UK fixed-line broadband performance, May 2014

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

Research Report

Publication date: 3 October 2014

About this document

The report contains data and analysis regarding the performance of UK residential fixed-line broadband services. Specifically, the report contains information on the average performance of ADSL, cable and fibre broadband packages. We present this information both at national average level, and separately by package for the major ISPs.

We publish this report to provide consumers and other stakeholders with useful comparative information on the performance of broadband services. This is consistent with Ofcom's duty to carry out and publish research on the experience of consumers.

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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 fixed 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 these services. This is the eleventh 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 May 2014, during which 2.7 billion test results were collected from a panel of 2,175 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 robust presentation of UK fixed-line broadband speeds.

Fixed broadband performance is an issue for many consumers, and Ofcom research conducted in Q1 2014 suggested that while 84% 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) connections in the UK. Likewise, where we refer to 'connections', we mean residential connections.

[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.

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 was subsequently 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.

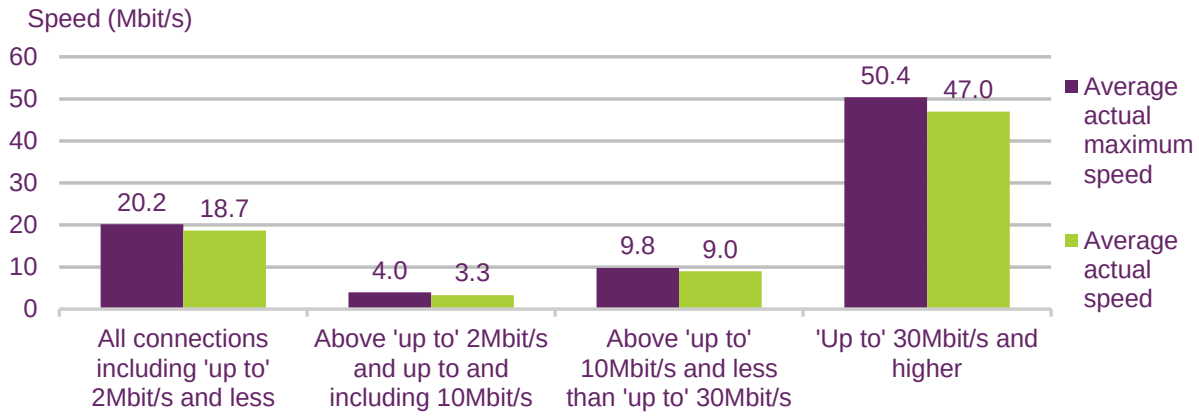
Section 1

Overview of fixed broadband speeds

1.1 The average UK residential fixed broadband speed reached 18.7Mbit/s in May 2014

Our research found that the average actual speed for UK residential fixed-line broadband connections was 18.7Mbit/s in May 2014 (Figure 1.1). The average actual speed of superfast fixed broadband connections (which in this report are defined as being those with headline speeds of 30Mbit/s or more) was found to be 47.0Mbit/s, more than five times the average actual speed of those connections with headline speeds above 'up to' 10Mbit/s and less than 'up to' 30Mbit/s (9.0Mbit/s). The average actual speed of connections above 'up to' 2Mbit/s and up to and including 10Mbit/s was 3.3Mbit/s.

Figure 1.1 **Average UK broadband speed: May 2014**



Source: SamKnows measurement data for all panel members with a connection in May 2014
Panel Base: 956
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 May 2014; (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.

1.2 Average broadband speeds increased by 0.9Mbit/s in the six months to May 2014

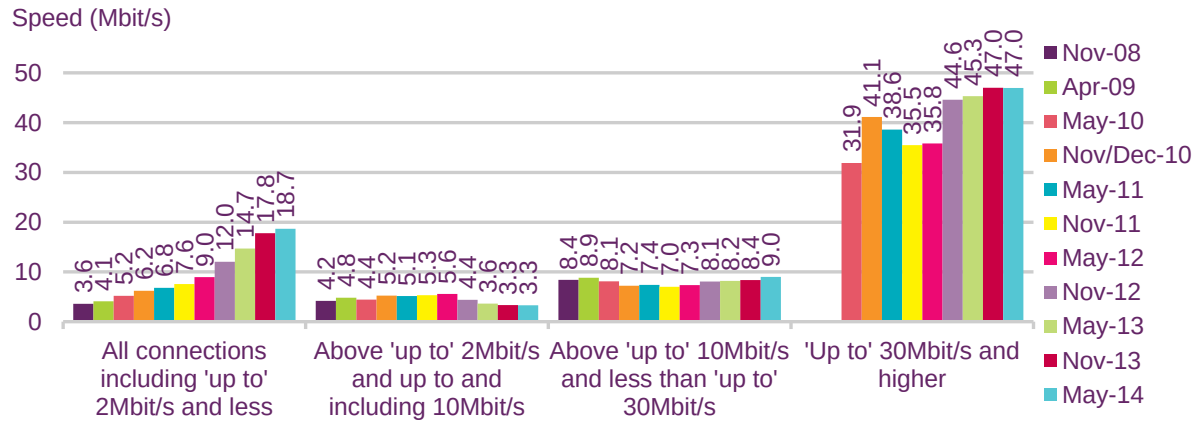
Residential fixed broadband speeds continued to increase in the six months leading up to May 2014 when the average actual speed of these connections (18.7Mbit/s), represented an increase of 0.9Mbit/s (5%) on November 2013 (Figure 1.2). This was a marked slowing in the rate of increase, as between May 2013 and November 2013 the average speed increased by 3.1Mbit/s (21%).

Over the last few years, increases in average residential fixed broadband services have mainly been driven by increasing take-up of superfast broadband services and average speeds among these connections. However, the average speed of superfast connections was unchanged at 47.0Mbit/s in the six months to May 2014 (see section 1.4 for more

details), and as a result the increase in average speeds across all connections was lower than in previous periods. Average actual download speeds also remained stable for connections with a headline speed above 'up to' 2Mbit/s and up to and including 10Mbit/s in the six months to May 2014, at 3.3Mbit/s, while the speed for above 'up to' 10Mbit/s and less than 'up to' 30Mbit/s increased by 0.6Mbit/s (8%) over the same period.

Sufficient sample sizes were not available among our panel for connections with headline speeds of 'up to' 2Mbit/s and less, because of the low market share of these connections, so the performance of these connections is not analysed in detail. They are however included in Figure 1.2 so that average actual speeds are reflected across all connections.

Figure 1.2 **Average actual broadband speeds: November 2008 to May 2014**



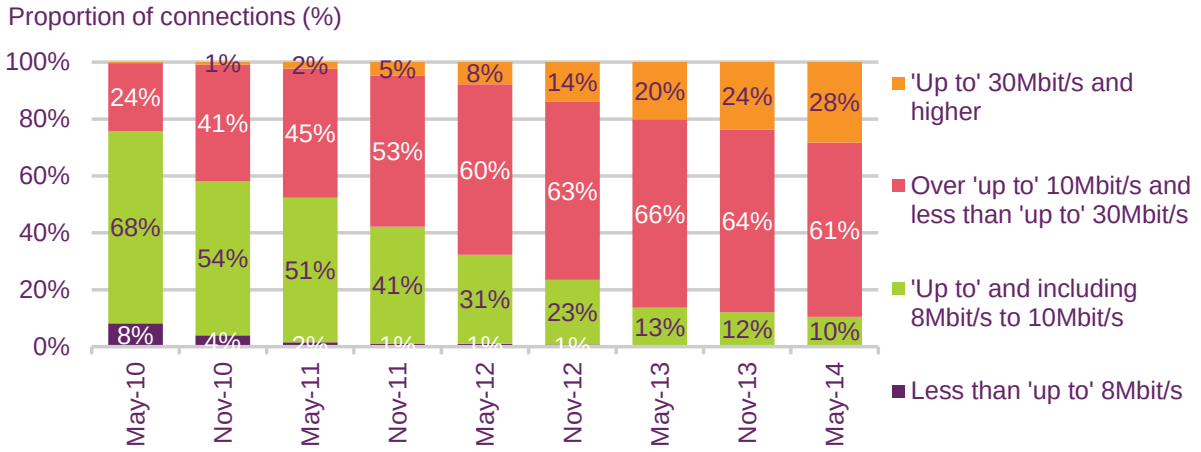
Source: SamKnows measurement data for all panel members
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) 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 May 2014; (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.

