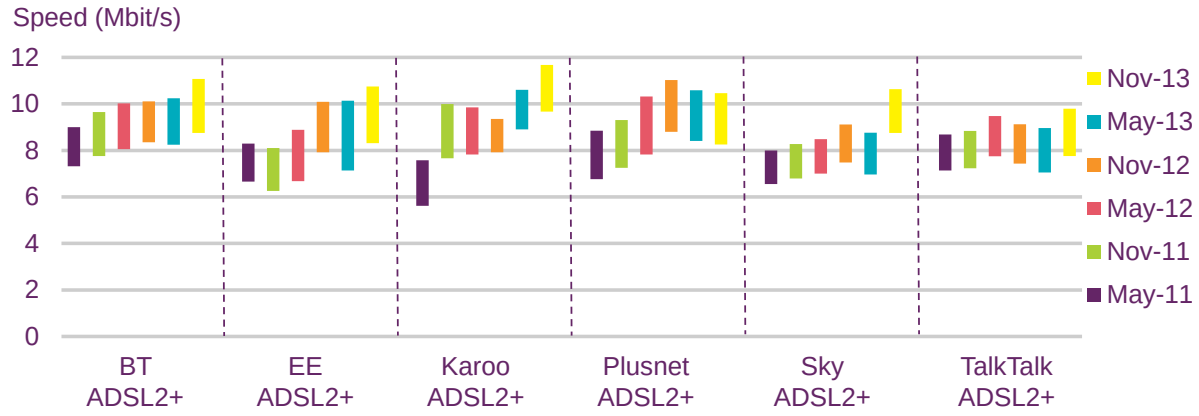
Figure 2.2 Significant difference, to a 95% confidence level, between maximum, average and peak download speeds for ADSL2+ ISP packages: November 2013

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

Source: Ofcom
**Difference not significant to a 99% level of confidence*

The average download speeds recorded in the previous periods of testing for the ADSL2+ ISP packages included in this report are shown in Figure 2.3 below. This shows that the average 24-hour download speed of Sky's ADSL2+ package increased by 1.8Mbit/s to 9.7Mbit/s in the six months to November 2013. No other changes were statistically significant.

Figure 2.3 Average download speeds for ADSL2+ ISP packages: May 2011 to November 2013



Source: SamKnows measurement data for all panel members.
Notes: (1) Only includes customers within 5km of the local exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data 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; (6) figures for O2 ADSL2+ also include Be prior to November 2013.

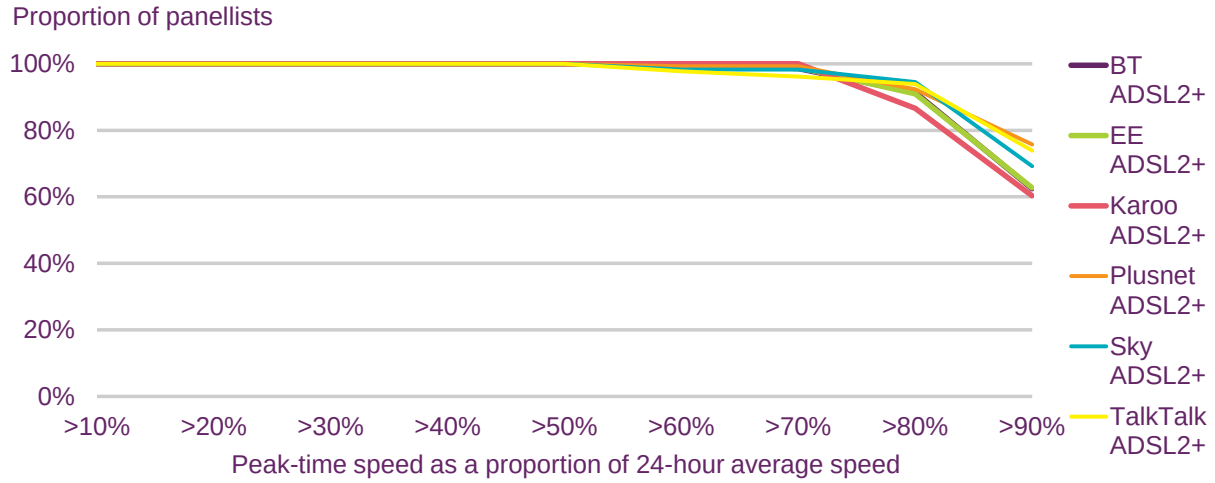
Figure 2.4 shows the distribution of our ADSL2+ panellists' average speeds during the 8pm to 10pm weekday peak period as a proportion of maximum speed delivered by their connections. The intention of this analysis is to assess whether certain panellists are disproportionately affected by network congestion.[10] Higher levels of network congestion limit achievable download speeds, and we would therefore expect to see fewer panellists

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

experiencing higher average peak speeds to maximum speed if congestion was higher, and in this analysis, higher lines indicate better performance.

Among all of the ADSL2+ ISP packages compared, more than half of panellists achieved peak-time speeds that were higher than 90% of their maximum speed. Karoo's ADSL2+ service had the lowest proportion of panellists experiencing peak-time speeds that were higher than 90% of their maximum speed in November 2013, at 60%. This suggests that there was a higher level of contention in the Karoo ADSL2+ network than in the other ISPs' ADSL2+ networks during the period. Plusnet's ADSL2+ package was the best performing ISP package analysed here, with 76% of panellists achieving peak-time speeds that were greater than 90% of their maximum speed.

Figure 2.4 Distribution of average peak-time speed as a proportion of maximum speed for ADSL2+ ISP packages: November 2013

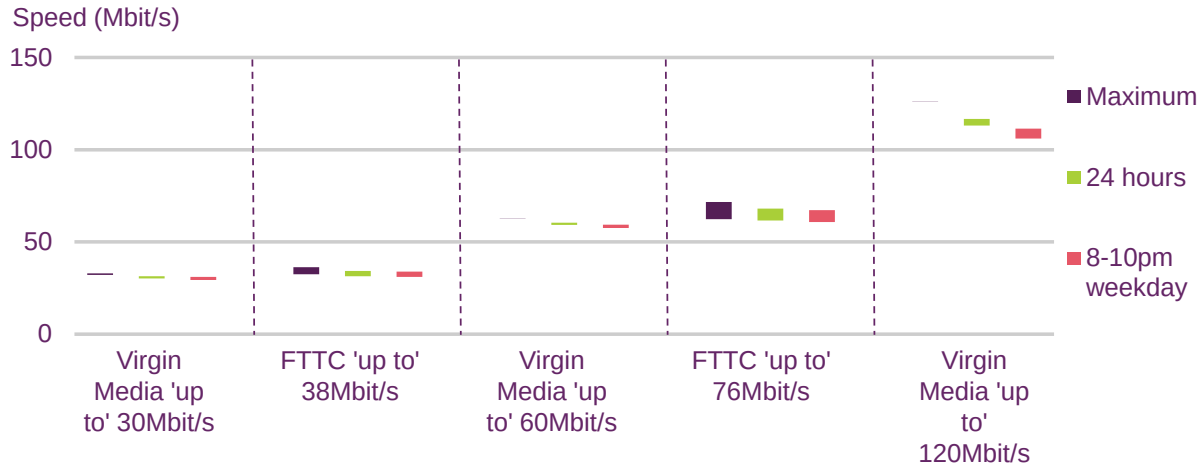


Source: SamKnows measurement data for all panel members.
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines 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.

'Up to' 30Mbit/s and higher connections

Virgin Media's 'up to' 120Mbit/s package had the fastest download speeds of the ISP packages covered in our research in terms of its average maximum speed (126.3Mbit/s), 24 hour average speed (114.9Mbit/s) and its peak-time download speed (108.8Mbit/s). 'Up to' 76Mbit/s FTTC connections had the second fastest average maximum speeds (67.0Mbit/s), 24 hour average speed (64.8Mbit/s) and peak-time download speed (64.0Mbit/s). The relative performance, in terms of maximum, 24 hour average and 8pm to 10pm weekday peak-time speeds of the superfast ISP packages covered by our research generally reflected the speeds at which they were advertised. Average peak-time speeds as a proportion of maximum speeds ranged from 86% for Virgin Media's 'up to' 120Mbit/s package to 96% for 'up to' 76Mbit/s FTTC connections. As noted previously and explained on page 14, it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

Figure 2.5 Maximum, average and peak-time download speeds for 'up to' 30Mbit/s and above ISP packages: November 2013



Source: SamKnows measurement data for all panel members with a connection in November 2013.
Notes: (1) Data for Virgin Media's cable service have been weighted to regional coverage only; (2) Data collected from multi-thread download speed tests; (3) The range shown represents a 95% confidence interval around the mean; (4) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

Figure 2.6 summarises the statistically significant differences in the download speed performance of ISP packages 'up to' 30Mbit/s and above included in our research in November 2013. Again, it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

Figure 2.6 Significant differences, to a 95% level of confidence, between maximum, average and peak-time download speeds for 'up to' 30Mbit/s and above ISP packages: November 2013

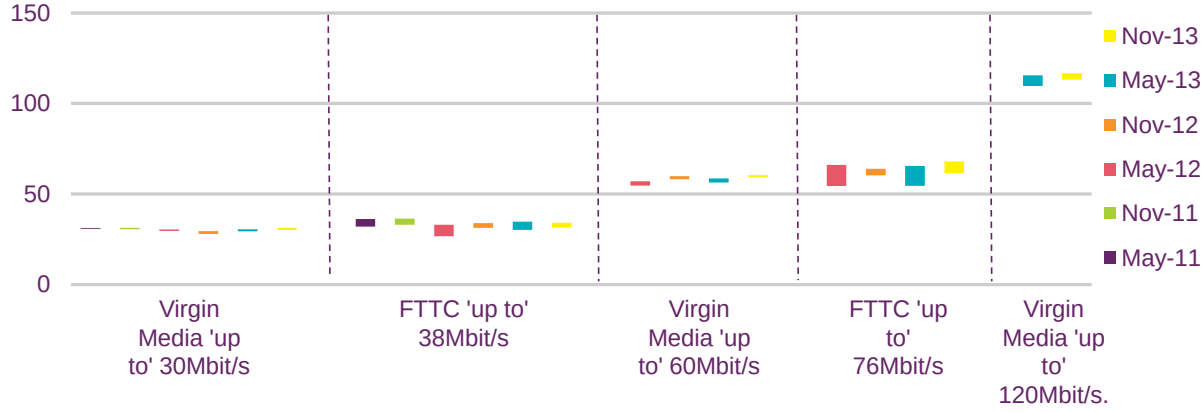
	Maximum	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**	**Is faster than...**
Virgin Media 120	FTTC 76, FTTC 38, Virgin Media 60, Virgin Media 30	FTTC 76, FTTC 38, Virgin Media 60, Virgin Media 30	FTTC 76, FTTC 38, Virgin Media 60, Virgin Media 30
FTTC 76	Virgin Media 30, FTTC 38	Virgin Media 60*, Virgin Media 30, FTTC 38	Virgin Media 60*, Virgin Media 30, FTTC 38
Virgin Media 60	FTTC 38, Virgin Media 30	FTTC 38, Virgin Media 30	FTTC 38, Virgin Media 30

Source: Ofcom
*Notes: (1) No other differences were statistically significant; *difference not significant to a 99% level of confidence. (2) It is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.*

Figure 2.7 shows the average download speeds recorded for the 'up to' 30Mbit/s and above ISP packages covered in this report over various time periods. This shows that the average download speed for Virgin Media's 'up to' 60Mbit/s package increased by 2.3Mbit/s to 59.8Mbit/s in the six months up to November 2013. There were no other statistically significant changes during this period. Again, it is not possible to draw any conclusions

regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

Figure 2.7 Average download speeds for 'up to' 30Mbit/s and above ISP packages: May 2011 to November 2013



Source: SamKnows measurement data for all panel members with a connection in November 2013.

Notes: (1) Data for Virgin Media's cable service have been weighted to regional coverage only; (2) Data collected from multi-thread download speed tests; (3) The range shown represents a 95% confidence interval around the mean; (4) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

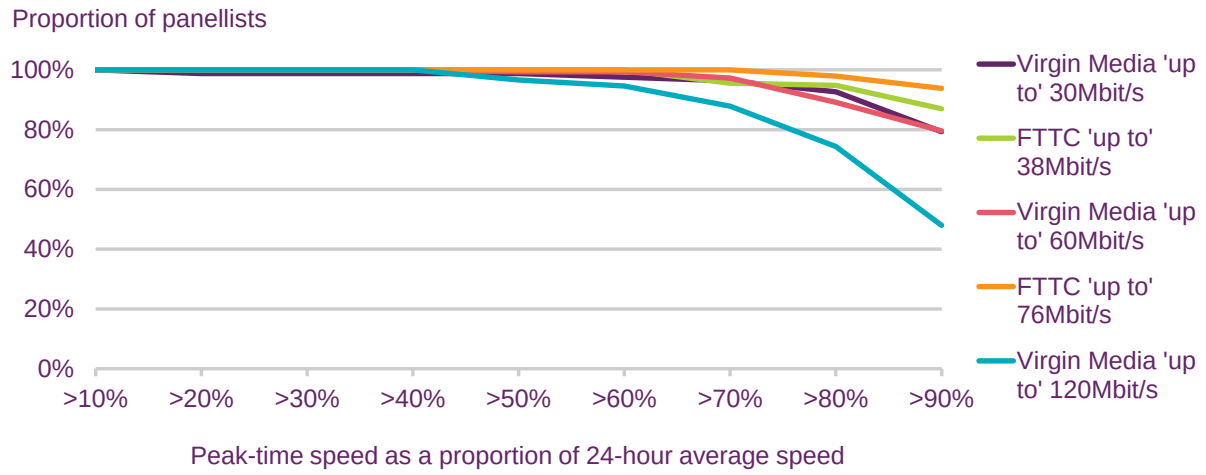
The analysis of the distribution of panellists with a headline speed of 'up to' 30Mbit/s and higher in terms of average speeds during the 8pm to 10pm peak period as a proportion of average maximum speeds shows that the proportion of panellists who received average peak-time speeds more than 90% of their maximum speed was lower among all the superfast cable services than among FTTC packages (Figure 2.8). As before, in this analysis higher lines indicate better performance.

Among the superfast ISP packages analysed, the two FTTC packages performed better than Virgin Media's cable services[11], with 94% of panellists on 'up to' 76Mbit/s FTTC service and 87% of panellists on the 'up to' 38Mbit/s FTTC service achieving peak-time download speeds that were higher than 90% of their maximum speed. Again, it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on these summary FTTC figures.

Virgin Media's 'up to' 120Mbit/s package had the lowest proportion of panellists achieving peak-time speeds higher than 90% of their maximum speed, at 48%. For Virgin Media's 'up to' 30Mbit/s package, 79% of panellists achieved peak-time speeds that were faster than 90% of their maximum speed, while for its 'up to' 60Mbit/s package, the proportion was 80%.

Figure 2.8 Distribution of average peak-time speed as a proportion of maximum speed for 'up to' 30Mbit/s and above ISP packages: November 2013

[11] In terms of the proportion of panellists who achieved peak-time download speeds that were higher than 90% of the average maximum download speed.