1.3 Twenty-eight per cent of UK residential broadband connections had a headline speed of 'up to' 30Mbit/s or higher in May 2014

We consider the increased take-up of superfast connections to be a major driver in the increase of actual speeds across all connections. The proportion of connections of residential fixed broadband that had a headline speed of 'up to' 30Mbit/s and higher was 28% in May 2014 an increase of four percentage points from November 2013. The proportion of connections with headline speeds over 'up to' 10Mbit/s and less than 'up to' 30Mbit/s fell by three percentage points to 61% in the six months to November 2013, consistent with the decrease for these connections between May 2013 and November 2013, as consumers upgrade to superfast services.

The proportion of connections that were 'up to' and including 8Mbit/s to 10Mbit/s also fell, down by two percentage points in May 2014 to 10%, while connections with a headline speed of less than 'up to' 8Mbit/s accounted for less than 1% 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.

1.4 The average speed of cable broadband services overtook that of fibre connections in the six months to May 2014

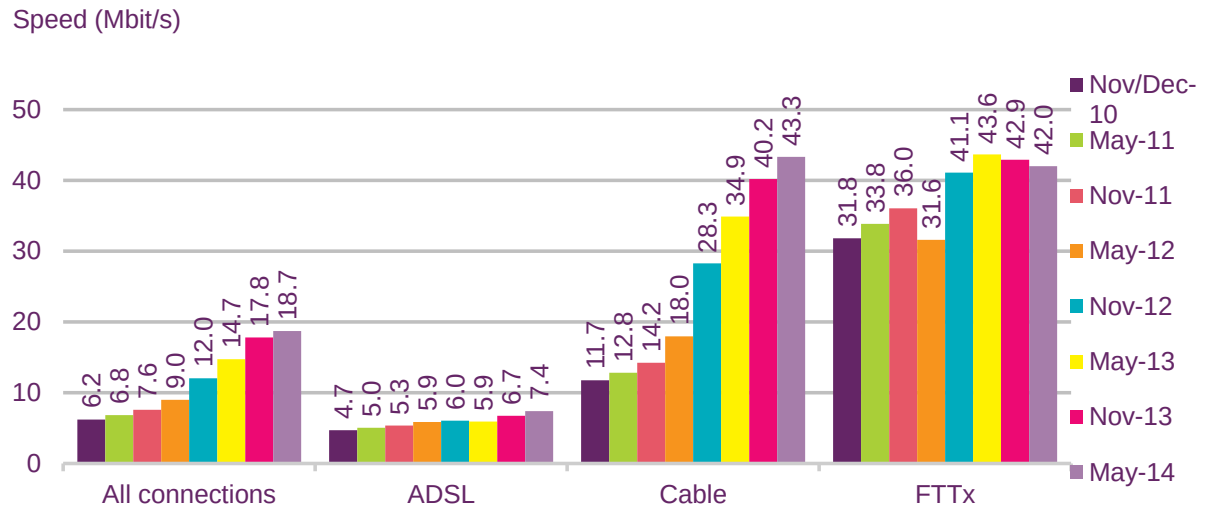
The average actual download speed of fibre broadband (FTTx) connections was 42.0Mbit/s in May 2014, down from 42.9Mbit/s in November 2013, a reduction in speed of 2%, continuing the trend of falling average fibre broadband speeds seen in the six months to November 2013.

In the UK, most residential fibre broadband connections (around 99% of the total) are 'up to' 38Mbit/s or 'up to' 76Mbit/s fibre-to-the-cabinet (FTTC) services. In the six months to May 2014 the proportion of these connections which were 'up to' 38Mbit/s increased slightly and this, coupled with small decrease in the average speeds recorded for both 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC connections, resulted in the observed decline in the average speed for fibre broadband connections.

For all other technologies average actual download speeds increased, with the average speed of ADSL connections increasing by 10% to 7.4Mbit/s (possibly a result of infrastructure improvements related to fibre rollout) and cable speeds increasing by 3.2Mbit/s to 43.3Mbit/s. The increase in the average speed of cable connections is partly due to Virgin Media's launch of a new cable speed upgrade programme in February 2014. However, the increase in average actual cable broadband speeds slowed in the six months to May 2014 (from 15% in the six months to November 2013 to 8% in the six months to May 2014), possibly due to the current upgrades being opt-in (rather than automatic as was the case with Virgin Media's last upgrade programme).

Despite this slowing, the increase in the average speed recorded for cable connections during the period (and the fall in average fibre broadband speeds outlined previously) was sufficient to result in the average actual cable broadband speeds being higher than that of fibre broadband services for the first time since we have collected comparable data for the two.

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



Source: SamKnows measurement data for all panel members with a connection in May 2014
Panel Base: 956
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.

1.5 The gap between rural and urban speeds appears to have narrowed slightly

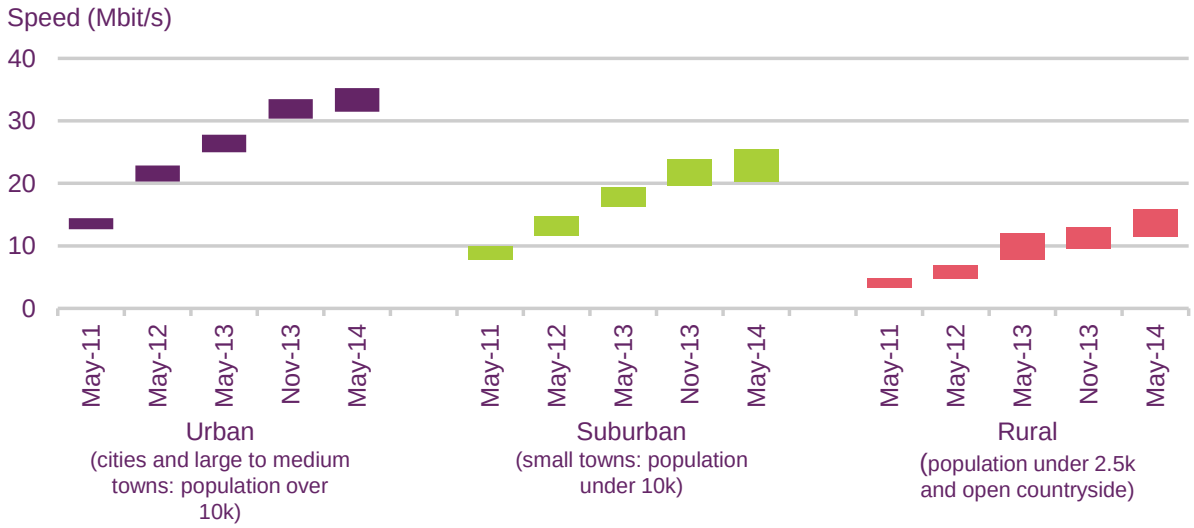
Average speeds in urban areas tend to exceed those in suburban and rural areas due to the higher availability of cable and fibre services and because average line lengths are longer in rural areas due to population density being lower. Longer line lengths between local exchanges and customers' premises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

The higher availability of cable and fibre in urban areas is due to the fact that initial network rollout tends to be concentrated in areas where population density is higher, resulting in a higher number of premises being covered for a given network investment and giving a larger potential customer base.

In the six months to November 2013, average actual download speeds in urban areas increased by 21%, while suburban speeds grew by 22% and average rural speeds grew by 15% (although this increase was not statistically significant). However, our analysis suggests that in the six months to May 2014 average rural speeds experienced the highest growth (up from 11.3Mbit/s to 13.6Mbit/s, a 20% increase), while in both urban and suburban areas average speeds increased by just 5% (to 33.4Mbit/s and 22.9Mbit/s respectively).

None of the recorded increases in average speeds in urban, suburban and rural areas or the reduction in the gap between average urban and rural areas were statistically significant to the 95% level of confidence used in this report in the six months to May 2014. However, the data suggests that the gap between speeds in rural and urban areas may be starting to narrow, as we would expect to happen as the rural availability and take-up of fibre broadband services increases. This is supported by the increases in speeds recorded in rural areas in the six months to May 2014 being concentrated among a small proportion of rural panellists.

Figure 1.5 **Average download speeds for fixed broadband connections in urban, suburban and rural areas: May 2011 to May 2014**



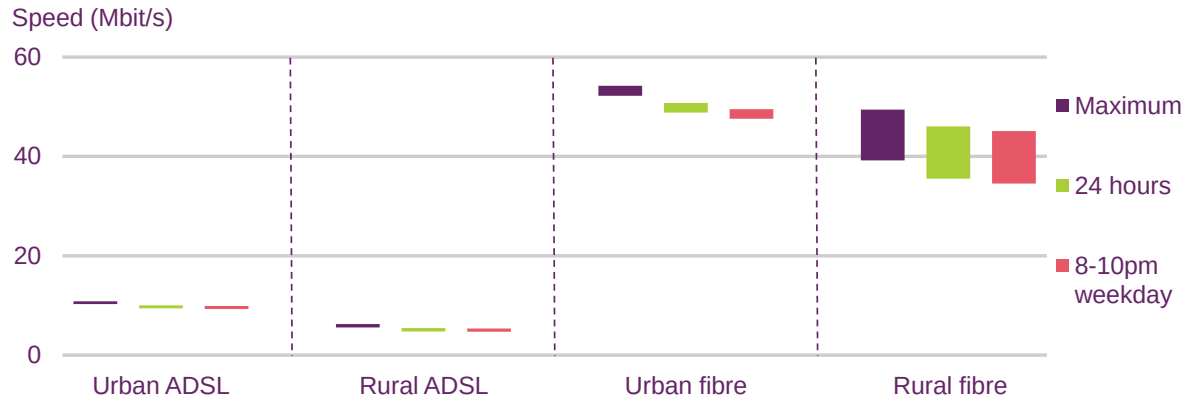
Source: SamKnows
Panel Base: 2011; Urban 999, Suburban 382, Rural 323; 2012 Urban 1099, Suburban 391, Rural 294; and 2013 May Urban 1362, Suburban 448, Rural 365; 2013 November Urban 746, Suburban 292; Rural 271; 2014 May Urban 1280, Suburban 503, Rural 370
Notes: The UK average above will not match shown elsewhere in this report as different weightings have been used to enable us to provide comparisons by urbanity. Further statistical methodology is provided in Annex 3.

1.6 Rural areas are affected more by contention at peak-times than urban areas when using both ADSL and fibre technologies

The low availability of cable broadband services to rural areas means that ADSL and fibre broadband services are more prevalent in rural areas. Our May 2014 research shows that rural ADSL and fibre connections provided lower average download speeds than those in urban areas. Rural ADSL connections had an average actual download speed of 5.1Mbit/s over the 24-hour period, compared to 9.7Mbit/s for urban connections. For fibre connections, urban consumers achieved a 24-hour average actual download speed of 49.8Mbit/s compared to 40.8Mbit/s for rural consumers.

Contention affects rural consumers more on average than urban consumers: rural ADSL connections received an average of 85% of their maximum speed during the 8pm to 10pm weekday peak period, compared to 91% for urban ADSL connections. This is also the case for fibre packages, however, the difference between rural and urban performance was much smaller, with rural fibre connections receiving an average of 90% of their maximum speed at peak-times, compared to 91% for urban connections.

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



Source: SamKnows
Panel Base: Urban fibre 135, rural fibre 18. Urban ADSL 406, rural ADSL 169.

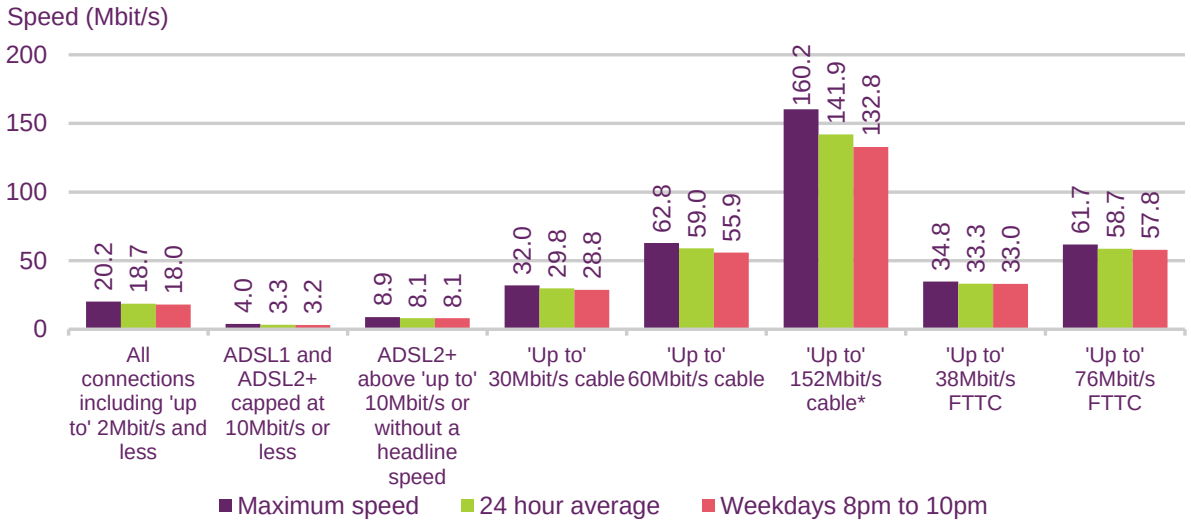
1.7 The extent to which download speeds are affected by peak-time network contention varies by technology

Download speeds typically vary by time of day and tend to fall during peak times, when a larger number of connections are being used and as a result of capacity constraints (contention) on the networks of internet service providers (ISPs) (Figure 1.7). For all the connection categories analysed, the peak time average actual speeds were lower than both the actual average maximum speed and the 24 hour actual average speed. In May 2014 the actual average speed across all connections was 18.0Mbit/s during the 8pm to 10pm weekday peak-time period, which was 89% of the 20.2Mbit/s average maximum speed and 96% of the 18.7Mbit/s 24-hour average.

ADSL1 and ADSL2+ connections capped at 10Mbit/s or less experienced the most variation between maximum and peak-time download speeds, with average peak-time speeds (3.2Mbit/s) being 80% of the average maximum speed (4.0Mbit/s). ADSL2+ connections with a headline speed above 'up to' 10Mbit/s or without a headline speed performed better, with average peak-time speeds (8.1Mbit/s) being 91% of the 8.9Mbit/s average maximum speeds, while for cable broadband connections this proportion ranged from 83% for ‘up to’ 152Mbit/s connections to 90% for ‘up to’ 30Mbit/s connections (for ‘up to 60Mbit/s cable connections it was 89%).

FTTC connections were less affected by the peak-time contention than the cable connections of all speeds. The peak-time download speed on ‘up to’ 38Mbit/s FTTC connections was 33.0Mbit/s, 95% of the maximum average speed and 99% of the 24 hour average. For ‘up to’ 76Mbit/s FTTC connections the peak-time download speed was 57.8Mbit/s, 94% of the maximum average speed and 99% of the 24 hour average.

Figure 1.7 **Variations in download speeds by the time of day: May 2014**

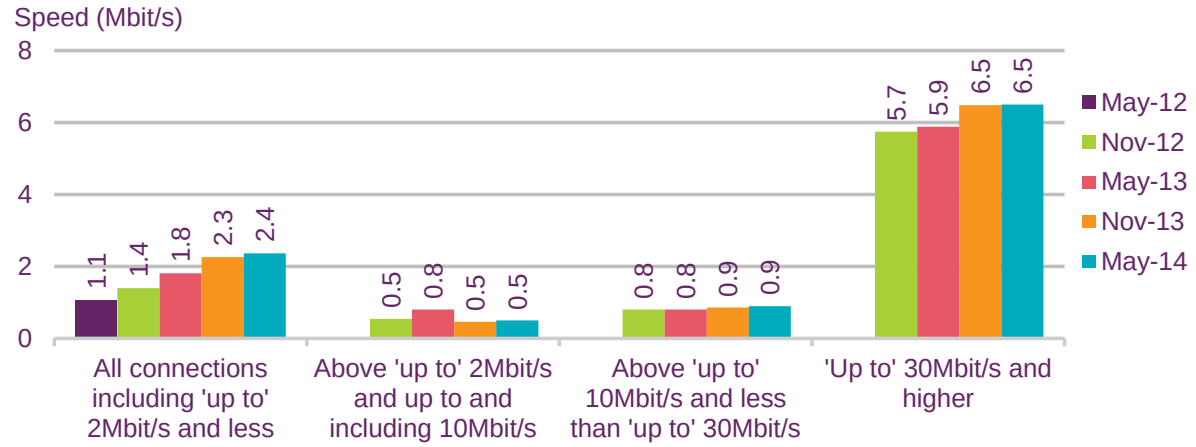


Source: SamKnows measurement data for all panel members with a connection in May 2014. Panel Base: 956
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential 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 May 2014; (3) Data collected from multi-thread download speed tests.

1.8 The average actual upload speed of a UK residential fixed-line broadband connection was 2.4Mbit/s in May 2014

Broadband advertising tends to focus on download speeds. However upload speeds are important for a subset of the population, such as those sharing large files and using real-time two-way video communications. Our research shows that average actual upload speeds increased by 0.1Mbit/s (5%) to 2.4Mbit/s between the six months from November 2013 and May 2014.