Source: SamKnows measurement data for all panel members.
Notes: (1) Data for Virgin Media's cable service have been weighted to regional coverage only; (2) Data collected from multi-thread download speed tests; (3) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

Summary of average download speeds of all ISP packages

Figure 2.9 summarises the average maximum, 24-hour and weekday peak period download speeds achieved by all of the ISP packages included in our research in November 2013. 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, with a 95% confidence level, that the average speed of these packages falls somewhere in the stated range. As before, it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

Figure 2.9 Summary of average download speed by ISP package: November 2013

	Average download speed during period		
	Maximum	24 hours	8-10pm weekdays
BT ADSL2+	9.5Mbit/s to 11.9Mbit/s	8.8Mbit/s to 11.1Mbit/s	8.7Mbit/s to 11.0Mbit/s
EE ADSL2+	9.0Mbit/s to 11.7Mbit/s	8.3Mbit/s to 10.8Mbit/s	8.2Mbit/s to 10.6Mbit/s
Karoo ADSL2+	10.5Mbit/s to 12.5Mbit/s	9.7Mbit/s to 11.7Mbit/s	9.5Mbit/s to 11.5Mbit/s
Plusnet ADSL2+	8.8Mbit/s to 11.1Mbit/s	8.3Mbit/s to 10.5Mbit/s	8.2Mbit/s to 10.4Mbit/s
Sky ADSL2+	9.4Mbit/s to 11.4Mbit/s	8.8Mbit/s to 10.6Mbit/s	8.7Mbit/s to 10.6Mbit/s
TalkTalk ADSL2+	8.3Mbit/s to 10.4Mbit/s	7.8Mbit/s to 9.8Mbit/s	7.7Mbit/s to 9.8Mbit/s
Virgin Media 'up to' 30Mbit/s	32.1Mbit/s to 32.9Mbit/s	30.2Mbit/s to 31.4Mbit/s	29.4Mbit/s to 31.1Mbit/s
FTTC 'up to' 38Mbit/s	32.4Mbit/s to 36.3Mbit/s	31.4Mbit/s to 34.2Mbit/s	31.0Mbit/s to 33.9Mbit/s
Virgin Media 'up to' 60Mbit/s	62.8Mbit/s to 62.8Mbit/s	59.2Mbit/s to 60.4Mbit/s	57.5Mbit/s to 59.3Mbit/s
FTTC 'up to' 76Mbit/s	62.4Mbit/s to 71.6Mbit/s	61.6Mbit/s to 68.0Mbit/s	60.8Mbit/s to 67.2Mbit/s
Virgin Media 'up to' 120Mbit/s	126.2Mbit/s to 126.4Mbit/s	113.2Mbit/s to 116.7Mbit/s	106.1Mbit/s to 111.5Mbit/s

Source: SamKnows measurement data for all panel members with a connection in November 2013. Panel Base:1,878
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (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; (6) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

Analysis of individual panellists' download speeds

This report is the tenth in which Ofcom has measured fixed-line broadband speeds, and we thought it an appropriate time to consider how a number[12] of panellists' average actual download speeds have changed over time. While some of our panellists have been taking part in our research since 2009, a change in panel management in early 2010 means that it is not possible to produce reliable like-for-like per-panellist speed comparisons for measurement periods prior to May 2010 so no data before this date has been included below. It should also be noted that there was a change to our speed testing methodology in November/December 2010 which means that the average speeds recorded prior to this are not directly comparable to those recorded from November/December 2010 onwards.[13]

The 'experience' data in this section of the report (where panellists reported issues with their connection) comes from the results of a short survey regarding connection performance when browsing, streaming making VoIP calls and gaming which some panellists completed in June 2013. In order to protect the anonymity of panellists we give only broad location data, have rounded distance from the local exchange information to the nearest 100m.

Panellists in urban areas using ADSL services in May 2010

ADSL1, which offers theoretical download speeds of up to 8Mbit/s, was first deployed in the UK in 2000. From 2005 onwards, the UK's ADSL infrastructure was improved by the roll-out of ADSL2+, which offers theoretical speeds of up to 24Mbit/s (but actual speeds that are typically much lower). This analysis considers the experiences of four panellists who live in urban areas and who were using an ADSL service in May 2010.

Although the average actual download speed in urban areas was 31.9Mbit/s in November 2013, not everyone living in an urban area benefits from fast speeds. Panellist A lives in a large city and received an average actual download speed of just 0.3Mbit/s over their ADSL1 service in May 2010. They subsequently upgraded to the same supplier's ADSL2+ service, resulting in an increase in their average download speed to 5.0Mbit/s in May 2011, and have remained on this package since, receiving stable speeds of 5.2Mbit/s from May 2012 onwards. This comparatively 'poor' performance (ADSL2+ connections with a headline

[12] We have selected 11 panellists who have been taking part in our research since at least May 2010 to give some anecdotal evidence of some consumers' experiences of the UK fixed-line broadband market over this time period.

[13] From November/December 2010 onwards we have measured actual fixed broadband speeds using multi-thread tests. Multi-thread testing represents the speeds achieved when three files are downloaded simultaneously and better represents the way in which applications and browsers retrieve data. Multi-thread tests typically record faster speeds than single-thread tests, in particular for higher-speed services: in November/December 2010 we found that, on average, multi-thread tests recorded speeds that were around 59% faster than single-thread tests for Virgin Media's 'up to' 50Mbit/s package and around 28% faster than single-thread tests for BT's 'up to' 40Mbit/s FTTC product.

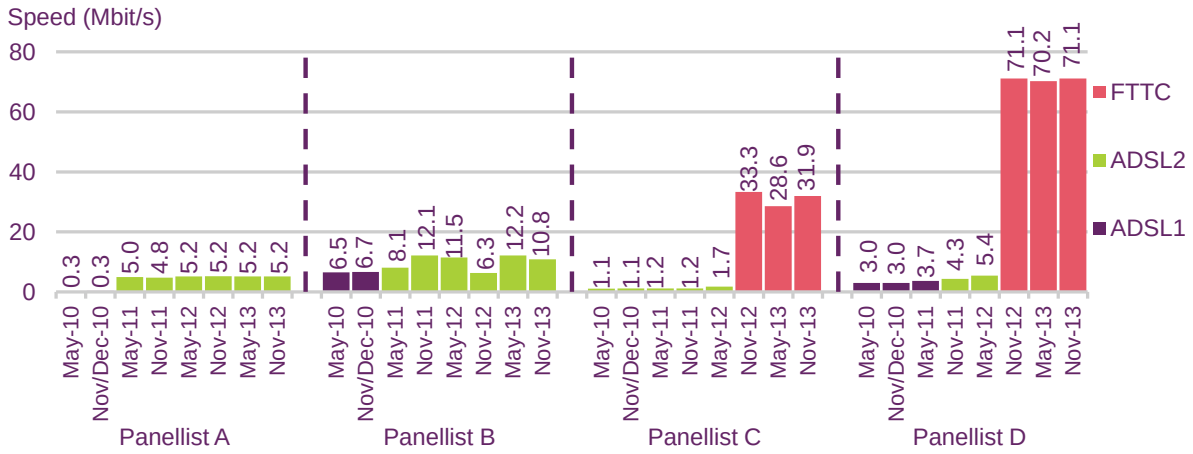
speed above 'up to' 8Mbit/s had an average speed of 7.4Mbit/s in November 2013) can be explained partially by how far Panellist A lives from the exchange: 1.5km.

In contrast, Panellist B lives less than 400m from the local exchange in a small town and therefore receives faster ADSL download speeds than Panellist A. Panellist B followed a similar upgrade path to Panellist A, and was migrated by their ISP, an LLU provider, from an ADSL1 service (over which they received an average speed of 6.7Mbit/s in November/December 2010) to an ADSL2+ service in May 2011. They recorded an average actual download speed of 10.8Mbit/s over this service in November 2013, more than twice that received by Panellist A in the same period.

Panellists C and D were both using ADSL services in May 2010 and both later opted to upgrade to superfast fibre services. Panellist C lives 4km from the local exchange in a small city and was on an LLU ADSL2+ package in May 2010. Due to the distance of the property from the exchange, Panellist C experienced poor ADSL performance and never achieved an average actual speed in excess of 2Mbit/s using this service. By November 2012, they had upgraded to an 'up to' 38Mbit/s fibre package taken from the same supplier, resulting in the average download speeds than they received increasing more than ten-fold, from 1.7Mbit/s in May 2012 to 33.3Mbit/s in November 2012.

Panellist D lives in a medium city but, similarly to Panellist C, lives relatively far from the exchange: 1.5km. In May 2010, they were using an ADSL1 service over which they experienced below-average performance, recording an average actual download speed of 3.0Mbit/s. Panellist D subsequently pro-actively sought to improve download speeds on the connection, first by upgrading to the same supplier's ADSL2+ service by November 2011, then by switching to another ISP's ADSL2+ service in May 2012. They finally upgraded to the same supplier's 'up to' 76Mbit/s fibre package in November 2012, at which point speeds on the connection increased dramatically to 71.1Mbit/s from the 5.4Mbit/s average recorded in May 2012.

Figure 2.10 Average download speeds experienced by panellists in urban areas, May 2010 to November 2013



Source: Ofcom panel.

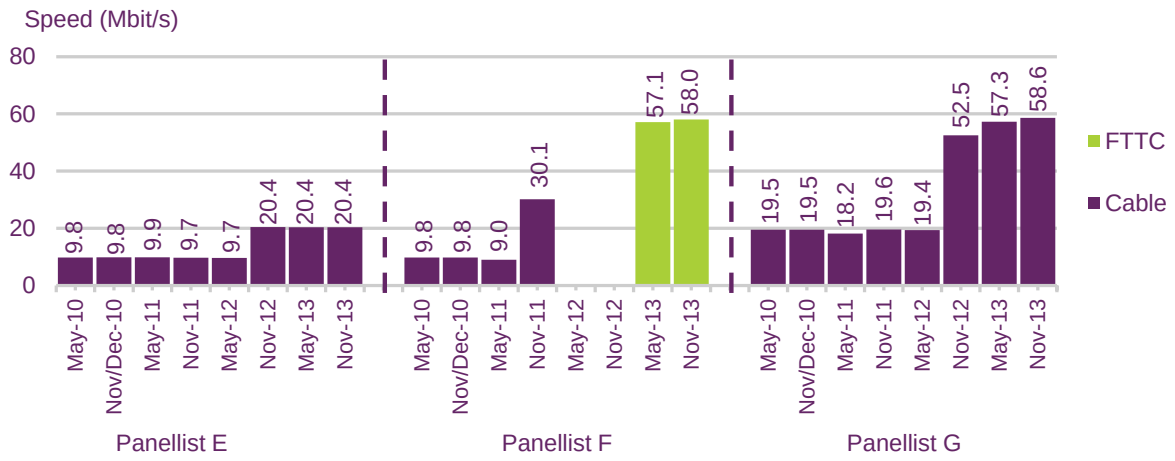
Panellists in urban areas using cable services in May 2010

Panellist E lives in a medium-sized city and was using an 'up to' 10Mbit/s cable service in May 2010, achieving average actual speeds of 9.8Mbit/s. Although Panellist E did not pro-actively change broadband provider or upgrade their package during the research period, they have benefitted from an ISP network upgrade programme, and by November 2013 were receiving speeds of 20.4Mbit/s, over twice their average download speed in May 2010.

Panellists F and G live in medium and large cities respectively. Panellist F was on an 'up to' 10Mbit/s cable service in May 2010 but upgraded to the same supplier's 'up to' 30Mbit/s package in 2011, and as a result the average download speed over their connection more than tripled from 9.0Mbit/s in May 2011 to 30.1Mbit/s in November 2011. Panellist F did not return data for May and November 2012,[14] however, by May 2013 they were using an 'up to' 76Mbit/s FTTC service, and were achieving average download speeds of 57.1Mbit/s, almost double the speed received in November 2011.

Panellist G was on an 'up to' 20Mbit/s cable service from May 2010 to May 2012 but was upgraded to the same supplier's 'up to' 60Mbit/s cable package in May 2013 as a result of the ISP's network upgrade programme. The panellist was achieving download speeds of 58.6Mbit/s by November 2013, around three times their 19.5Mbit/s average download speed in May 2010, without having to pro-actively upgrade their service.

Figure 2.11 Average download speeds experienced by panellists on cable connections in urban areas, May 2010 to November 2013



Source: Ofcom panel.

Performance of broadband connections in rural areas

Consumers in rural areas tend to receive lower speeds and are more likely to have less reliable connections than those in urban areas as a result of having longer average line lengths from the local exchange to their premises and because of the availability of superfast services being lower. This analysis considers four consumers who live in rural areas but have had different experiences of their fixed-line broadband performance.

[14] A panellist needs to achieve at least 5 valid test results for each time period within the reporting month to be included in the active panel. If this is not achieved, or if for some reason their white box becomes inactive, they will not be included in the results. Reasons for inactivity include panellists forgetting to reset the white box if, for example, they move their computer, have a power-cut or obtain a new router. Follow-up emails encourage panellists to reinstall the white box.

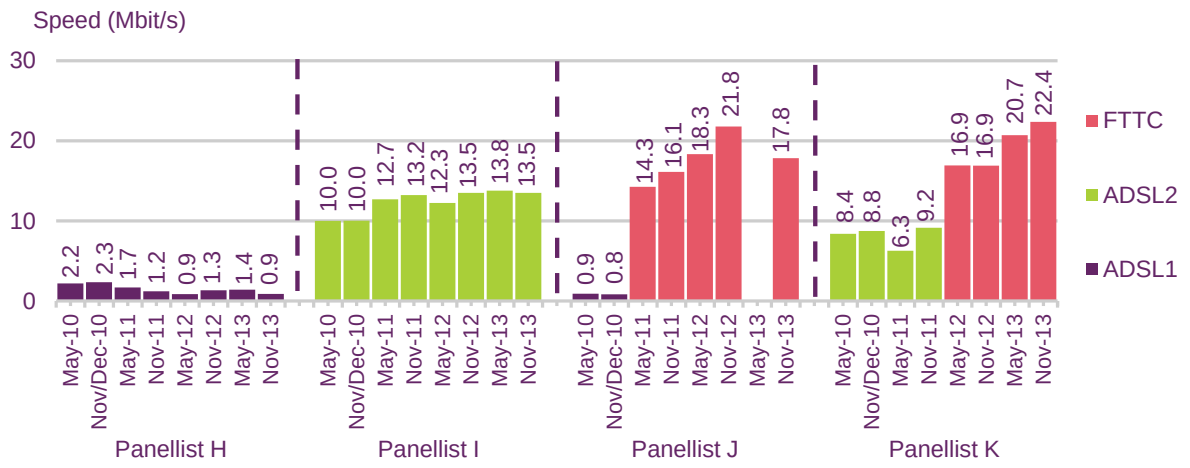
As well as living in a rural area, Panellist H lives over 5km from the local exchange and experiences poor fixed-line broadband speeds with frequent issues. Panellist H was on an ADSL1 service in May 2010 but switched to another supplier's ADSL1 in May 2012 in an attempt to receive a more stable service. Panellist H switched again in November 2012 to a third supplier's ADSL1 service and has remained with this supplier since, but has not received average speeds in excess of 3Mbit/s during the research period.

Panellist I also lives over 5km from the local exchange in a rural area but achieved an average speed of 13.5Mbit/s in November 2013 over an ADSL2+ package. A line over 5km is not usually able to support such a high average speed, and we think that the line is subjected to boosting in some way to achieve this performance. The user reports occasional issues with webpages being slow to load and 1-2 "freezes" when streaming, but this is a similar to the experience of people living a much shorter distance from the exchange.

Panellist J is a rural customer who lives closer to exchange than Panellists H and I, around 3.3km away. In May 2010, Panellist J was an ADSL1 customer and was achieving average download speeds of around 0.9Mbit/s. By May 2011, they had upgraded to an 'up to' 38Mbit/s FTTC package, over which they received an average actual download speed of 14.3Mbit/s, and by May 2012 they had moved to the same ISP's 'up to' 76Mbit/s FTTC package, achieving an average download speed of 18.3Mbit/s. As the average speed recorded over their connection was less than 20Mbit/s, Panellist J was moved to the same supplier's 'up to' 15Mbit/s FTTC package, which is reserved for customers who cannot achieve higher speeds on fibre connections. On this package, Panellist J achieved speeds of 17.8Mbit/s in November 2013 and was paying the same price as their ISP's equivalent ADSL service.

Panellist K lives in a rural area but lives closer to the exchange: 1.4km away. In May 2010, they were an ADSL2+ and remained on this package until May 2012, by when they had upgraded to the same supplier's FTTC service. Due to the rurality of the area and the distance between the cabinet and the panellist's premises, Panellist K, like Panellist J, is on their ISP's 'up to' 15Mbit/s FTTC package, and they achieved an average download speed of 22.4Mbit/s in November 2013. The panellist reports occasional issues with VoIP quality and slow loading of webpages but otherwise has a good streaming experience.

Figure 2.12 Average download speeds experienced by panellists in rural areas, May 2010 to November 2013



Source: Ofcom panel.

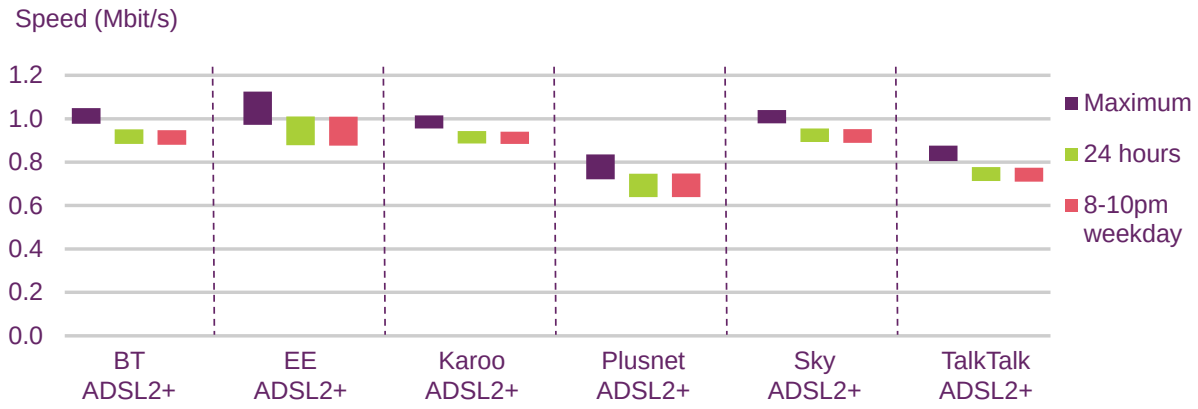
Upload speeds

As mentioned previously, broadband connections work both ways, as they have an upstream as well as a downstream direction. Upload speeds are important to those looking to share large files, use real-time two-way video communications and for some online gaming. We therefore also consider upload speeds in our research.