Figure 1.8 **Average upstream broadband speeds: May 2014**



Source: SamKnows measurement data for all panel members with a connection in May 2014.
Panel Base: 956
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.

Fibre-to-the-cabinet data normalisation

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. To take into account the differing ISP profiles when comparing the performance of ADSL ISP packages, we 'normalise' the test data by distance from the exchange to take into account differing ISP customer profiles. This enables us to make like-for-like comparisons of performance across ADSL services. More information on this normalisation 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 FTTC speeds are therefore also affected by the length (and quality) of the wiring over which the data signal is transmitted. This means that differing ISP user profiles may result in similar systematic biases to those associated with ADSL in FTTC test result data, and we excluded ISP package-specific FTTC data from the report covering November 2013 while we considered whether it was necessary to normalise the FTTC test result data.

Working closely with Openreach and SamKnows we identified the most appropriate methodology for normalising the FTTC data and engaged an external statistician to critique this methodology and perform the normalisation on our behalf. Using this analysis we have considered the issue and have provisionally concluded that it is not currently appropriate to normalise the FTTC test results as:

- The statistical analysis showed that any differences between ISP customer bases are not currently having a material effect on the average FTTC download speeds reported in our research.
- The method of normalisation meant that differences in performance occurring for other reasons could be removed from the data, and as the variations in FTTC ISP package performance are relatively small, there is the potential for the normalisation to introduce additional biases to the analysis.

However, while be believe that it is not currently appropriate to normalise our FTTC data, the effect of customer base biases may become more marked as FTTC take-up increases in rural areas of the UK, and we will continue to monitor this situation and review this decision as our panellist base changes.

ISP packages

Our ability to compare specific ISP packages to each other is dependent upon achieving sufficient panel sizes for the packages. We were able to attain sufficient panellists for the following ISP packages in May 2014 (listed in alphabetical order):

- BT's ADSL2+, 'up to' 38Mbit/s FTTC and 'up to' 76Mbit/s FTTC services;
- EE's ADSL2+ and 'up to' 38Mbit/s FTTC services;
- Karoo's ADSL2+ service;
- Plusnet's ADSL2+, 'up to' 38Mbit/s FTTC and 'up to' 76Mbit/s FTTC services;
- Sky's ADSL2+ and 'up to' 38Mbit/s FTTC services;
- TalkTalk's ADSL2+ service;
- Virgin Media's 'up to' 30Mbit/s, 'up to' 60Mbit/s and 'up to' 152Mbit/s cable services.

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

New disconnection test

In this report we also include preliminary results gathered a new test which was trialled among a subset of our panellists in May 2014. This shows data regarding the average number of disconnections over 30 seconds in duration per ISP package per day and the distribution of the duration of these disconnections among panellists.

Presentation of results

All results are presented in terms of bars showing the 95% confidence interval. This means that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists within our sample) falls within the ranges shown. The sample size for each group and the variation of performance among panellists within the same group combine to determine the size of the bars. We must emphasise that these bars indicate the average (mean) performance rather than the range of performance delivered.

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

ADSL2+ connections – download speeds

2.1 Maximum, average and peak-time download speeds for ADSL2+ ISP packages: May 2014

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

In May 2014, the average actual 24-hour speed of the ADSL2+ ISP packages included in this report ranged from 8.6Mbit/s for TalkTalk's service to 10.9Mbit/s for Karoo's (Figure 2.2). Karoo's ADSL2+ package was faster than TalkTalk's in terms of average maximum speed, 24 hour average speed and peak-time average speed, while EE's ADSL2+ package was faster than TalkTalk's in terms of its average maximum speed. The proportion of average maximum speeds delivered during the weekday 8pm to 10pm peak-time period ranged from 90% for EE's ADSL2+ package to 93% for BT's ADSL2+ package among the ADSL2+ packages covered by our research.

Figure 2.1 **Maximum, average and peak-time download speeds for ADSL2+ ISP packages: May 2014**

*Source: SamKnows measurement data for all panel members with a connection in May 2014. Notes: (1) Includes only customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for 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.(6) * denotes small sample size (<50)*

Figure 2.2 summarises the statistically significant differences in the download speed over different time periods of ADSL2+ ISP packages covered in our research.

Figure 2.2 **Significant differences, to a 95% level of confidence, between maximum, average and peak download speeds for ADSL2+ ISP packages: May 2014**

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

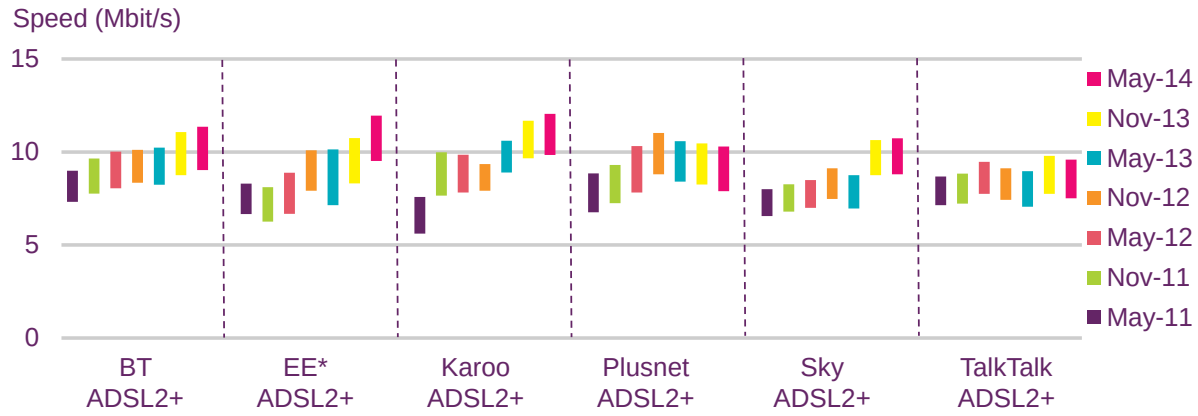
Source: Ofcom

**Difference not significant to a 99% level of confidence*

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

Figure 2.3 shows the average download speeds recorded in previous reporting periods for the ADSL2+ ISP packages included in this report.

Figure 2.3 **Average download speeds for ADSL2+ packages: May 2011 to May 2014**



Source: SamKnows measurement data for all panel members.
Notes: (1) Only includes customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes o
*n-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 May 2014.(7) * denotes small sample size (<50)*

2.3 The proportion of ADSL2+ panellists receiving more than 90% of their maximum speed at peak times varied between 54% and 73% of panellists in May 2014

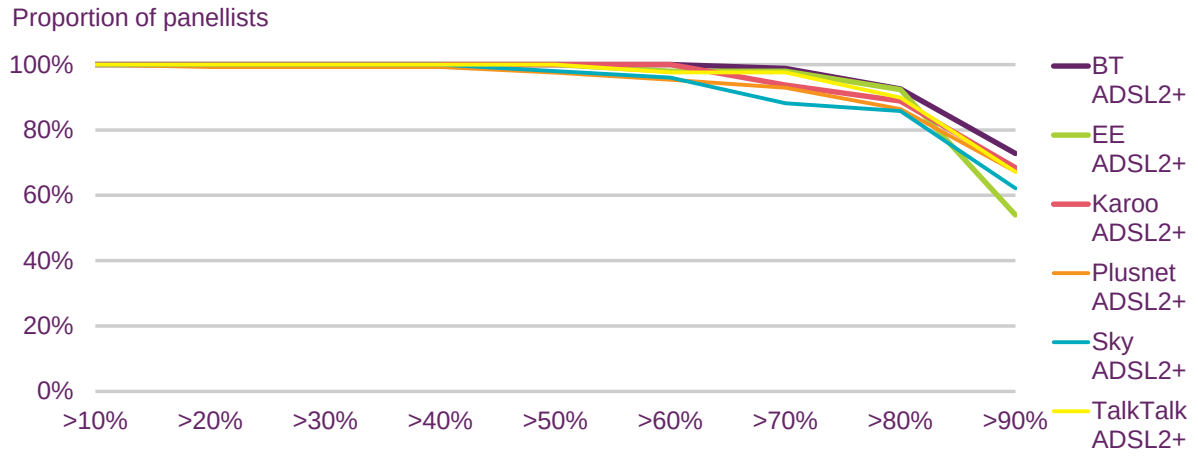
Figure 2.4 shows the distribution of average speeds across our ADSL2+ panellists' during the 8pm to 10pm weekday peak-time period as a proportion of maximum speed delivered by their connections. The intention of this analysis is to measure whether certain panellists are disproportionately affected by network contention. Higher levels of network congestion (contention) limit download speeds,[9] and we would therefore expect to see fewer panellists experiencing higher average peak speeds to maximum speed if contention was higher. In this analysis higher lines indicate better performance.

Among all of the ADSL2+ ISP packages compared, more than half of panellists experienced peak-time speeds that were higher than 90% of their maximum speed. EE's ADSL2+ service (which had the highest average speed among our ADSL2+ panellists) had the lowest proportion of panellists experiencing peak-time speeds that were higher than 90% of their maximum speed in May 2014, at 54%. This suggests that there were higher levels of contention in the EE ADSL2+ network than in other ISPs' ADSL2+ networks during the May

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

2014 measurement period. BT's ADSL2+ service was the best performing, with 73% 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: May 2014**



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

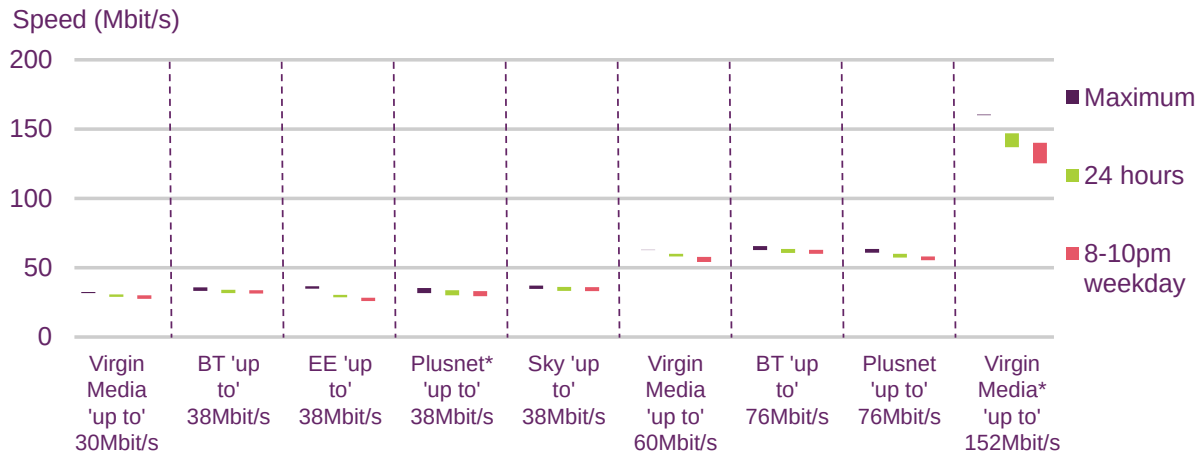
'Up to' 30Mbit/s and higher connections – download speeds

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

Virgin Media is currently upgrading its cable broadband network, with its 'up to' 30Mbit/s, 60Mbit/s and 120Mbit/s being able to upgrade onto 'up to' 50Mbit/s, 100Mbit/s and 152Mbit/s services respectively. While enough of our panellists had migrated to the 152Mbit/s service by May 2014 to enable us to include it in this report, an insufficient number of 'up to' 30Mbit/s and 60Mbit/s panellists had upgraded to enable us to include the new 'up to' 50Mbit/s and 100Mbit/s service tiers in this report.

As shown in Figure 2.6, Virgin Media's 'up to' 152Mbit/s package had the fastest download speeds of the ISP packages covered in our research in terms of its average maximum speed (160.2Mbit/s), 24 hour average speed (141.9Mbit/s) and peak-time average speed (132.8Mbit/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 the packages were advertised and average peak-time speeds as a proportion of maximum speeds ranged from 76% in the case of EE's 'up to' 38Mbit/s package, to 96% for Sky's 'up to' 38Mbit/s package.

Figure 2.5 **Maximum, average and peak-time download speeds for 'up to' 30Mbit/s and above ISP packages: May 2014**



Source: SamKnows measurement data for all panel members with a connection in May 2014.
*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; *caution – small sample size (<50)*

Figure 2.6 summarises the statistically significant differences between the download performance of different ISP packages 'up to' 30Mbit/s and above included in our research in May 2014.

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: May 2014**

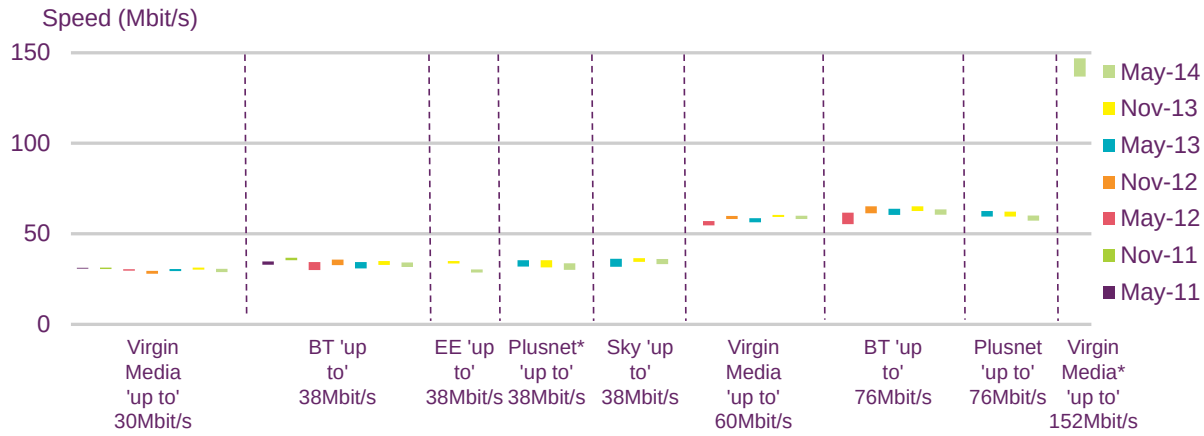
	Maximum	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**	**Is faster than...**
Virgin Media 152	BT 76, Plusnet 76, Virgin Media 60, Sky 38, BT 38, Plusnet 38, EE 38, Virgin Media 30	BT 76, Plusnet 76, Virgin Media 60, Sky 38, BT 38, Plusnet 38, Virgin Media 30, EE 38	BT 76, Plusnet 76, Virgin Media 60, Sky 38, BT 38, Plusnet 38, Virgin Media 30, EE 38
BT 76	Sky 38, BT 38, Plusnet 38, EE 38, Virgin Media 30	Plusnet 76*, Virgin Media 60, Sky 38, BT 38, Plusnet 38, Virgin Media 30, EE 38	Plusnet 76, Virgin Media 60, Sky 38, BT 38, Plusnet 38, Virgin Media 30, EE 38
Plusnet 76	Sky 38, BT 38, Plusnet 38, EE 38, Virgin Media 30	Virgin Media 60, Sky 38, BT 38, Plusnet 38, Virgin Media 30, EE 38	Sky 38, BT 38, Plusnet 38, Virgin Media 30, EE 38
Virgin Media 60	Sky 38, BT 38, Plusnet 38, Virgin Media 30, EE 38	Sky 38, BT 38, Plusnet 38, Virgin Media 30, EE 38	Sky 38, BT 38, Plusnet 38, Virgin Media 30, EE 38
Sky 38	Virgin Media 30	Virgin Media 30, EE 38	Virgin Media 30, EE 38
BT 38	Virgin Media 30	Virgin Media 30, EE 38	Virgin Media 30, EE 38
Plusnet 38	No Differences	No Differences	EE 38

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

2.5 Average download speeds for 'up to' 30Mbit/s and above ISP packages: May 2011 to May 2014

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 speeds for EE's 'up to' 38Mbit/s package fell by 4.8Mbit/s (14.0%) to 29.5Mbit/s in the six months to May 2014. The speed decreases for Plusnet's 80Mbit/s and Virgin Media's 30Mbit/s packages were also significant, to a 95% level of confidence.

Figure 2.7 **Average download speeds for 'up to' 30Mbit/s and above ISP packages: May 2011 to May 2014**



Source: SamKnows measurement data for all panel members with a connection in May 2014.
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.