ADSL2+ connections

EE, Sky, BT and Karoo's ADSL2+ packages were all faster than TalkTalk and Plusnet's ADSL2+ packages in terms of their average maximum, 24 hour and peak-time upload speeds in November 2013. Both TalkTalk and Plusnet had 24 hour average upload speeds of 0.7Mbit/s, compared to 0.9Mbit/s for all of the other ADSL2+ packages included in our research (Figure 2.13).

Figure 2.13 Maximum, average and peak-time upload speeds for ADSL2+ ISP packages: November 2013



Source: SamKnows measurement data for all panel members with a connection in November 2013.
Notes: (1) Includes only customers within 5km of the local exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data 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 2.14 Significant differences, to a 95% level of confidence, between maximum, average and peak-time upload speeds for ADSL2+ ISP packages: November 2013

	Maximum	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**	**Is faster than...**
EE	TalkTalk & Plusnet	TalkTalk & Plusnet	TalkTalk & Plusnet
Sky	TalkTalk & Plusnet	TalkTalk & Plusnet	TalkTalk & Plusnet
BT	TalkTalk & Plusnet	TalkTalk & Plusnet	TalkTalk & Plusnet
Karoo	TalkTalk & Plusnet	TalkTalk & Plusnet	TalkTalk & Plusnet

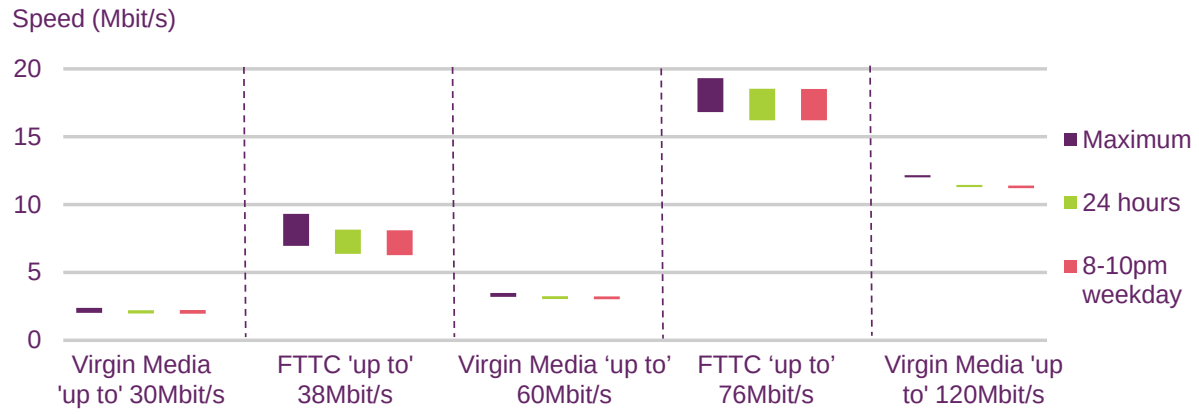
Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

'Up to' 30Mbit/s and higher connections

Among ISP packages with headline speeds 'up to' 30Mbit/s and above, FTTC connections with a headline speed of 'up to' 76Mbit/s had the fastest upload speeds in terms of their maximum, 24 hour average and peak-time upload speeds. The 24 hour average upload speed for these connections was 17.4Mbit/s, 10.1Mbit/s faster than the 24 hour average upload speed on FTTC connections 'up to' 38Mbit/s (7.3Mbit/s). Again, it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

The 24 hour average upload speed on Virgin Media's 'up to' 60Mbit/s package was 3.1Mbit/s, which was 1.0Mbit/s faster than the 24 hour average upload speed on Virgin Media's 'up to' 30Mbit/s package (2.1Mbit/s). The 24 hour average upload speed on Virgin Media's 'up to' 120Mbit/s package was 11.4Mbit/s. In November 2013, the proportion of average maximum upload speeds delivered during the weekday peak period ranged from 88% for 'up to' 38Mbit/s FTTC packages to 96% for 'up to' 76Mbit/s FTTC packages across the superfast packages covered by our research.

Figure 2.15 Maximum, average and peak-time upload speeds for 'up to' 30Mbit/s and above ISP packages: November 2013



Source: SamKnows measurement data for all panel members with a connection in November 2013). Notes: (1) Data for Virgin Media's cable service have been weighted to regional coverage only; (2) Data collected from multi-thread download speed tests; (3) The range shown represents a 95% confidence interval around the mean; (4) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

Figure 2.16 Significant differences, to a 95% level of confidence, between maximum, average and peak-time upload speeds for 'up to' 30Mbit/s and above ISP packages: November 2013

	Maximum	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**	**Is faster than...**
FTTC 76	Virgin Media 120, FTTC 38, Virgin Media 60, Virgin Media 30	Virgin Media 120, FTTC 38, Virgin Media 60, Virgin Media 30	Virgin Media 120, FTTC 38, Virgin Media 60, Virgin Media 30
Virgin Media 120	FTTC 38, Virgin Media 60, Virgin Media 30	FTTC 38, Virgin Media 60, Virgin Media 30	FTTC 38, Virgin Media 60, Virgin Media 30
FTTC 38	Virgin Media 60, Virgin Media 30	Virgin Media 60, Virgin Media 30	Virgin Media 60, Virgin Media 30
Virgin Media 60	Virgin Media 30	Virgin Media 30	Virgin Media 30

Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence. (1) It is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.*

Section 3

Other metrics affecting performance

There are a number of other metrics which can be used to evaluate fixed-line broadband performance, and the most important of these are outlined below in Figure 3.1. 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 different ISP packages. In this section we compare the performance of different ISP packages with respect to these metrics.

Figure 3.1 Summary of additional metrics covered in the research

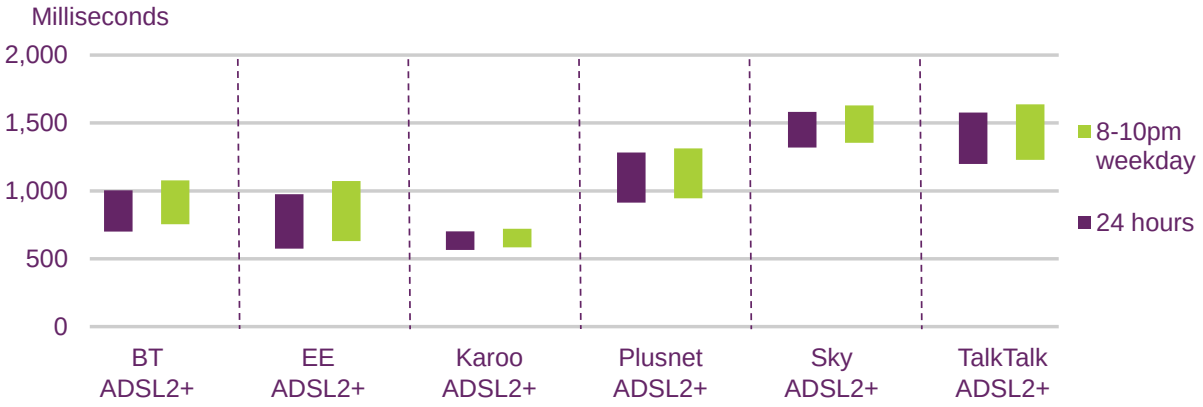
Variable	Definition and importance
Web browsing speed	**The time taken to fetch the main HTML and assets (text, basic code and content files) from a webpage** *Dependent on download speeds, latency and DNS resolution times*
Latency	**The time it takes a packet of data to travel to a third-party server 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 assess the basic web browsing performance of packages with different headline speeds, 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 figures 3.2 and 3.4 better performance equates to faster loading times, which are shown by lower bars.

Figure 3.2 Average and peak-time loading of web pages for ADSL2+ ISP packages: November 2013
(Lower values indicate better performance)



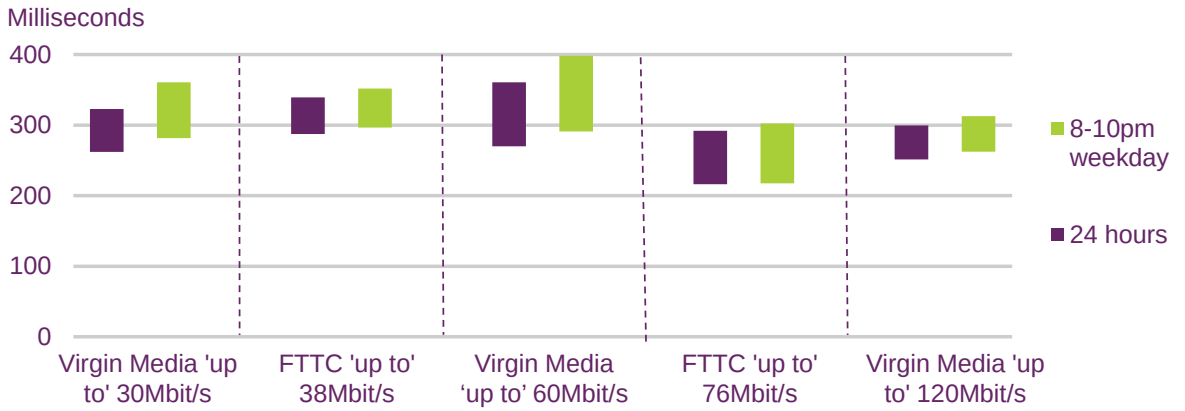
Source: SamKnows measurement data for all panel members with a connection in November 2013.
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to 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 for AOL Broadband, EE, Plusnet and TalkTalk were excluded as the measurement values had a large variance, and their sample was insufficient (5) Data collected from multi-thread download speed tests; (6) The range shown represents a 95% confidence interval around the mean; (7) Better performance is indicated by a faster loading time, i.e. lower values.

Figure 3.3 Significant difference, to a 95% level of confidence, between average and peak-time loading of web pages for ADSL2+ ISP packages: November 2013

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

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

Figure 3.4 Average and peak-time loading of web pages for 'up to' 30Mbit/s and above ISP packages: November 2013
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in November 2013.
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (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; (6) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

Figure 3.5 Significant differences, to a 95% level of confidence, between average and peak-time loading of web pages for 'up to' 30Mbit/s and above ISP packages: November 2013

	24 hours	8-10pm weekday
ISP package	Is faster than...	Is faster than...
No differences	No differences	No differences

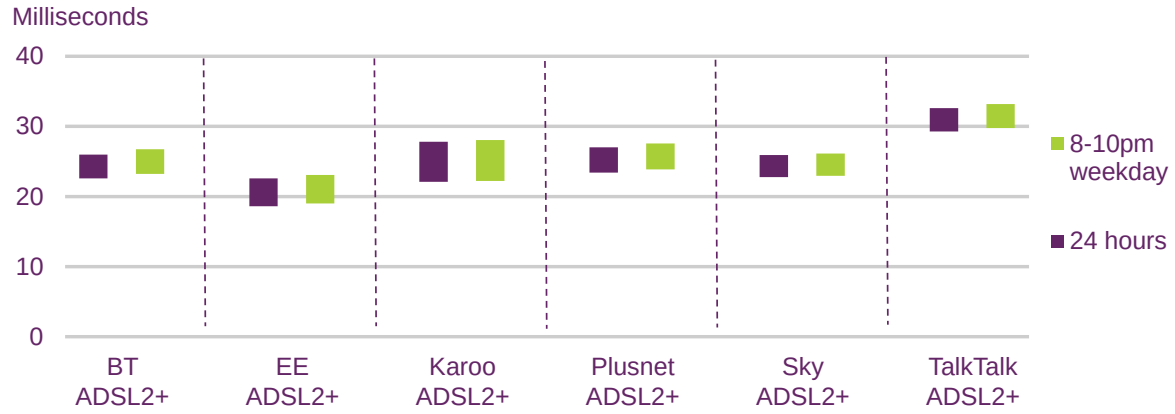
Source: Ofcom
*Notes: (1) No differences were statistically significant; *difference not significant to a 99% level of confidence; (2) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.*

Latency

Latency is 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 seem more responsive in the delivery of simple tasks like web browsing. Certain applications, particularly some games, perform far better with lower latency. Note that in Figures 3.6 and 3.8 better performance equates to lower latency, which is indicated by lower bars.

Figure 3.6 Average and peak-time latency for ADSL2+ ISP packages: November 2013

(Lower values indicate better performance)



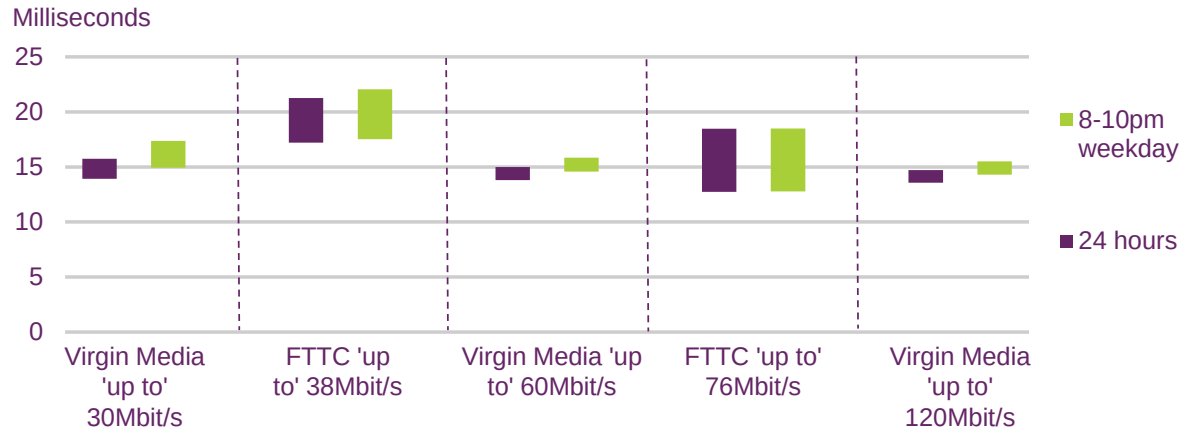
Source: SamKnows measurement data for all panel members with a connection in November 2013.
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to 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; (6) Better performance is indicated by a low speed (i.e. lower values).

Figure 3.7 Significant differences, to a 95% level of confidence, between average and peak-time latency for ADSL2+ ISP packages: November 2013

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

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

Figure 3.8 Average and peak-time latency for 'up to' 30Mbit/s and above ISP packages: November 2013
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in November 2013.
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (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; (6) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

Figure 3.9 Significant differences, to a 95% level of confidence, between average and peak-time latency for 'up to' 30Mbit/s and above ISP packages: November 2013

	24 hours	8-10pm weekday
ISP package	Is better than...	Is better than...
Virgin Media 120	FTTC 38	FTTC 38
Virgin Media 60	FTTC 38	FTTC 38
Virgin Media 30	FTTC 38	FTTC 38*

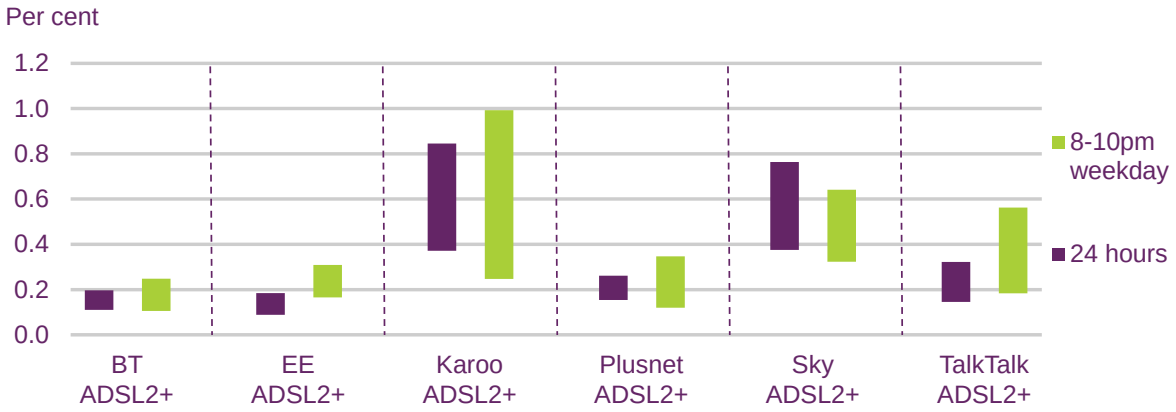
Source: Ofcom
*Notes: (1) No other differences were statistically significant; *difference not significant to a 99% level of confidence; (2) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.*

Packet loss

Packets of data can be lost during transmission over an internet connection. Packet loss can considerably degrade the performance of real-time applications, and although network 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 slow-down.

This can be a major concern for online gamers, users of voice over IP (VoIP) telephony and those streaming audio or video content (a small number of dropped packets is generally acceptable, as each packet in the test accounts for only 0.2 seconds, but extended periods of loss lead to choppy and broken-up video and audio). Note that in figure 3.10 and figure 3.12 better performance equates to lower packet loss, which is indicated by lower bars.

Figure 3.10 Average and peak-time packet loss for ADSL2+ ISP packages: November 2013
(Lower bars indicate better performance)



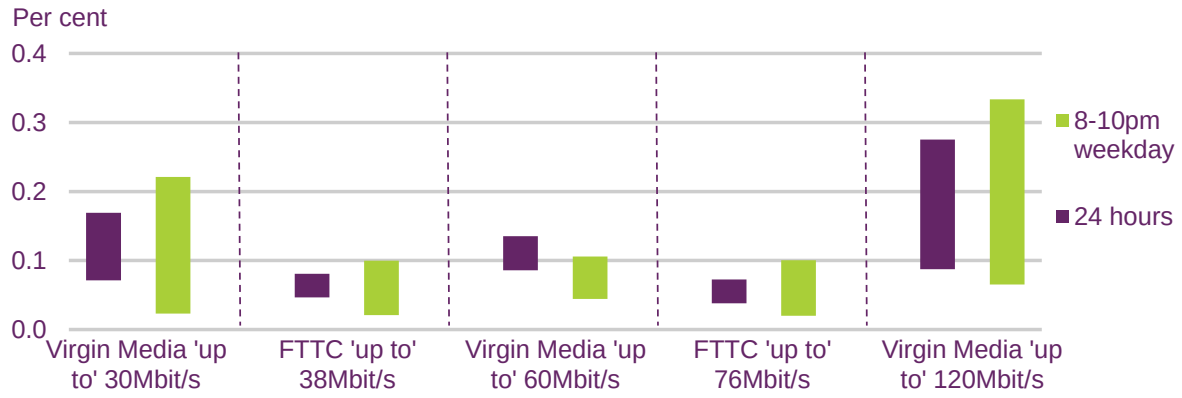
Source: SamKnows measurement data for all panel members with a connection in November 2013
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to 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; (6) Note that better performance is indicated by lower packet loss (i.e. lower values).

Figure 3.11 Significant differences, to a 95% level of confidence, between average and peak-time packet loss for ADSL2+ ISP packages: November 2013

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
EE	Sky & Karoo	Sky*
BT	Sky & Karoo	Sky*
Plusnet	Sky & Karoo	No differences
TalkTalk	Sky* & Karoo*	No differences

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

Figure 3.12 Average and peak-time packet loss for 'up to' 30Mbit/s and above ISP packages: November 2013
(Lower bars indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in November 2013
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (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; (6) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

Figure 3.13 Significant differences, to a 95% level of confidence, between average and peak-time packet loss for 'up to' 30Mbit/s and above ISP packages: November 2013

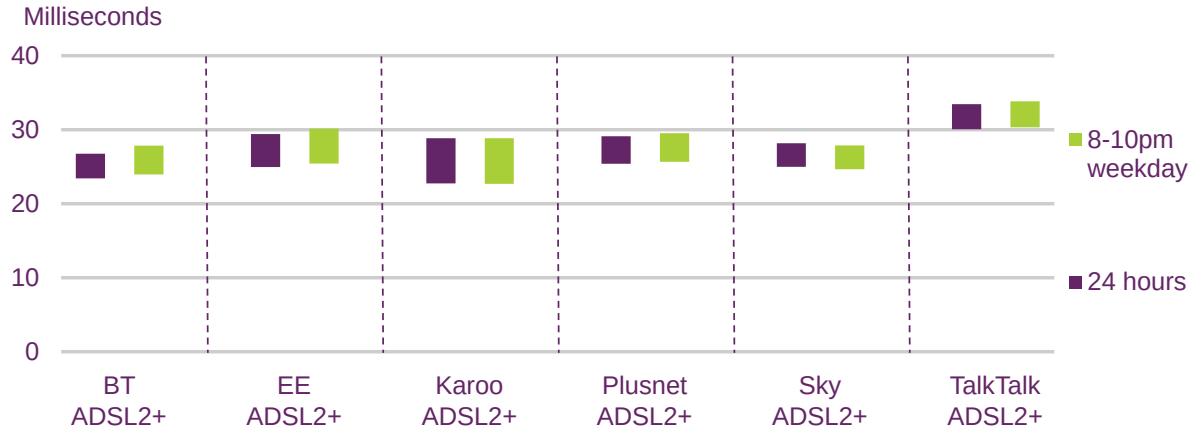
	24 hours	8-10pm weekday
ISP package	Is better than...	Is better than...
FTTC 76	Virgin Media 120*, Virgin Media 60	No differences
FTTC 38	Virgin Media 120*, Virgin Media 60*	No differences

Source: Ofcom
*Notes: (1) No differences were statistically significant; *difference not significant to a 99% level of confidence; (2) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.*

DNS resolution

DNS (the domain name service) plays a crucial role in the way the internet operates. This protocol translates domain names (such as ofcom.org.uk) into the IP addresses that are actually 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 servers fail or operate slowly, web browsing and other online activities suffer. A slow DNS time does not affect download speed, but can severely affect the responsiveness of the internet while browsing. Note that in Figures 3.14 and 3.16 better performance equates to faster resolution times, which are indicated by lower bars.

Figure 3.14 Average and peak-time DNS resolution time for ADSL2+ ISP packages: November 2013
(Lower bars indicate better performance)



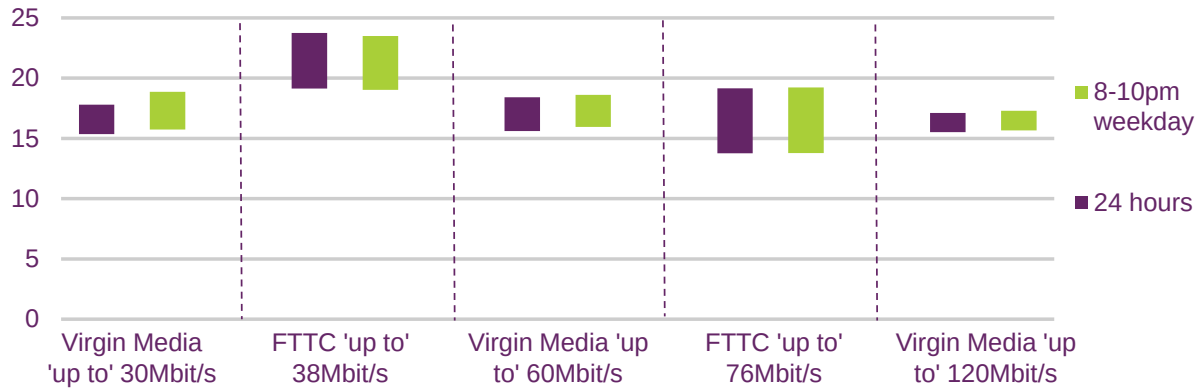
Source: SamKnows measurement data for all panel members with a connection in November 2013.
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to 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; (6) Note that better performance is indicated by faster resolution times (i.e. lower values).

Figure 3.15 Significant differences, to a 95% level of confidence, between average and peak-time DNS resolution time for ADSL2+ ISP packages: November 2013

	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**
BT	TalkTalk	TalkTalk
Sky	TalkTalk	TalkTalk
Plusnet	No differences	TalkTalk*
Karoo	TalkTalk*	TalkTalk*

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

Figure 3.16 Average and peak-time DNS resolution time for 'up to' 30Mbit/s and above ISP packages: November 2013
(Lower bars indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in November 2013.

Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (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; (6) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

Figure 3.17 Significant differences, to a 95% level of confidence, between average and peak-time DNS resolution time for 'up to' 30Mbit/s and above ISP packages: November 2013

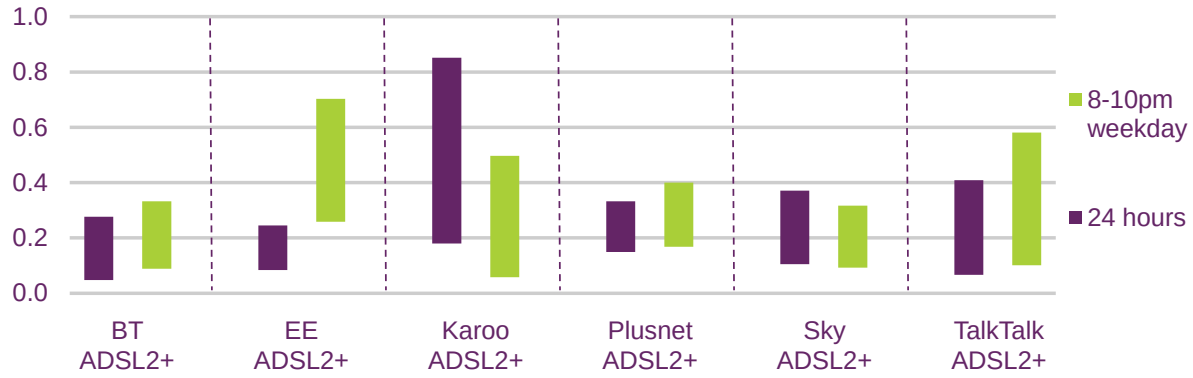
	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**
Virgin Media 120	FTTC 38	FTTC 38
Virgin Media 30	FTTC 38	FTTC 38
FTTC 76	FTTC 38*	FTTC 38*
Virgin Media 60	FTTC 38*	FTTC 38

Source: Ofcom
*Notes: (1) No other differences were statistically significant; *difference not significant to a 99% level of confidence; (2) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.*

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 be found"*, and is unable to access the requested page on that occasion. Note that in figures 3.18 and 3.20 better performance equates to short times, which are indicated by lower bars.

Figure 3.18 Average and peak-time DNS failure rates for ADSL2+ ISP packages: November 2013
(Lower values indicate better performance)



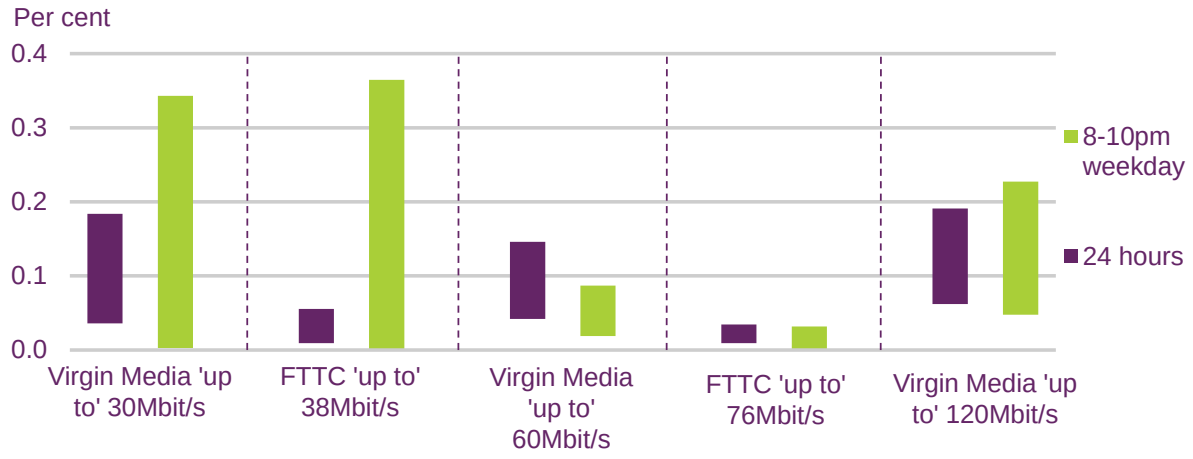
Source: SamKnows measurement data for all panel members with a connection in November 2013.
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to 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; (6) Note that better performance is indicated by faster resolution times (i.e. lower values).

Figure 3.19 Significant differences, to a 95% level of confidence, between average and peak-time DNS failure rates for ADSL2+ ISP packages: November 2013

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
No differences	No differences	No differences

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

Figure 3.20 Average and peak-time DNS failure rates for 'up to' 30Mbit/s and above ISP packages: November 2013
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in November 2013
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic

Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (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; (6) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

Figure 3.21 Significant differences, to a 95% level of confidence, between average and peak-time DNS failure rates for 'up to' 30Mbit/s and above ISP packages: November 2013

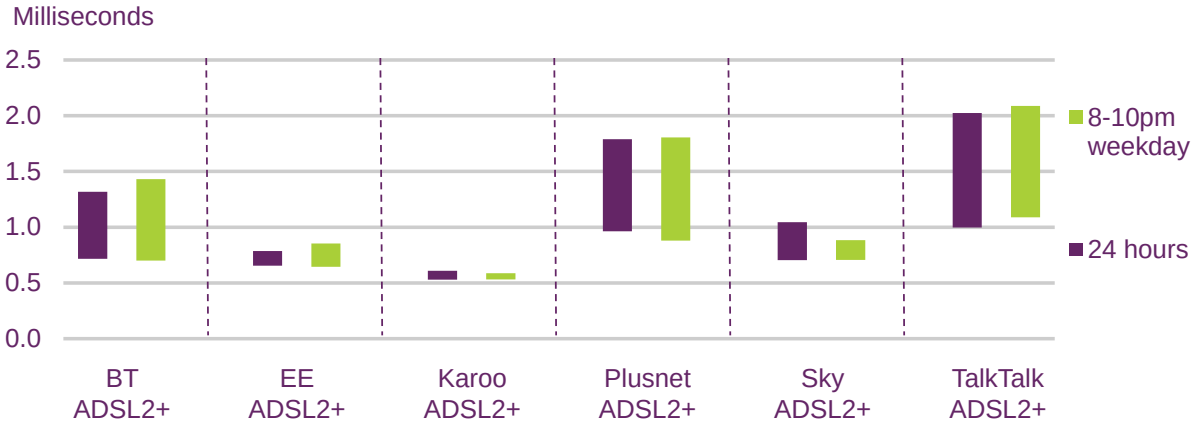
	24 hours	8-10pm weekday
ISP package	Is better than...	Is better than...
FTTC 76	Virgin Media 120	Virgin Media 120*
FTTC 38	Virgin Media 120*	No differences

Source: Ofcom
*Notes: (1) No other differences were statistically significant; *difference not significant to a 99% level of confidence; (2) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.*

Jitter

'Jitter' is defined as the rate of change of latency. The lower the measure of jitter, the more stable a connection is. 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 figures 3.22, 3.24, 3.26 and 3.28 better performance equates to shorter times, which are indicated by lower bars.

Figure 3.22 Average and peak-time upstream jitter for ADSL2+ ISP packages: November 2013
(Lower bars indicate better performance).



Source: SamKnows measurement data for all panel members with a connection in November 2013.
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators

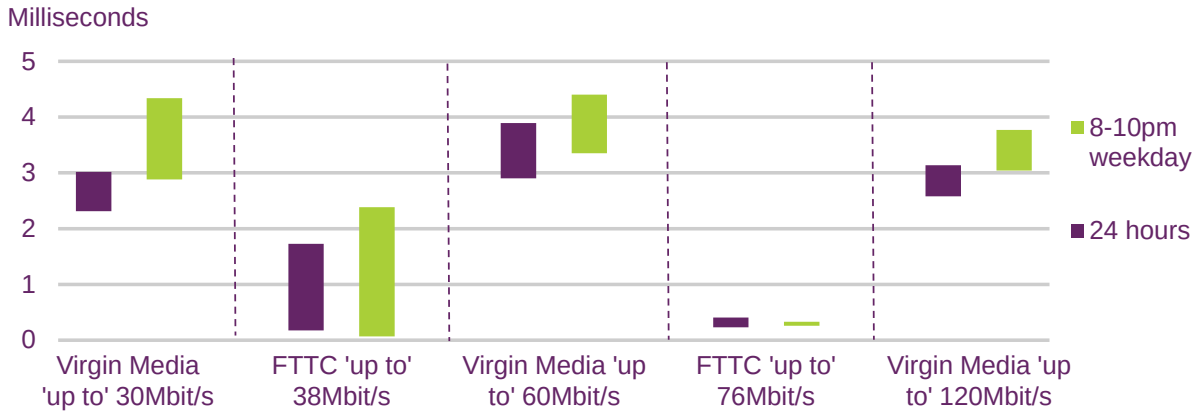
have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Note that better performance is indicated by shorter times (i.e. lower values).