2.6 Distribution of average peak-time speed as a proportion of maximum speed for 'up to' 30Mbit/s and above ISP packages: May 2014

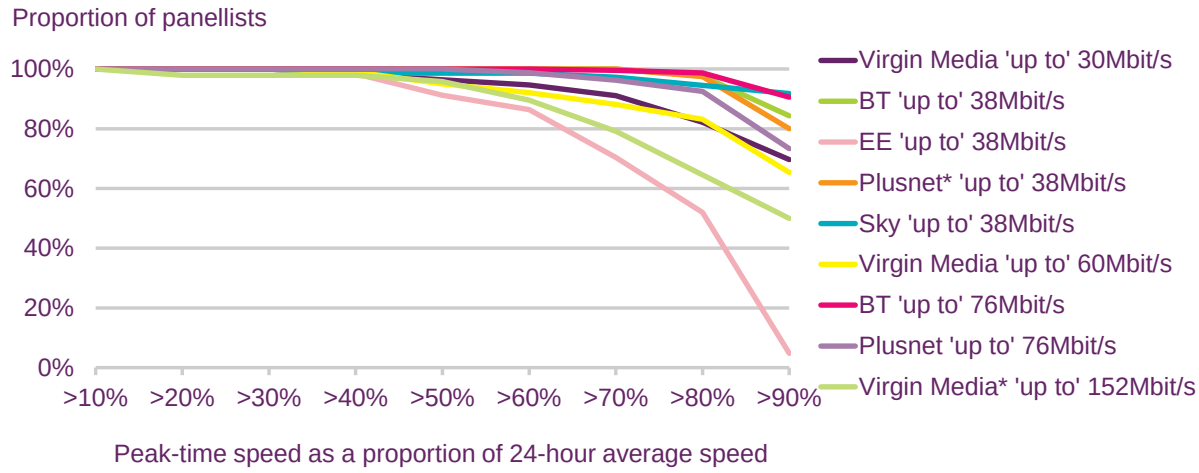
The analysis of the distribution of panellists with a headline speed of 'up to' 30Mbit/s and higher in terms of average speeds during the 8pm to 10pm weekday peak-time period as a proportion of average maximum speeds is shown below in Figure 2.6. As before, in this analysis, higher lines represent better performance.

Figure 2.8 shows that both the best and worst performing packages, in terms of peak-time distribution, were FTTC 'up to' 38Mbit/s packages. EE's 'up to' 38Mbit/s package performed the least well of the packages, with just 5% of panellists receiving average peak-time speeds more than 90% of their maximum speed, a significant fall compared to the proportion recorded in November 2013. This suggests that the drop in average speeds for the service shown in Figure 2.7 may be partly due to increased contention in EE's network in May 2014. The best performing package was Sky's 'up to' 38Mbit/s service, with 92% of panellists receiving speeds more than 90% of their maximum speed. The 'up to' 76Mbit/s FTTC packages also varied in performance, with 73% of Plusnet's 'up to' 76Mbit/s panellists and 91% of BT's receiving speed more than 90% of their maximum speed at peak times.

Among Virgin Media's packages, the 'up to' 152Mbit/s package performed worst, with half (50%) of panellists getting speeds more than 90% of their maximum speed. The 'up to' 30Mbit/s package performed best with 70% of panellists getting over 90% of their maximum

(the proportion was 65% for 'up to' 60Mbit/s panellists). As Virgin Media's cable services' maximum speeds are higher than their headline speeds, the proportions of panellists getting at least 90% of their headline speeds at peak times are higher than the figures given above. For Virgin Media's 'up to' 30Mbit/s, 60Mbit/s and 152Mbit/s services these proportions were 73%, 77% and 58% respectively in May 2014.

Figure 2.8 **Distribution of average peak-time speed as a proportion of maximum speed for 'up to' 30Mbit/s and above ISP packages: May 2014**



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) * denotes small sample size (<50); (4) Virgin Media's cable network is configured to provide maximum speeds that are higher the relevant services' advertised speeds. As such, the figures above understate Virgin Media's performance compared to ISP packages which are not configured in this way.*

2.7 Summary of average download speeds of all ISP packages

Figure 2.9 summarises the average maximum, 24 hour and weekday peak-time download speeds achieved by all of our ISP packages included in our research in May 2014. 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.

Figure 2.9 **Summary of average download speed by ISP package: May 2014**

	Average download speed during period		
	Maximum	24 hours	8-10pm weekdays
BT ADSL2+	9.7Mbit/s to 12.1Mbit/s	9.0Mbit/s to 11.4Mbit/s	8.9Mbit/s to 11.3Mbit/s
EE* ADSL2+	10.4Mbit/s to 13.1Mbit/s	9.5Mbit/s to 12.0Mbit/s	9.4Mbit/s to 11.8Mbit/s
Karoo ADSL2+	10.6Mbit/s to 12.8Mbit/s	9.8Mbit/s to 12.0Mbit/s	9.6Mbit/s to 11.8Mbit/s
Plusnet ADSL2+	8.7Mbit/s to 11.1Mbit/s	7.9Mbit/s to 10.3Mbit/s	7.8Mbit/s to 10.2Mbit/s
Sky ADSL2+	9.7Mbit/s to 11.7Mbit/s	8.8Mbit/s to 10.7Mbit/s	8.7Mbit/s to 10.7Mbit/s
TalkTalk ADSL2+	8.2Mbit/s to 10.4Mbit/s	7.5Mbit/s to 9.6Mbit/s	7.5Mbit/s to 9.6Mbit/s
Virgin Media 'up to' 30Mbit/s	31.6Mbit/s to 32.4Mbit/s	28.9Mbit/s to 30.7Mbit/s	27.5Mbit/s to 30.1Mbit/s
BT 'up to' 38Mbit/s	33.3Mbit/s to 35.8Mbit/s	31.7Mbit/s to 34.1Mbit/s	31.4Mbit/s to 33.8Mbit/s
EE 'up to' 38Mbit/s	34.9Mbit/s to 36.6Mbit/s	28.6Mbit/s to 30.4Mbit/s	26.0Mbit/s to 28.3Mbit/s
Plusnet* 'up to' 38Mbit/s	31.7Mbit/s to 35.4Mbit/s	30.1Mbit/s to 33.7Mbit/s	29.5Mbit/s to 33.2Mbit/s
Sky 'up to' 38Mbit/s	34.7Mbit/s to 37.0Mbit/s	33.3Mbit/s to 36.0Mbit/s	33.1Mbit/s to 36.0Mbit/s
Virgin Media 'up to' 60Mbit/s	62.7Mbit/s to 62.9Mbit/s	58.1Mbit/s to 60.0Mbit/s	54.1Mbit/s to 57.7Mbit/s
BT 'up to' 76Mbit/s	62.6Mbit/s to 65.5Mbit/s	60.6Mbit/s to 63.5Mbit/s	60.1Mbit/s to 62.9Mbit/s
Plusnet 'up to' 76Mbit/s	60.8Mbit/s to 63.5Mbit/s	57.3Mbit/s to 60.1Mbit/s	55.4Mbit/s to 58.2Mbit/s
Virgin Media* 'up to' 152Mbit/s	160Mbit/s to 160.5Mbit/s	136.9Mbit/s to 146.9Mbit/s	125.3Mbit/s to 140.2Mbit/s

Source: SamKnows measurement data for all panel members with a connection in May 2014.
Panel Base: 1,711
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for 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.

2.8 Upload speeds

As mentioned previously, broadband connections work both ways, and as such have both measureable download and upload speeds. The upload speeds are important to those looking to share large files, use real-time two-way communication and for some online gaming. We therefore consider upload speeds in our research.

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

Our research shows that 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 May 2014. Both TalkTalk and Plusnet's ADSL services had average 24 hour upload speeds of 0.7Mbit/s compared to either 0.9Mbit/s or 1.0Mbit/s for all of the other ADSL2+ packages included in our research (Figure 2.10).

Figure 2.10 **Maximum, average and peak-time upload speeds for ADSL2+ ISP packages: May 2014**

Source: SamKnows measurement data for all panel members with a connection in May 2014.
*Notes: (1) Includes only customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for 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.(6) * denotes small sample size (<50)*

Figure 2.11 summarises the statistically significant differences in the upload speed performance of the ADSL2+ ISP packages covered in our research.