Figure 3.23 Significant differences, to a 95% level of confidence, between average and peak-time upstream jitter for ADSL2+ ISP packages: November 2013

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

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

Figure 3.24 Average and peak-time upstream jitter for 'up to' 30Mbit/s and above ISP packages: November 2013
(Lower values indicate better performance)



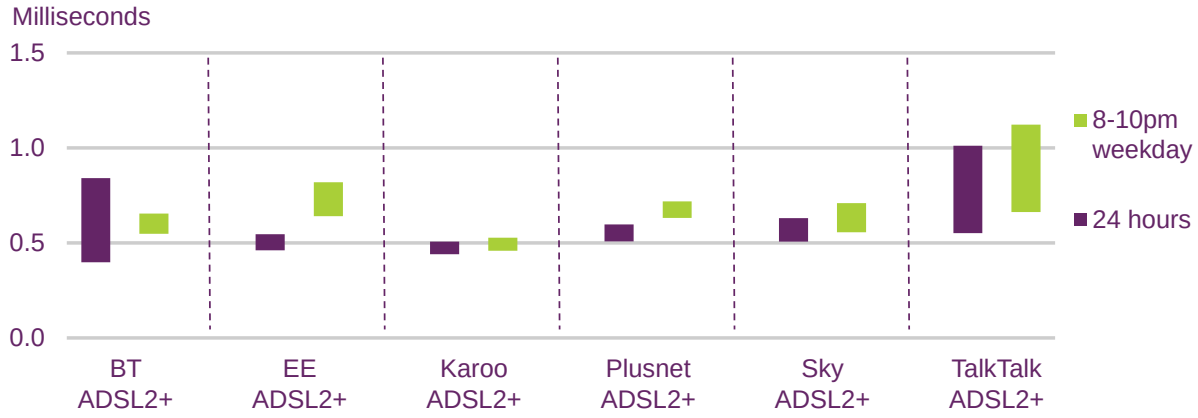
Source: SamKnows measurement data for all panel members with a connection in November 2013.
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) 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; (6) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

Figure 3.25 Significant differences, to a 95% level of confidence, between average and peak-time upstream jitter for 'up to' 30Mbit/s and above ISP packages: November 2013

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
FTTC 76	Virgin Media 120, Virgin Media 60, Virgin Media 30	Virgin Media 120, Virgin Media 60, Virgin Media 30
FTTC 38	Virgin Media 120, Virgin Media 60, Virgin Media 30	Virgin Media 120, Virgin Media 60, Virgin Media 30

Source: Ofcom
*Notes: (1) No other differences were statistically significant; *difference not significant to a 99% level of confidence; (2) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.*

Figure 3.26 Average and peak-time downstream jitter for ADSL2+ ISP packages: November 2013
(Lower bars indicate better performance).



Source: SamKnows measurement data for all panel members with a connection in November 2013.
Notes: (1) Includes only ADSL customers within 5km of the local 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; (6) Note that better performance is indicated by shorter times (i.e. lower values).

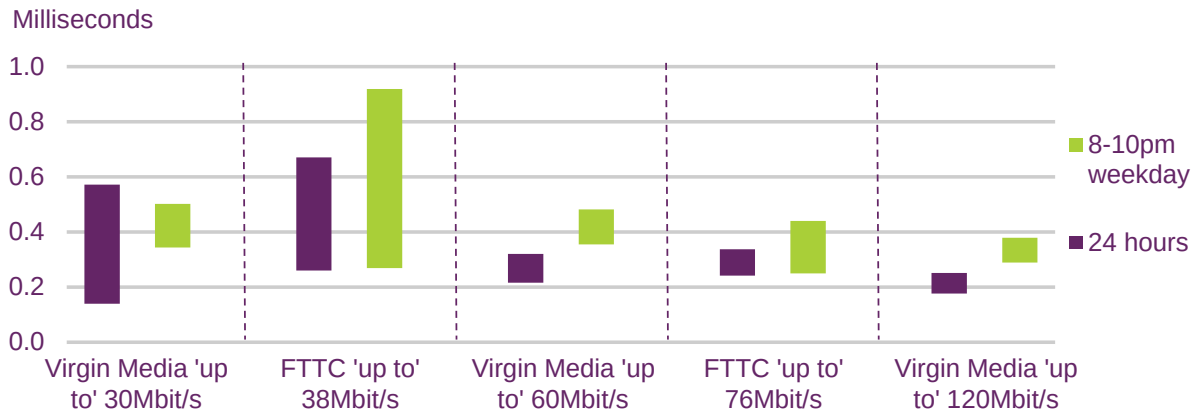
Figure 3.27 Significant differences, to a 95% level of confidence, between average and peak-time downstream jitter for ADSL2+ ISP packages: November 2013

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

Source: Ofcom

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

Figure 3.28 Average and peak-time downstream jitter for 'up to' 30Mbit/s and above ISP packages: November 2013
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in November 2013.
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (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; (6) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

Figure 3.29 Significant differences, to a 95% level of confidence, between average and peak-time downstream jitter for 'up to' 30Mbit/s and above ISP packages: November 2013

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
No differences	No differences	No differences

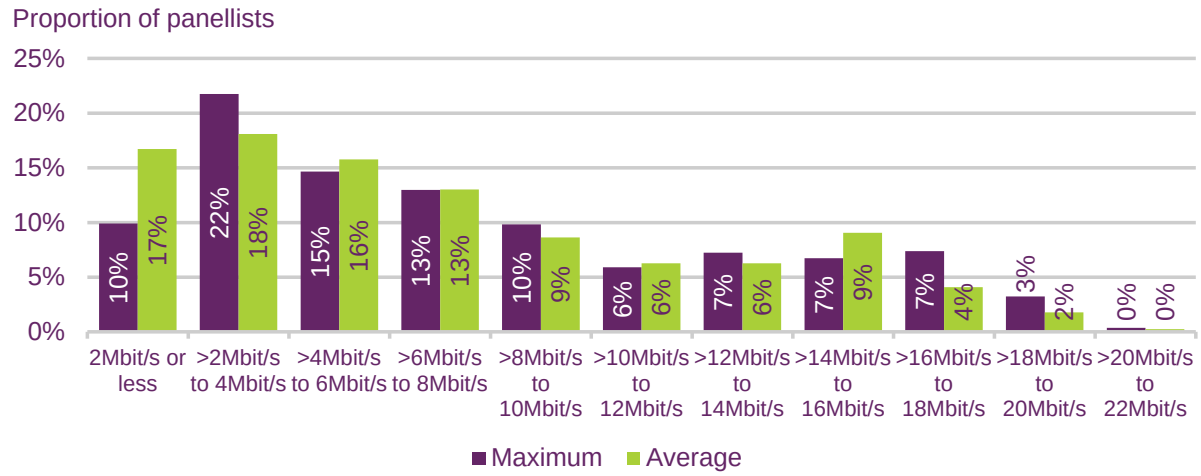
Source: Ofcom
*Notes: (1) No other differences were statistically significant; *difference not significant to a 99% level of confidence; (2) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.*

Annex 1

Additional Analysis

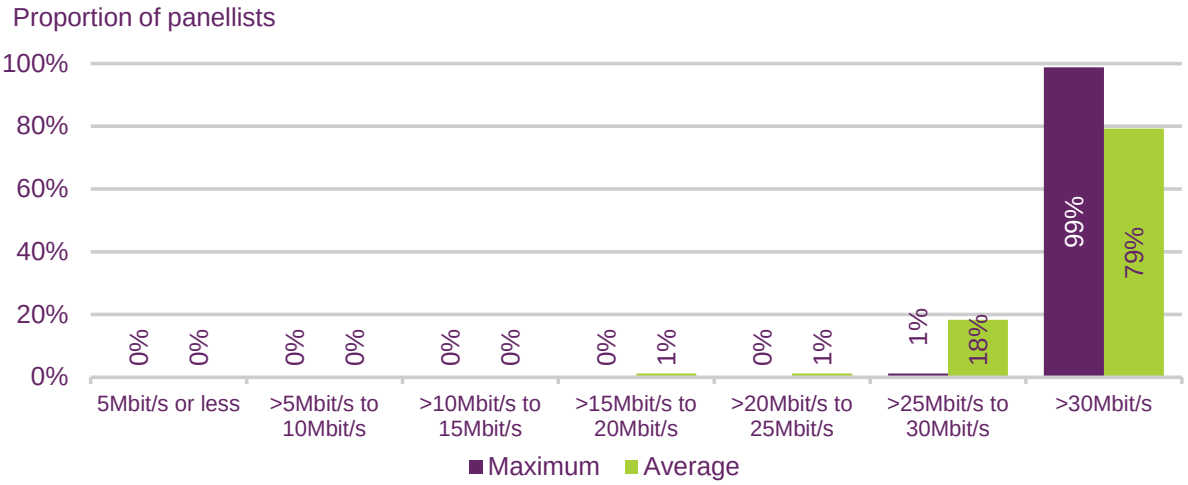
The distribution of actual broadband speeds

Figure 1 Distribution of maximum and average download speeds for ADSL2+ packages: November 2013



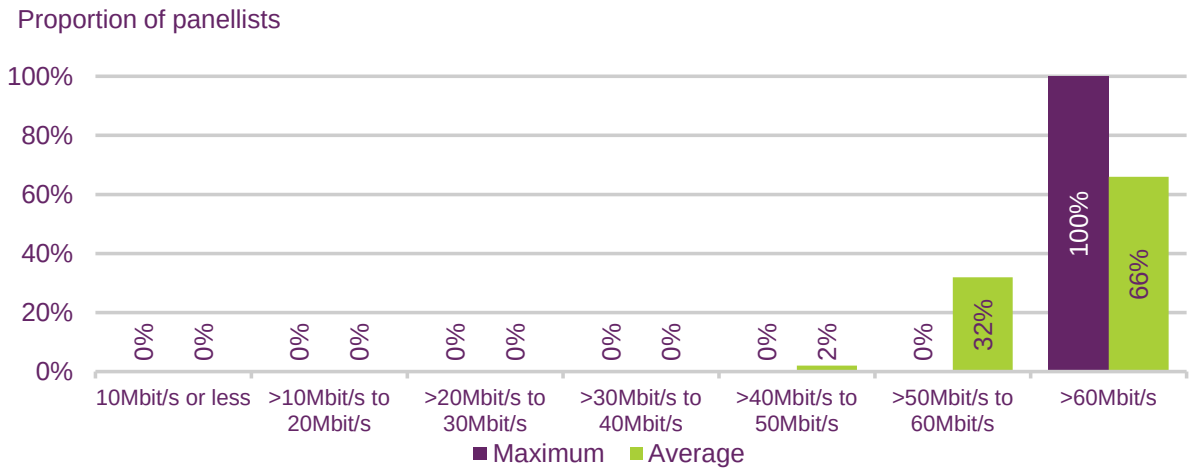
Source: SamKnows measurement data for panel members with a connection in November 2013. Unweighted Panel size: 984
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK ADSL2+ residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 2 Distribution of maximum and average download speeds for 'up to' 30Mbit/s cable packages: November 2013



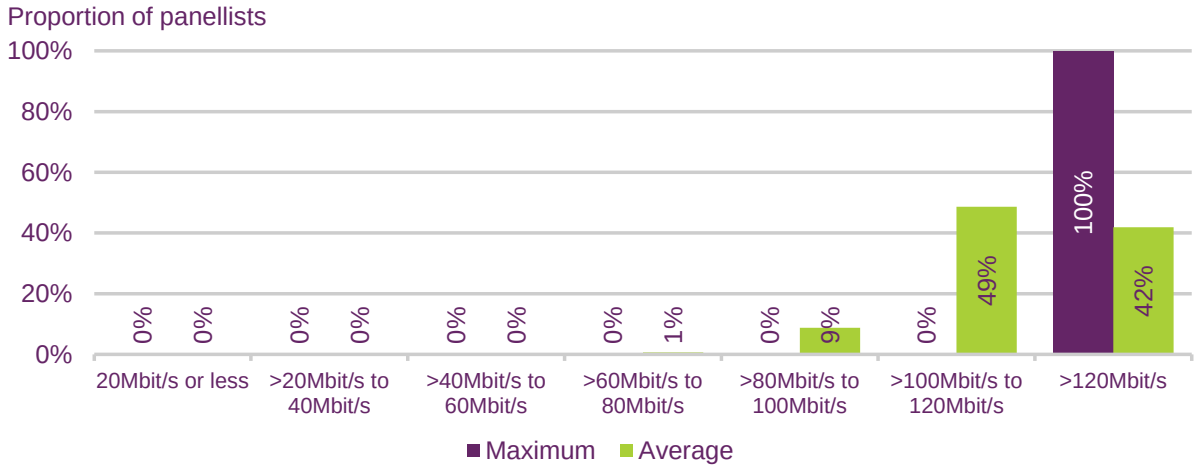
Source: SamKnows measurement data for panel members with a connection in November 2013. Unweighted Panel size: 109
Notes: (1) Data collected from multi-thread download speed tests.

Figure 3 Distribution of maximum and average download speeds for 'up to' 60Mbit/s cable packages: November 2013



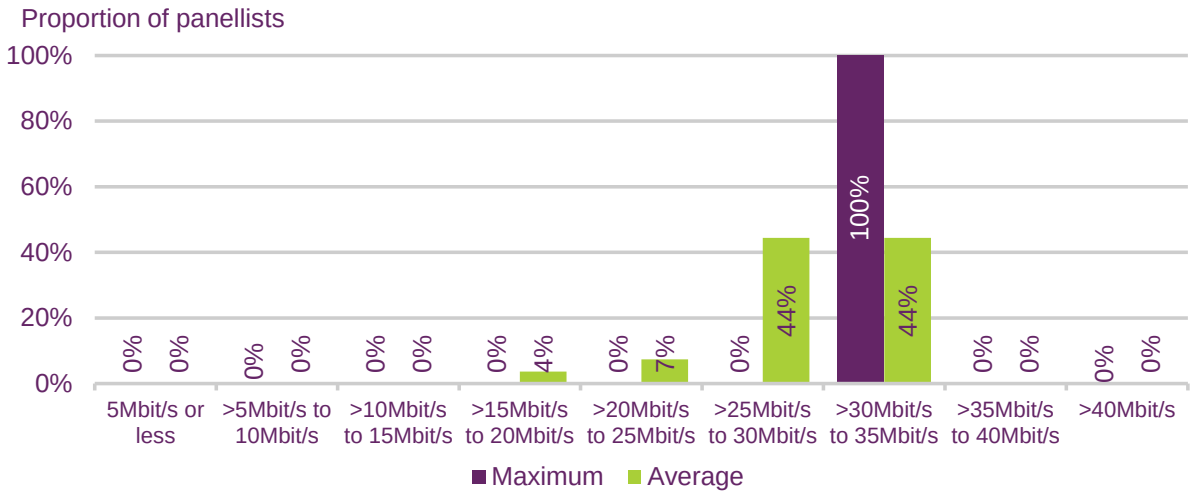
Source: SamKnows measurement data for panel members with a connection in November 2013.
Unweighted Panel size: 84
Notes: (1) Data collected from multi-thread download speed tests.

Figure 4 Distribution of maximum and average download speeds for 'up to' 120Mbit/s cable packages: November 2013



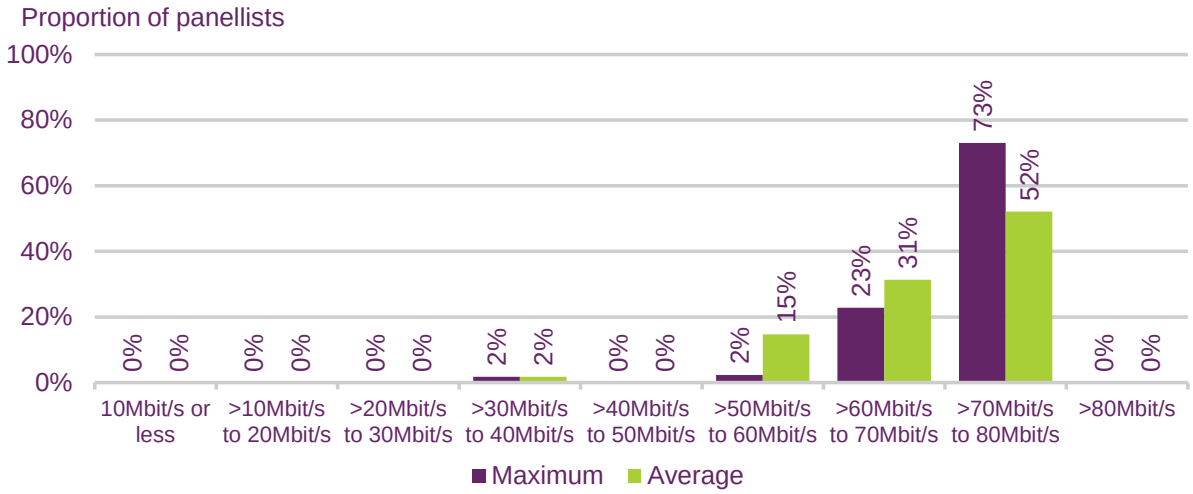
Source: SamKnows measurement data for panel members with a connection in November 2013.
Unweighted Panel size: 36
Notes: (1) Data collected from multi-thread download speed tests.

Figure 5 Distribution of maximum and average download speeds for 'up to' 38Mbit/s FTTC packages: November 2013



Source: SamKnows measurement data for panel members with a connection in November 2013.
Unweighted Panel size: 89
Notes: (1) Data collected from multi-thread download speed tests.

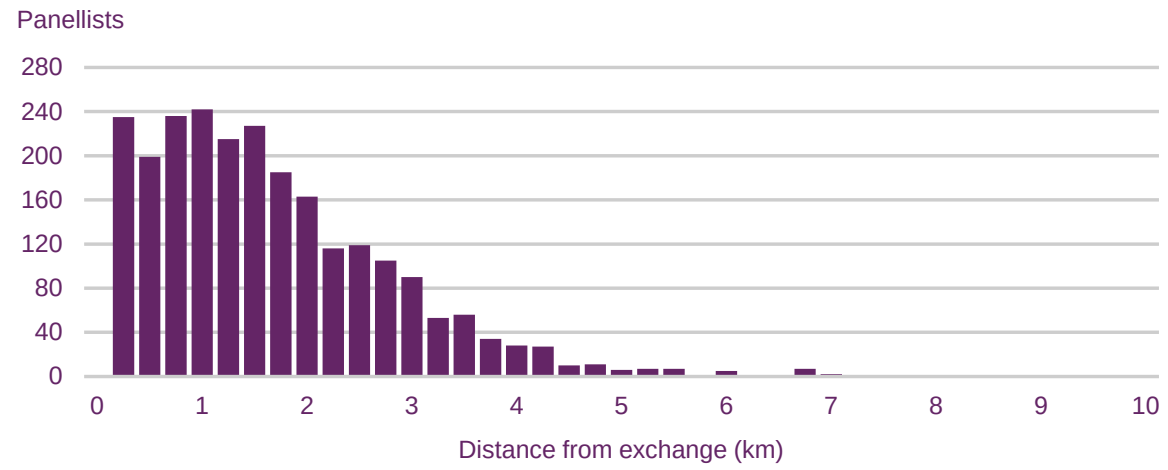
Figure 6 Distribution of maximum and average download speeds for 'up to' 76Mbit/s FTTC packages: November 2013



Source: SamKnows measurement data for panel members with a connection in November 2013.
Unweighted Panel size: 34
Notes: (1) Data collected from multi-thread download speed tests.

Variation of speeds by geographic location

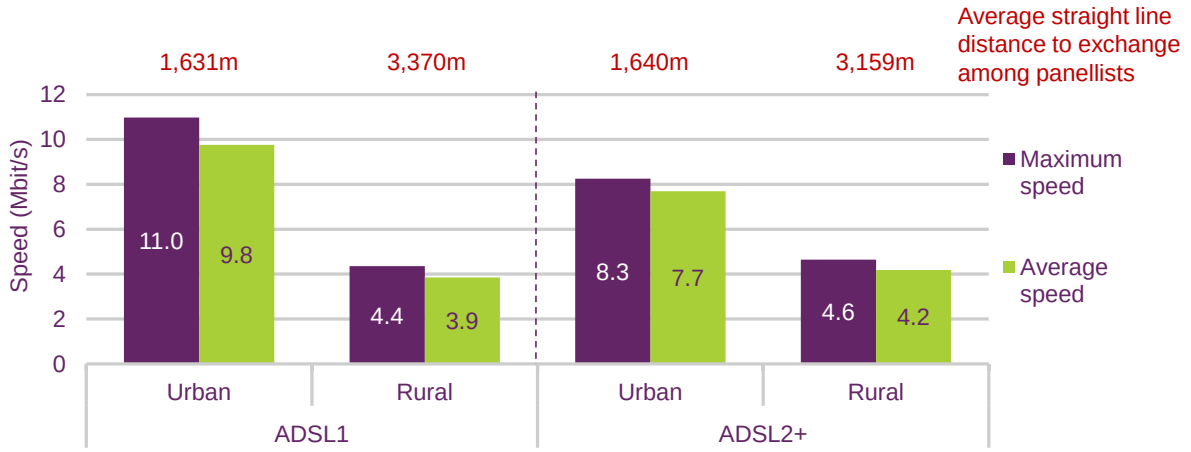
Figure 7 Distribution of panellists, by distance from exchange



Source: Ofcom, using data supplied by SamKnows
Unweighted Panel size: 2,391

Geographic market situation[15]

Figure 8 Average and maximum download speeds for ADSL broadband connections in rural and urban areas: November 2013

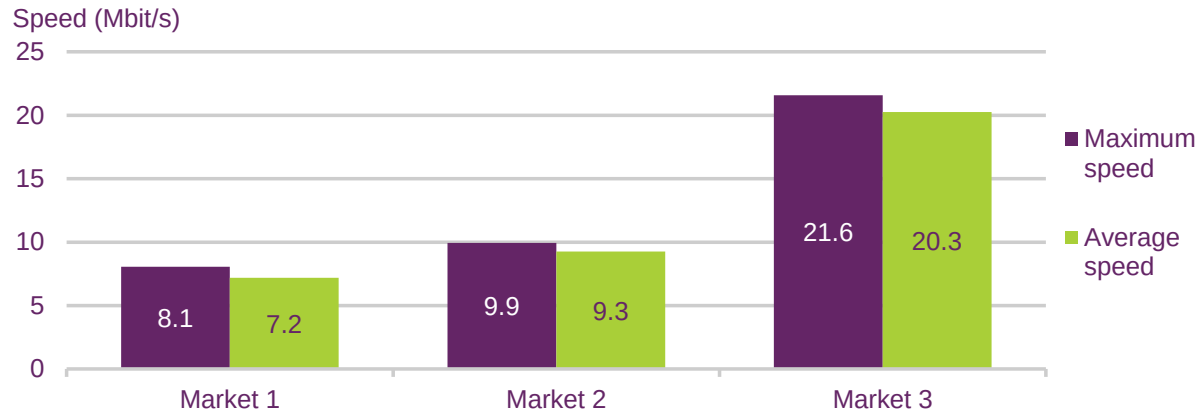


Source: SamKnows measurement data for all panel members with a connection in November 2013.
Unweighted Panel size: 984

[15] The geographic markets used are those identified by Ofcom in the *Review of the wholesale 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). These are:
Market 1: exchanges where only BT is present or forecast to be present;
Market 2: exchanges where two Principal Operators (operators capable of providing a material constraint in the market) 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%; and
Market 3: 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%.

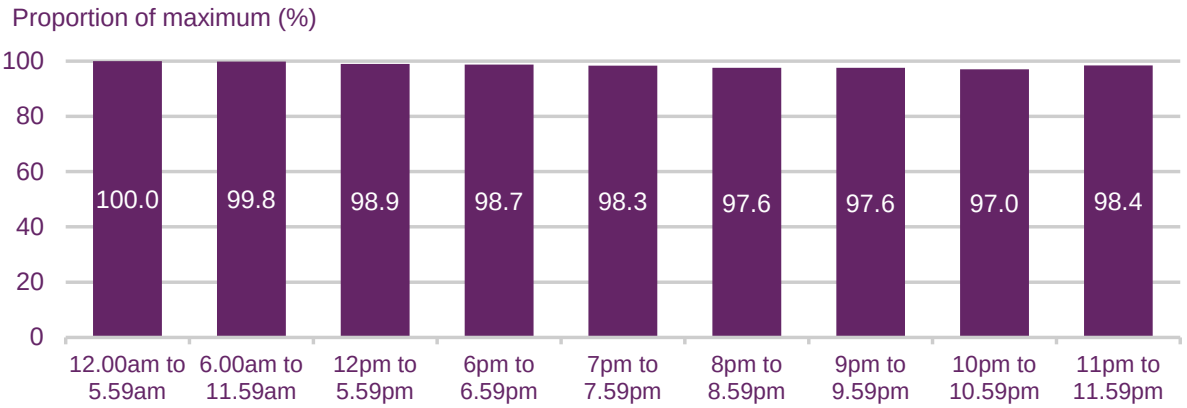
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests

Figure 9 Average and maximum download speeds, by geographic market: November 2013



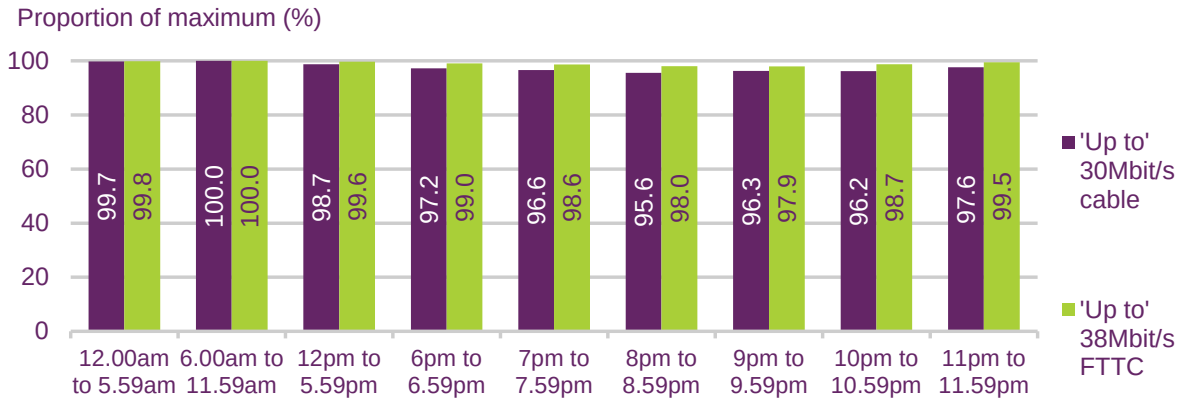
Source: SamKnows measurement data for all panel members with a connection in November 2013. Unweighted Panel size: 984
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative 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 2013 and an estimated split between rural and urban areas; (3) Data collected from multi-thread download speed tests.

Figure 10 Average download speed as a proportion of maximum speed by time of day for ADSL2+ ISP packages: November 2013



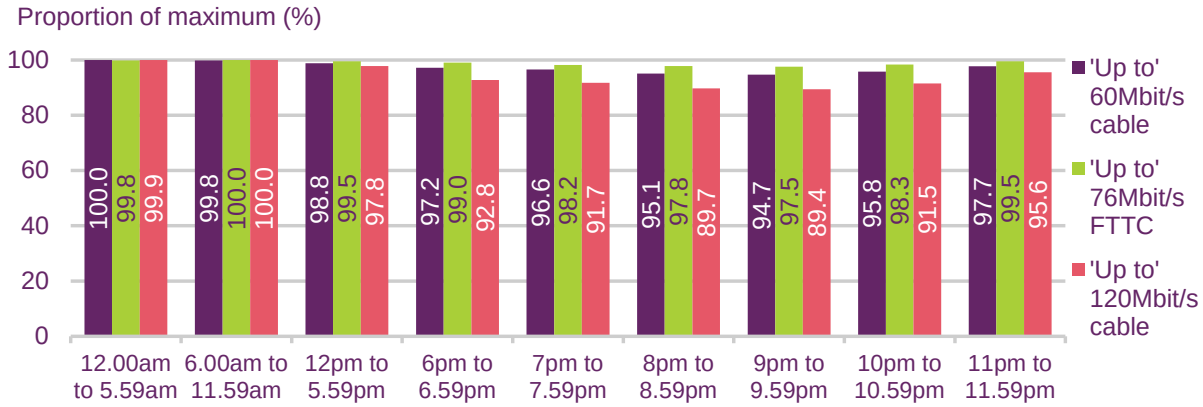
Source: SamKnows measurement data for all panel members with a connection in November 2013. Unweighted Panel size: 441
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK ADSL2+ residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 11 Average download speed as a proportion of maximum speed, by time of day for above 'up to' 30Mbit/s and 'up to' 38Mbit/s ISP packages: November 2013



Source: SamKnows measurement data for all panel members with a connection in November 2013. Unweighted Panel size: Virgin Media 'up to' 30Mbit/s 80, BT 'up to' 38Mbit/s 40 and Other 'up to' 38Mbit/s 48
Notes: (1) Data collected from multi-thread download speed tests

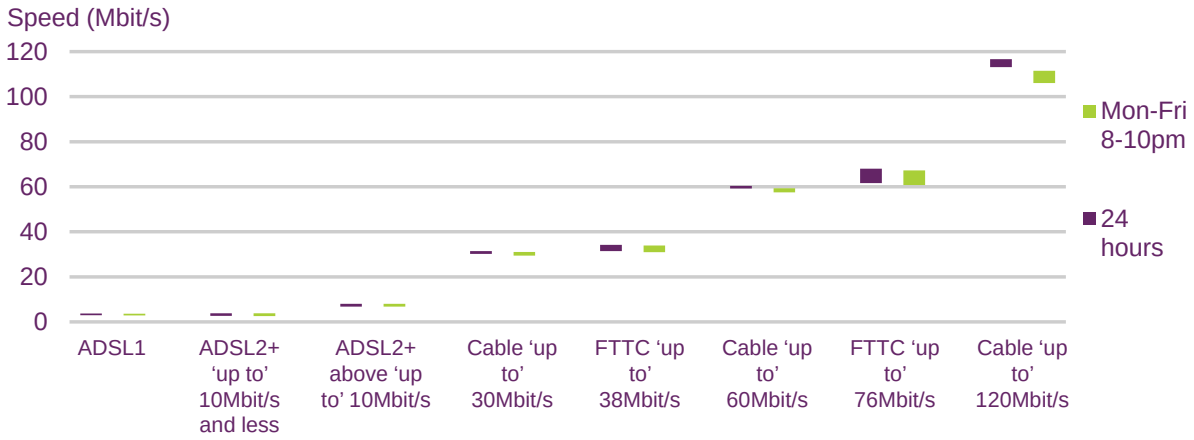
Figure 12 Average download speeds as a proportion of maximum speed, by time of day for 'up to' 60Mbit/s, 'up to' 76Mbit/s and 'up to' 120Mbit/s ISP packages: November 2013



Source: SamKnows measurement data for all panel members with a connection in November 2013. Unweighted Panel size: Virgin Media 'up to' 60Mbit/s 84, Virgin Media 'up to 120 Mbits' 27, BT "up to 76 Mbit/s" 48, Plusnet "up to 76 Mbit/s" 13, and Other "up to 76 Mbit/s" 5.
Notes: (1) Data collected from multi-thread download speed tests.

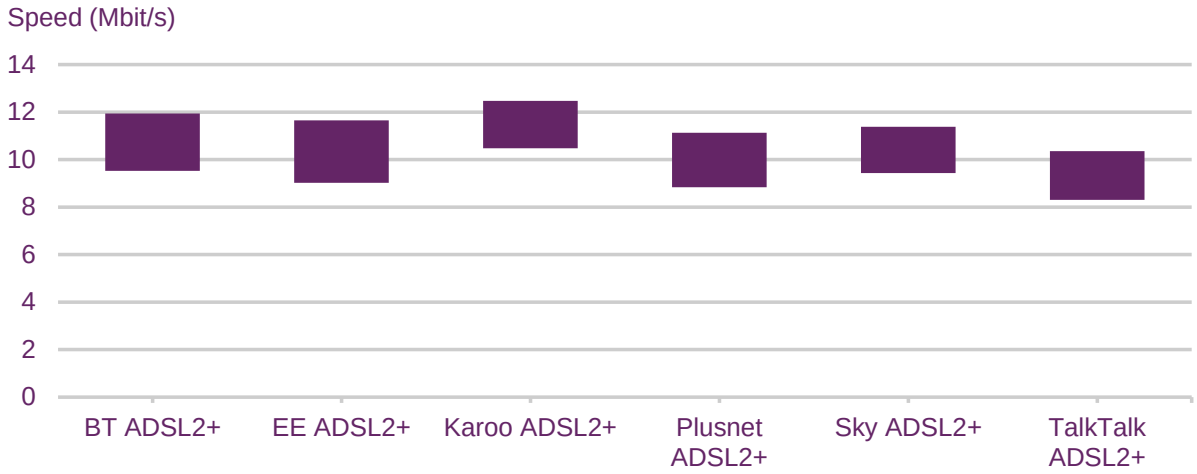
Variation in speeds, by access technology

Figure 13 Average download speeds, by technology and headline speed: November 2013



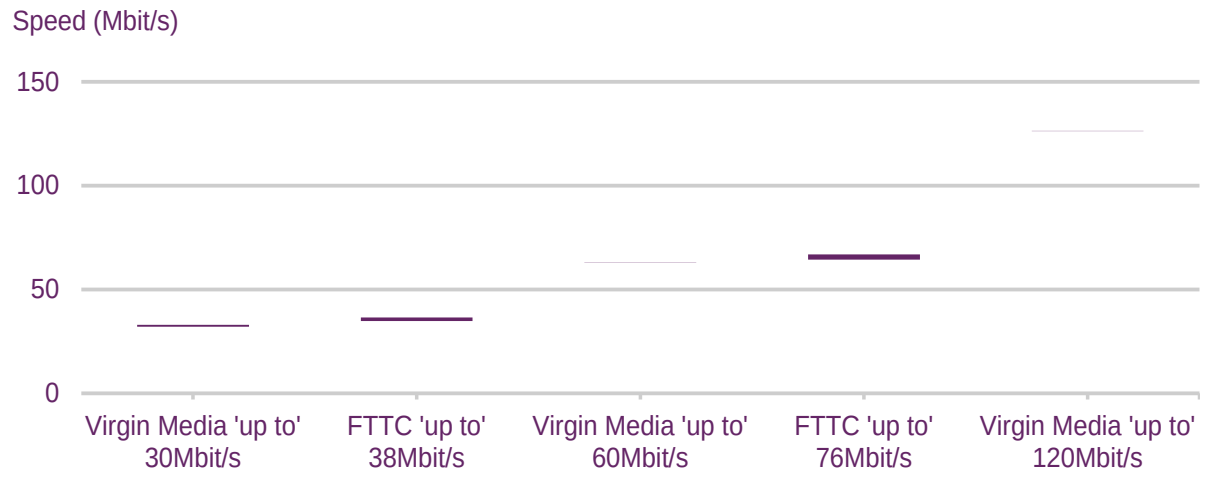
Source: SamKnows measurement data for all panel members with a connection in November 2013. Unweighted Panel size: 849
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative 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 2013; (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean.