Figure 2.11 **Significant differences, to a 95% level of confidence, between maximum, average and peak-time upload speeds for ADSL2+ ISP packages: May 2014**

	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*

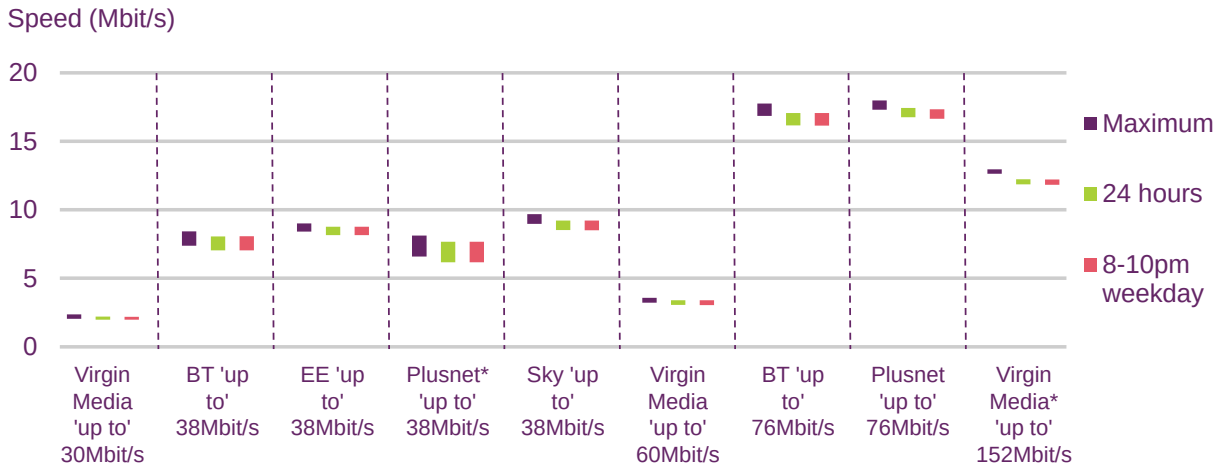
Maximum, average and peak-time upload speeds for 'up to' 30Mbit/s and above ISP packages

Among the ISP packages with a headline speed of 'up to' 30Mbit/s and above included in this report, Plusnet's and BT's 'up to' 76Mbit/s FTTC packages had the fastest upload speeds in terms of maximum, 24 hour average and peak-time upload speeds in May 2014. The average 24 hour upload speeds of these services were 17.1Mbit/s and 16.6Mbit/s respectively, compared to averages ranging from 6.9Mbit/s to 8.9Mbit/s among the 'up to' 38Mbit/s FTTC services shown below.

The 24 hour average upload speed of the three Virgin Media cable broadband services shown below ranged from 2.1Mbit/s for its 30Mbit/s service to 12.0Mbit/s for its 'up to' 152Mbit/s service. In May 2014, average peak-time upload speeds as a proportion of the

average maximum upload speeds ranged from 94% (for Virgin Media's 'up to 30Mbit/s and 152Mbit/s services and Plusnet's 'up to' 38Mbit/s FTTC service) to 97% for EE's 'up to' 38Mbit/s FTTC service.

Figure 2.12 **Maximum, average and peak-time upload speeds for 'up to' 30Mbit/s and above ISP packages**



*Source: SamKnows measurement data for all panel members with a connection in May 2014). 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) * denotes small sample size (<50)*

Figure 2.13 summarises the statistically significant differences between the upload performance of different ISP packages 'up to' 30Mbit/s and above included in our research in May 2014.

Figure 2.13 **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: May 2014**

	Maximum	24 hours	8-10pm weekday
ISP package	Is faster than...	Is faster than...	Is faster than...
Plusnet 76	Virgin Media 152, Sky 38, EE 38, BT 38, Plusnet 38, Virgin Media 60, Virgin Media 30	Virgin Media 152, Sky 38, EE 38, BT 38, Plusnet 38, Virgin Media 60, Virgin Media 30	Virgin Media 152, Sky 38, EE 38, BT 38, Plusnet 38, Virgin Media 60, Virgin Media 30
BT 76	Virgin Media 152, Sky 38, EE 38, BT 38, Plusnet 38, Virgin Media 60, Virgin Media 30	Virgin Media 152, Sky 38, EE 38, BT 38, Plusnet 38, Virgin Media 60, Virgin Media 30	Virgin Media 152, Sky 38, EE 38, BT 38, Plusnet 38, Virgin Media 60, Virgin Media 30
Virgin Media 152	Sky 38, EE 38, BT 38, Plusnet 38, Virgin Media 60, Virgin Media 30	Sky 38, EE 38, BT 38, Plusnet 38, Virgin Media 60, Virgin Media 30	Sky 38, EE 38, BT 38, Plusnet 38, Virgin Media 60, Virgin Media 30
Sky 38	BT 38, Plusnet 38, Virgin Media 60, Virgin Media 30	BT 38, Plusnet 38, Virgin Media 60, Virgin Media 30	BT 38, Plusnet 38, Virgin Media 60, Virgin Media 30
EE 38	Plusnet 38, Virgin Media 60, Virgin Media 30	BT 38, Plusnet 38, Virgin Media 60, Virgin Media 30	BT 38*, Plusnet 38, Virgin Media 60, Virgin Media 30
BT 38	Virgin Media 60, Virgin Media 30	Virgin Media 60, Virgin Media 30	Virgin Media 60, Virgin Media 30
Plusnet 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.*

2.9 Preliminary test result data for new disconnection test

In May 2014 we trialled a new test which measures service disconnections among a subset of our panellists. The test records when panellists' service suffered a disconnection (i.e. an instance where two or more packets of data are lost to all test servers simultaneously) along with the time and duration of the disconnection.

As the test was only run on a subset of our panellists' connections, the ISP packages which are included in the analysis differ slightly from those in the rest of this report. In addition, this means that the number of panellists included for each ISP package is lower in this section than elsewhere in the report, and it is difficult to draw any firm conclusions from the data shown below.

We intend to deploy this test across all of our panellists prior to the next measurement period (November 2014).

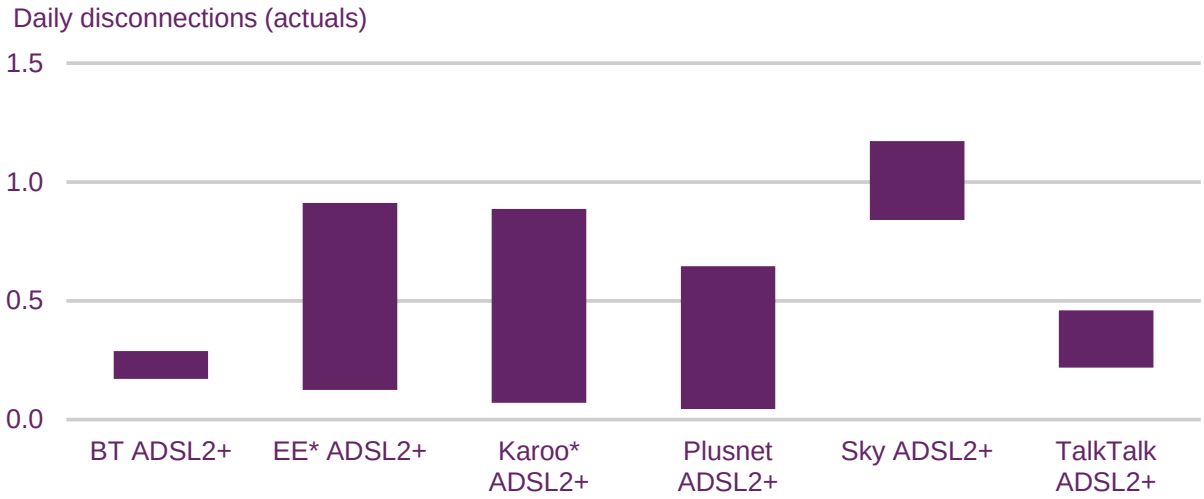
Average daily disconnections 30 seconds or longer for ADSL2+ ISP packages

Disconnections are an important metric for fixed-line broadband consumers, as numerous or lengthy disruptions in internet connectivity can be inconvenient and frustrating for users. It

should be noted that while the disconnection data below measures an important aspect of broadband connection performance, it does not give an overall view of service reliability.

Almost all of the ADSL2+ ISP packages shown in Figure 2.14 below had an average of less than one disconnection of 30 seconds or longer per day in May 2014, the only exception being Sky's ADSL2+ service, which had an average of just over one such disconnection per day. As noted previously, the low sample sizes in this analysis mean that the results should be treated with caution.

Figure 2.14 **Average daily disconnections 30 seconds or longer for ADSL2+ ISP packages: May 2014**
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in May 2014.
*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) *caution – small sample size (<50)*

Figure 2.15 summarises the statistically significant differences between the average daily number of disconnections of 30 seconds or longer for the ADSL2+ ISP packages included in our research in May 2014.