Figure 14 Maximum download speeds for ADSL2+ ISP packages: November 2013



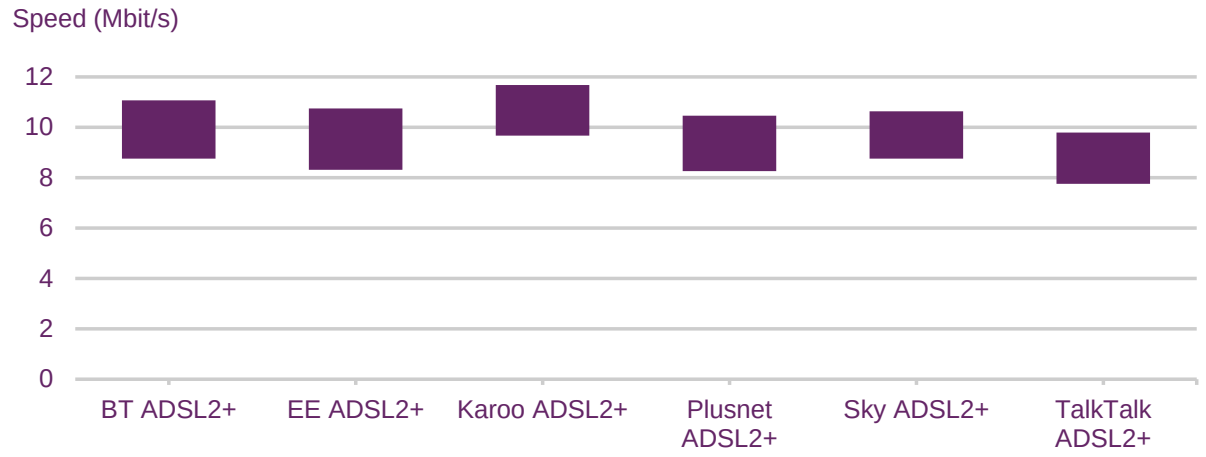
Source: SamKnows measurement data for all panel members with a connection in November 2013. Unweighted Panel size: BT ADSL 2+ 81, EE ADSL2+ 52,Karoo ADSL 2+ 74, Plusnet ADSL 2+ 92, Sky ADSL 2+ 122 and Talk Talk ADSL 2+ 95
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators has been weighted for distance from exchange; data for Virgin Media's cable service is not weighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 15 Maximum download speeds for 'up to' 30Mbit/s and above ISP packages: November 2013



Source: SamKnows measurement data for all panel members with a connection in November 2013. Unweighted Panel size: Virgin 'up to' 30Mbit/s 85; FTTC 'up to' 38Mbit/s 128; Virgin 'up to' 60Mbit/s 134; FTTC 'up to' 76Mbit/s 244; Virgin 'up to' 120Mbit/s 83)
Notes: (1) Includes only FTTC or cable customers within 5km of the local exchange and in Geographic Markets 2 and 3; (2) Data for fibre is weighted to market share; (3) cable services is not weighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

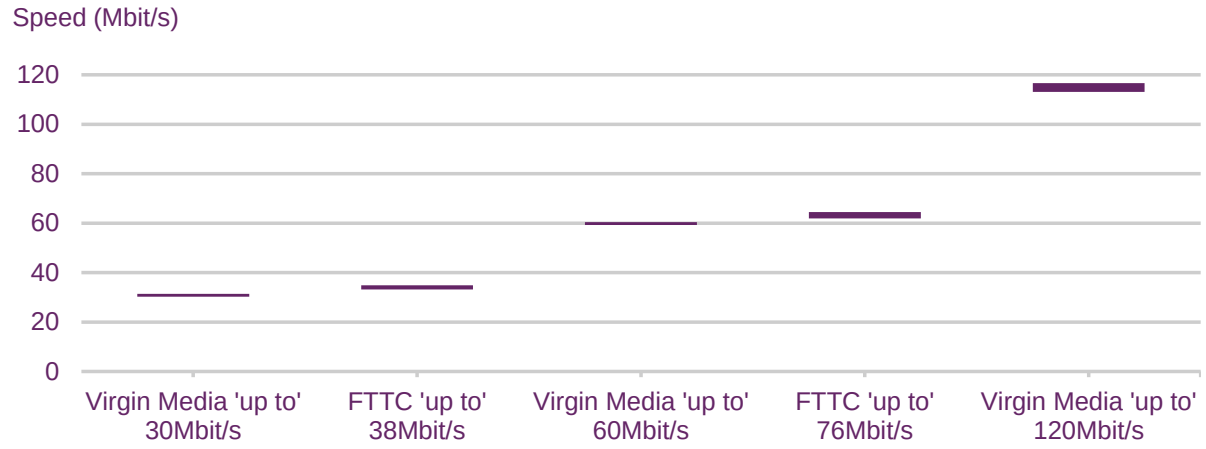
Figure 16 Average download speeds for ADSL2+ ISP packages, 24 hours: November 2013



Source: SamKnows measurement data for all panel members with a connection in November 2013 Unweighted Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators has been weighted for distance from exchange; data for Virgin Media's cable service is not weighted;

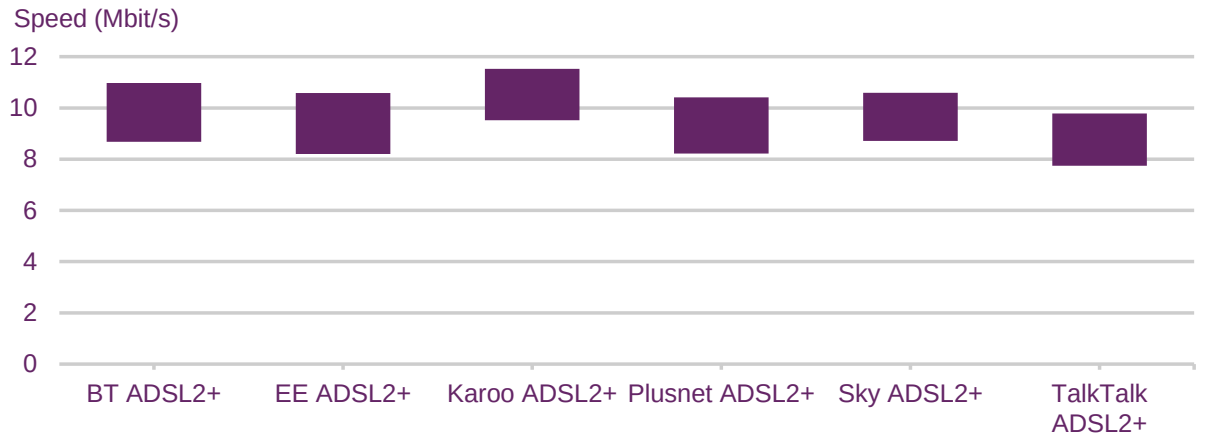
(4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

Figure 17 Average download speeds for 'up to' 30Mbit/s and above ISP packages, 24 hours: November 2013



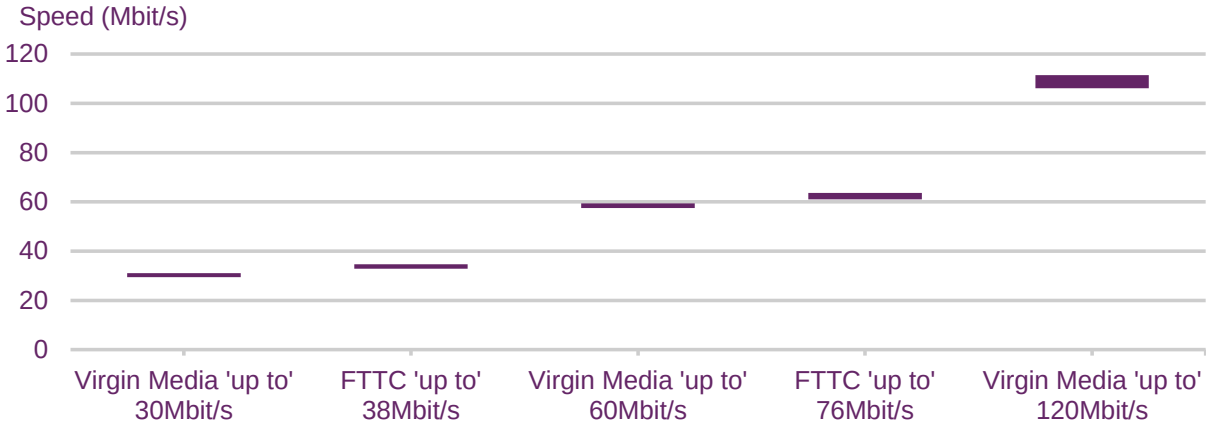
Source: SamKnows measurement data for all panel members with a connection in November 2013 Unweighted Panel size: Virgin 'up to' 30Mbit/s 85; FTTC 'up to' 38Mbit/s 128; Virgin 'up to' 60Mbit/s 134; FTTC 'up to' 76Mbit/s 244; Virgin 'up to' 120Mbit/s 83)
Notes: (1) Includes only FTTC or cable customers within 5km of the local exchange and in Geographic Markets 2 and 3; (2) Data for fibre is weighted to market share; (3) cable services is not weighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

Figure 18 Average download speeds for ADSL2+ ISP packages, 8pm to 10pm weekdays: November 2013



Source: SamKnows measurement data for all panel members with a connection in November 2013. Unweighted Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted for distance from exchange; data for Virgin Media's cable service is not weighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 19 Average download speeds for 'up to' 30Mbit/s and above ISP packages, 8pm to 10pm weekdays: November 2013



Source: SamKnows measurement data for all panel members with a connection in November 2013. Unweighted Panel size: Virgin 'up to' 30Mbit/s 85; FTTC 'up to' 38Mbit/s 128; Virgin 'up to' 60Mbit/s 134; FTTC 'up to' 76Mbit/s 244; Virgin 'up to' 120Mbit/s 83)
Notes: (1) Includes only FTTC or cable customers within 5km of the local exchange and in Geographic Markets 2 and 3; (2) Data for fibre is weighted to market share; (3) cable services is not weighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

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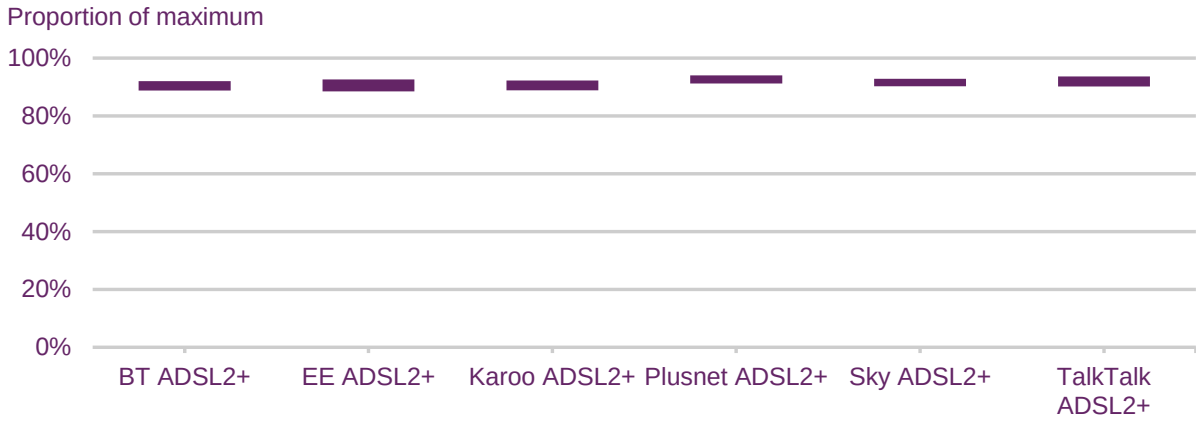
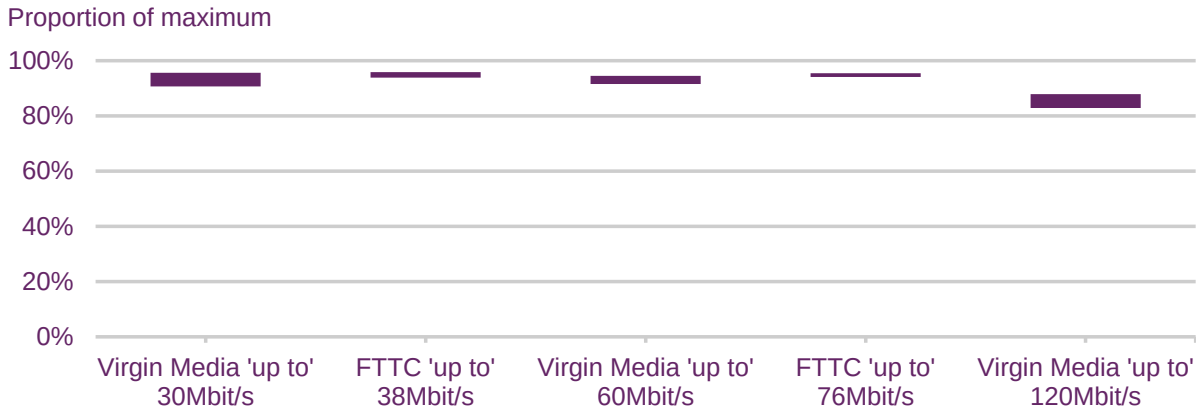
Peak-time download speeds as a proportion of maximum line speeds

Figure 20 Peak-time (8pm to 10pm weekdays) speeds as a proportion of maximum speeds for ADSL2+ ISP packages: November 2013



Source: SamKnows measurement data for all panel members with a connection in November 2013. Unweighted Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Includes only ADSL customers within 5km of the local exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators has been weighted for distance from exchange; data for Virgin Media's cable service is not weighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 21 Peak-time (8pm to 10pm weekdays) speeds as a proportion of maximum speeds for 'up to' 30Mbit/s and above ISP packages: November 2013



Source: SamKnows measurement data for all panel members with a connection in November 2013 Unweighted Panel size: Virgin 'up to' 30Mbit/s 85; FTTC 'up to' 38Mbit/s 128; Virgin 'up to' 60Mbit/s 134; FTTC 'up to' 76Mbit/s 244; Virgin 'up to' 120Mbit/s 83)
Notes: (1) Includes only FTTC or cable customers within 5km of the local exchange and in Geographic Markets 2 and 3; (2) Data for fibre is weighted to market share; (3) cable services is not weighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) it is not possible to draw any conclusions regarding the performance of any individual ISP's FTTC services based on the summary 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC figures which appear in this report.

Annex 2

Technical and research methodologies

Technical methodologies

This report is Ofcom's tenth fixed-line residential broadband speeds report and the eighth 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 up to 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 a wide variety of speed tests in order to monitor performance under different conditions.

For multi-thread HTTP downloads, all units download 3 x 2MB files using separate TCP sessions (in parallel). To avoid sending excessive amounts of data across the panellists' connection we limit the size of these files on lines that are known to have data caps. 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.

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). On connections faster than 50Mbit/s the test lasts 10 seconds, with no file size limitation. 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 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. On connections with upload speeds faster than 20Mbit/s the test lasts 10 seconds, with no file size limitation.

Four speed-test servers are deployed in a range of different data centres in and immediately around London to handle the traffic. 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 600 packets every hour.

Additionally, the test will also measure 'latency-under-load' whilst the download and upload throughput tests are operating. These latency-under-load measures are captured independently of the main latency/loss results.

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.

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 1 sets out Ofcom's definitions of geographic broadband markets (based on the definitions for the wholesale broadband access (WBA) market[16]). These were an important consideration in recruiting our panel and applying statistical analysis, because they enabled us to ensure that

[16] 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).

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 1 Ofcom definitions of geographic broadband markets

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

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

We have used statistical techniques to adjust our results to ensure that they are representative of the 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[17] 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.[18]

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

[18] 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 735 million[19] 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, distance from the exchange and market classification.

- 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 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

[19] 710 million of these were to test connection latency/packet loss.

towns and cities, simply because they have a different customer profile. To address this issue we have taken the following steps:

- For ADSL comparisons we have included only consumers who live in an area where the exchange has been 'unbundled' by at least one LLU operator[20]. 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.

- Distance weighting was applied only to ADSL operators in this report and not to cable or fibre to the cabinet (FTTC) services where performance is less influenced by distance from the exchange.

- For this report, in 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.

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: Karoo '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 Karoo 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.

[20] Local loop unbundling (LLU) is the process by which incumbent operators (BT for the large majority of exchanges and Kingston Communications for the area around Hull) make their local access network (i.e. the copper telephone lines that run from the exchange to consumers' premises) available to other communications providers. In exchanges which have been 'unbundled' an alternative operator (an LLU operator) has deployed its own equipment in the exchange and established a backhaul connection between this equipment and its core network.

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.

The panel is currently over-representative of the higher-speed packages, with 87.4% 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[21], 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 used data from 'up to' 2Mbit/s and less packages collected in April 2009 as representative of the performance of these packages, and have weighted them in accordingly when we present overall UK performance. There is only one remaining panellists that uses such a package.

Prior to despatch of the monitoring units, volunteers were pre-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 3,255 measurement units have been despatched since October 2008. Of the 1,296 which no longer provide data, 600 were phased out as not capable of reporting packages with speeds over 20Mbit/s. 2,019 of these were connected by panellists between 1st and 30th November 2012. Of these, 1,291 supplied data to the UK average, and 1,221 to the named ISP package comparisons.

Figure 1 Panellist numbers

Sample set		Number
Total number of boxes dispatched		**3,250 (600 phased out)**
Total number of boxes connected		**2,391**
	Excluded because of missing data, (i.e. measurements, packages, distance)	37
	Excluded 'up to' 2Mbit/s	6
	Other Exclusions to improve UK sample weighting (i.e. distance, market classification, region, ISP)	233
Total participants included in UK Analysis		**985**
Total participants included in ISP Package Analysis		**1,878**

[21] Published in reports dated January 2009 and July 2009. The January 2009 report included findings from the first month of data collection (23 October to 22 November 2008) and is available at http://stakeholders.ofcom.org.uk/market-data-research/telecoms-research/bbspeed_jan09/. 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/.

Source: Ofcom

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

The average number of measurements per respondent for the 24-hour multi-thread download speed tests in May 2013 was 228, from a theoretical maximum of 279 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 & 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.

The results and analysis of the 2,019 panellists' measurement results were divided into two separate datasets, each weighted to targets.

- **National panel** (over 'up to' 2Mbit/s packages): 985 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. All published national figures include the weighted addition of an estimated figure for 'up to' 2Mbit/s and less packages, based on measured averages in April 2009. This has decreased in size since November 2012 due to over-representation of super-fast services within panel.

- **ISP package panel**: 1,908 panellists. A subset of the national panel, consisting of panellists from Geographic Markets 2 & 3 only, panellists from LLU operators O2, 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 October 2011, urban/rural, Geographic Market classification and distance to exchange (fitted to April 2009 UK straight-line distance to exchange line distribution); 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, Gamma a=2.170 b=619

    - **Cable and fibre-to-the-cabinet (FTTC) packages** were 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 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 pre-screened by ISP package, and an average speed reading estimate was obtained to pre-screen actual versus stated package. Those who were successfully pre-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 provided the IP ranges associated with their packages and, where possible, these were used to reassign respondents to the correct package. This was necessary due to the large scale-migration of customers from ‘up to’ 8Mbit/s to ‘up to’ 20/24Mbit/s packages by some ISPs before the research commenced.

    - The second check was to reassign any panellist who received maximum speeds higher than the headline speed of the package they had stated to the next highest speed package offered by their ISP. A comparable threshold was used across ISPs – stated speed plus a 20% buffer.

    - Statistical analysis of maximum speed and distance from exchange identified a feature consistent with a number of panellists self-assigned as ‘up to’ 20Mbit/s or 24Mbit/s customers receiving speeds capped at 8Mbit/s and 10Mbit/s or less. The following selection criteria were used to eliminate those panellists from the ‘up to’ 20Mbit/s or ‘up to’ 24Mbit/s analysis.

        - Panellists with an ADSL connection who lived closer than 1km to the local exchange and received maximum speeds of between 7Mbit/s and 8Mbit/s

were assumed to be on headline packages of 'up to' 8Mbit/s or 10Mbit/s for analysis purposes.

- Finally, those participants whose stated and measured package assignments or ISP were not consistent and could not be definitively reconciled were excluded from comparison data. Only 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.

Therefore it was 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.

National panel

The national sample was weighted to match the line length distribution of the UK April 2009 research

Line Length Distribution April 2009:	Gamma a=2.223 b=1,000
Line Length Distribution November 2010:	Gamma a=1.863 b=1,203

An additional factor of 0.938 for ADSL2+ and 1.119 ADSL1 was applied this wave as, due to major upgrade works carried out by many operators, almost all Market 2 and 3 exchanges are now ADSL2+ enabled. As Market 1 tends to be rural, the average line lengths for ADSL1 are longer than in previous waves and for Markets 2 and 3 are shorter. This adjustment accounts for this structural shift. This adjustment was not needed for ISP as they are compared on a like-for-like basis.

ISP package panel

The ISP package comparisons were made for subscribers in Geographic Markets 2 and 3, and, where appropriate, 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.

SamKnows provided an estimated distribution of line lengths on LLU exchanges. Saville Rossiter-Base modelled this as a Gamma distribution and the ADSL1 packages were weighted to this distribution for the purposes of consistent comparison by distance from exchange.

Modelled LLU line length distribution:	Gamma a=2.060 b=760

There were statistically distinct differences in the distribution of line lengths for those panellists on ADSL1 packages and those on ADSL2+ packages and the same target distribution could not be used for both. The higher speed ISP packages had lower numbers over 2km from the exchange and to avoid missing weight categories the same distance bands could not be used.

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

Aggregate ADSL2+ line length distribution: Gamma a=2.170 b=619

Rural-Urban Comparison

For this analysis, an alternative weighting was used. All ADSL data was normalised to the May 2011 distance from exchange profile of lines within each area type. A separate Gamma distribution was identified for each area type in 2011 and panellists from 2012 and 2013 weighted to it. The data was 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 weight frame, the national panel achieved a weighting efficiency of 56%. The under-0.5s are primarily driven by the over representation (against current market shares) of both 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 3 National panel range of weights

Range	Count	Column N%
Less than 0.5	556	56%
0.5 to 1	308	31%
1 to 1.5	70	7%
1.5 to 2	43	4%
2 to 3	12	1%

Source: Ofcom

Overall, against the entire weight frame, the ISP package panel achieved a weighting efficiency of 81%. This is because Virgin Media cable packages and BT FTTC are not weighted as distance from exchange does not impair download speeds.

Figure 4 ISP package panel range of weights

Weights	Count	Column N %
0.5 to 1	324	17%
1 to 1.5	1511	80%
1.5 to 2	35	2%
2+	5	0%

Source: Ofcom

Figure 5 Weighting efficiency, by ISP package

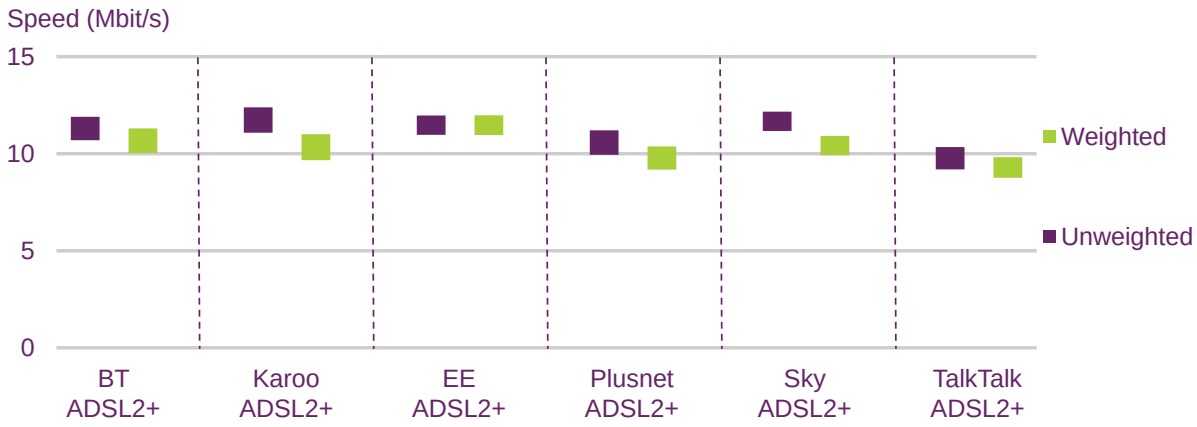
ISP package	Weighting efficiency
BT ADSL2+	65%
Karoo ADSL2+	68%
EE ADSL2+	48%
Plusnet ADSL2+	79%
Sky ADSL2+	85%
TalkTalk ADSL2+	53%
Virgin Media 'up to' 30Mbit/s	100%
FTTC 'up to' 38Mbit/s	100%
Virgin Media 'up to' 60Mbit/s	100%
FTTC 'up to' 76Mbit/s	100%
Virgin Media 'up to' 120Mbit/s	100%

Source: Ofcom

Weighted and unweighted measurement data for ADSL2+ ISP packages

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

Figure 6 Maximum download speeds for ADSL2+ ISP packages, weighted and unweighted figures: November 2013



Source: SamKnows measurement data for all panel members with a connection in November 2013. 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) Weighted data for ADSL operators have been unweighted to distance from exchange and data for Virgin Media's cable and BT fibre-to-the-cabinet is unweighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

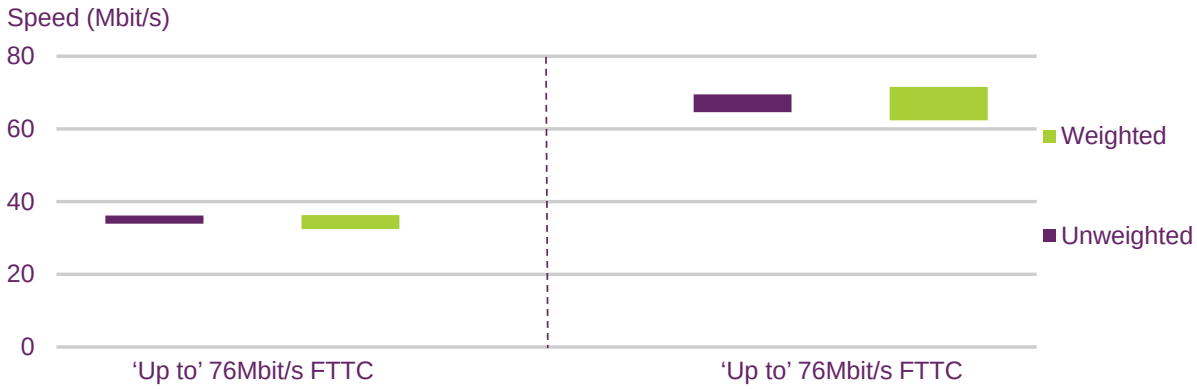
Figure 7 Average download speeds for ADSL2+ ISP packages, 24 hours, weighted and unweighted figures: November 2013

Source: SamKnows measurement data for all panel members with a connection in November 2013. 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) Weighted data for ADSL operators have been unweighted to distance from exchange and data for Virgin Media's cable and BT fibre-to-the-cabinet is unweighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 8 Peak-time download speeds for ADSL2+ ISP packages, 8pm to 10pm weekdays, weighted and unweighted figures: November 2013

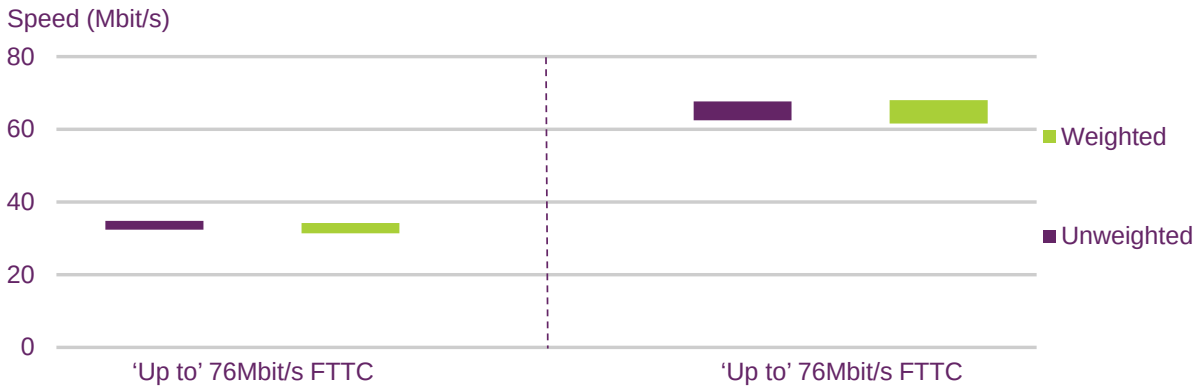
Source: SamKnows measurement data for all panel members with a connection in November 2013.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been unweighted to distance from exchange and data for Virgin Media's cable and BT fibre-to-the-cabinet is unweighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 9 Maximum download speeds for FTTC ISP packages, weighted and unweighted figures: November 2013



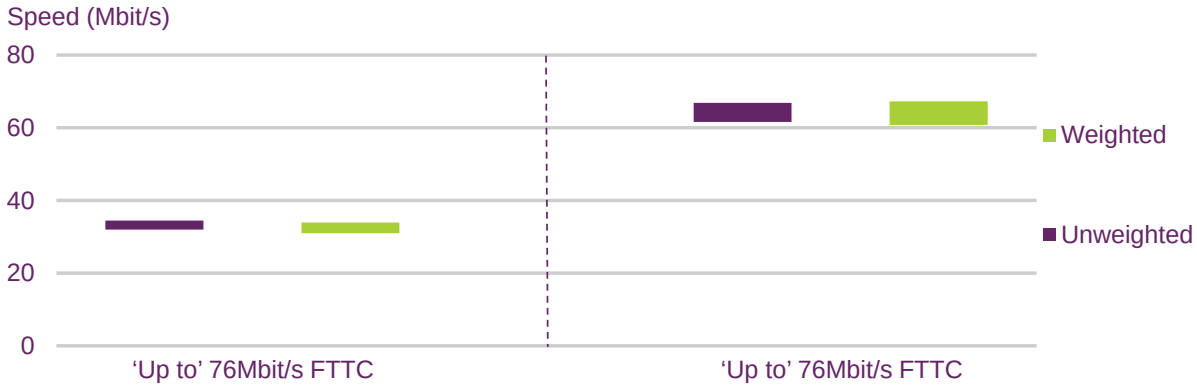
Source: SamKnows measurement data for FTTC panel members with a connection in November 2013.
Notes: (1) Weighted data for FTTC operators have been unweighted for ISP market share, rural-urban split and market classification; (2) Data collected from multi-thread download speed tests; (3) The range shown represents a 95% confidence interval around the mean.

Figure 10 Average download speeds for FTTC ISP packages, weighted and unweighted figures: November 2013



Source: SamKnows measurement data for FTTC panel members with a connection in November 2013.
Notes: (1) Weighted data for FTTC operators have been unweighted for ISP market share, rural-urban split and market classification; (2) Data collected from multi-thread download speed tests; (3) The range shown represents a 95% confidence interval around the mean.

Figure 11 Peak-time download speeds for FTTC ISP packages, weighted and unweighted figures: November 2013



Source: SamKnows measurement data for FTTC panel members with a connection in November 2013.
Notes: (1) Weighted data for FTTC operators have been unweighted for ISP market share, rural-urban split and market classification; (2) Data collected from multi-thread download speed tests; (3) The range shown represents a 95% confidence interval around the mean.

Comparison of urban and rural speeds over time

Using UK Geographics' 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 the settlement they live within is to a larger one or if it is the largest within ten miles. The seven groupings range from A which are large cities, such as London and Birmingham, to 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 under 2.5k and in open countryside). This grouping enables us to compare rural, suburban and urban areas over time.

When making comparisons over time, two things may affect the results. The first is that the panel changes over time, so to avoid this biasing the data, the results from May 2012, May 2013 and November 2013 have been normalised to match the panellists' distance profile in May 2011. The second is that take-up of packages changes every year as infrastructure is rolled out and improvements made. The data has been adjusted to match the overall UK market share by technology for each year but the market share of each technology within each grouping is not known and so no adjustments can be made.

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).

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' (for example, in November 2012 all of BT's nationally available ADSL broadband services are advertised as "'up to' 16Mbit/s").

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 this means 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.

Superfast Used to describe broadband connections with a headline speed of 'up to' 30Mbit/s or higher.

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.