Figure 2.15 **Significant differences, to a 95% level of confidence, between average daily disconnections 30 seconds or longer for ADSL2+ ISP packages: May 2014**

	24 hours
ISP package	**Is better than...**
BT	Sky
Plusnet	Sky
TalkTalk	Sky

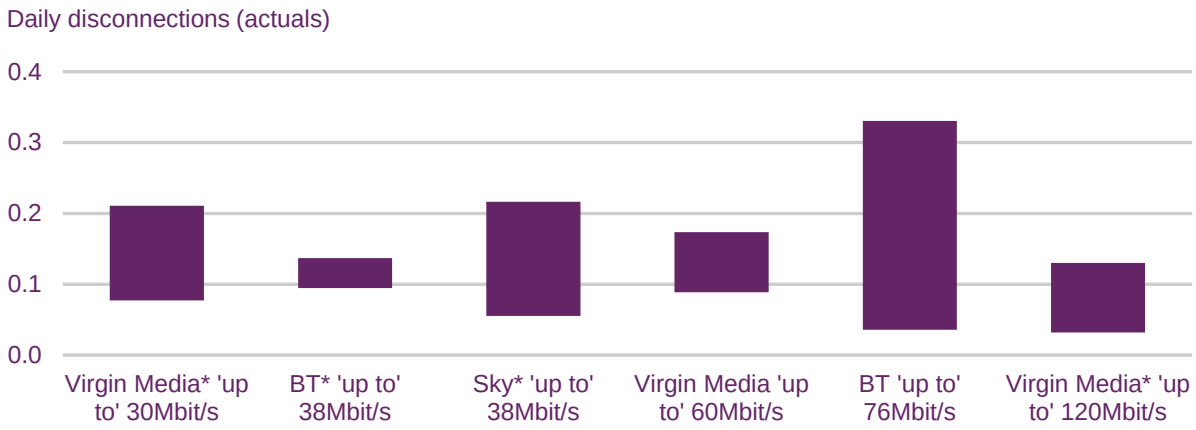
Source: Ofcom
Notes: No other differences were statistically significant

Average daily disconnections 30 seconds or longer for 'up to' 30Mbit/s and above ISP packages

As seen in Figure 2.16, the superfast ISP packages included in this analysis had a lower average number of daily disconnections of 30 seconds or longer than the ADSL2+ services

included in the analysis; in May 2014 ADSL2+ connections had an average of 0.5 such disconnections per day, compared to an average of 0.1 for both cable and FTTC services. As noted previously, the low sample sizes in this analysis mean that the results should be treated with caution.

Figure 2.16 **Average daily disconnection 30 seconds or longer for 'up to' 30Mbit/s and above ISP packages: May 2014**
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in May 2014.
*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; *caution – small sample size (<50)*

Figure 2.17 shows that there were no statistically significant differences between the average daily number of disconnections of 30 seconds or longer for the 'up to' 30Mbit/s and above ISP packages included in our research in May 2014.

Figure 2.17 **Significant differences, to a 95% level of confidence, between average daily disconnections 30 seconds or longer for 'up to' 30Mbit/s and above ISP packages: May 2014**

	24 hours
ISP package	**Is better than...**
No differences	No differences

Source: Ofcom
Notes: No other differences were statistically significant

2.10 Split of disconnections longer than 30 seconds by duration for ISP packages: May 2014

Figure 2.17 shows the split of the average number of disconnections longer than 30 seconds per ISP package by duration. The longer the disconnection that occurs, the greater the inconvenience for the user, so a larger proportion of the shorter disconnections is better in this case.

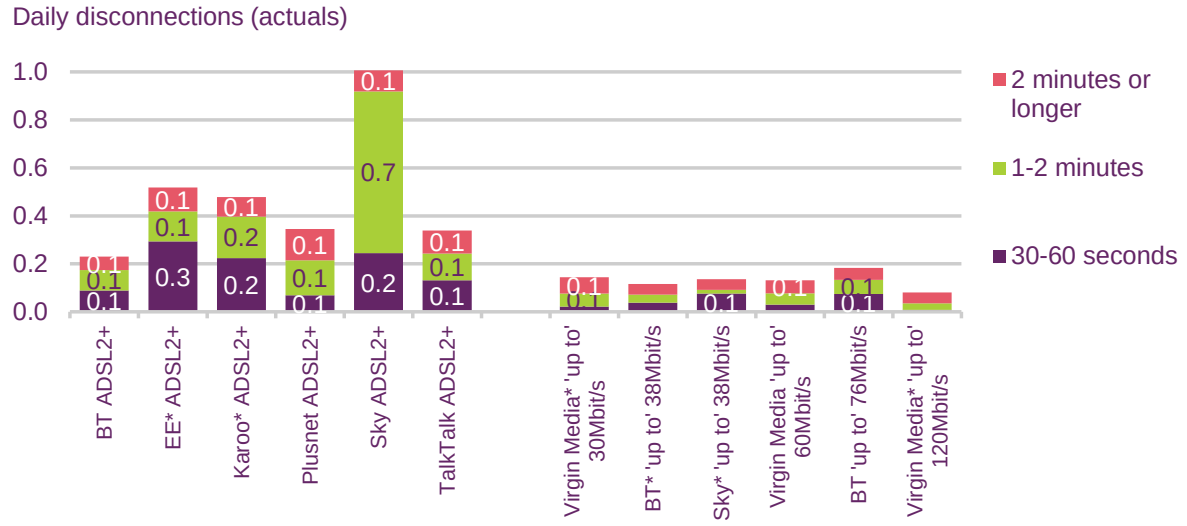
Out of the packages we researched, the average number of disconnection of 30 to 60 seconds in length ranged from less than 0.1 per day for BT's 'up to' 38Mbit/s FTTC service and Virgin Media's 'up to' 30Mbit/s, 60Mbit/s and 120Mbit/s packages, to 0.3 per day for EE's ADSL2+ service. Similarly, the average number of disconnections of one to two minutes ranged from less than 0.1 per day for BT and Sky's 'up to' 38Mbit/s FTTC services

and Virgin Media's 'up to' 60Mbit/s and 120Mbit/s cable services to 0.7 per day for Sky's ADSL2+ service.

All of the packages included in the analysis had an average of 0.1 disconnections longer that two minutes in duration per day in May 2014, except BT's 'up to' 38Mbit/s and 76Mbit/s FTTC services, Sky's 'up to' 38Mbit/s FTTC service and Virgin Media's 'up to' 120Mbit/s package, all of which had an average of less than 0.1 such disconnection per day during this period.

As noted previously, the low sample sizes in this analysis mean that the results should be treated with caution, and disconnection data does not give an overall view of service reliability.

Figure 2.18 **Split of disconnections longer than 30 seconds by duration for ISP packages: May 2014**
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in May 2014.
*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; *caution – small sample size (<50)*

Section 3

Other metrics affecting performance

There are a number of other metrics which can be used to evaluate the performance of fixed-line broadband services. The most important of these are outlined below in Figure 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 individual 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**

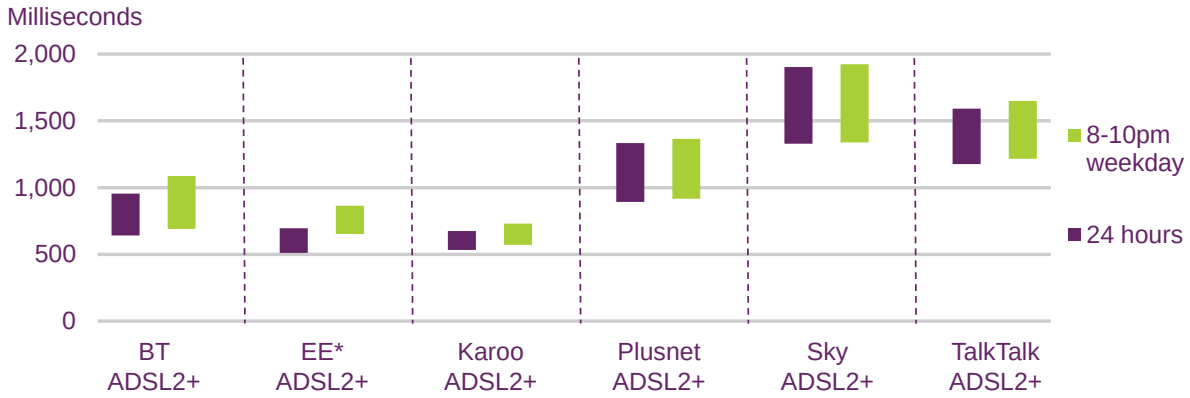
Variable	Definition and importance
Web browsing speed	**The time taken to fetch the main HTML and assets (text, basic code and content files) from a webpage** *Dependent on download speeds, latency and DNS resolution times*
Latency	**The time it takes a packet of data to travel to a third-party server 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 measure the basic web browsing performance of the different ISP packages, we measured the time in milliseconds to fetch the main HTML and assets (i.e. text, basic code and content files) from three test pages. Note that in Figure 3.2 and Figure 3.4 better performance is shown by lower bars.

Figure 3.2 **Average and peak-time loading of web pages for ADSL2+ ISP packages: May 2014**
(Lower values indicate better performance)



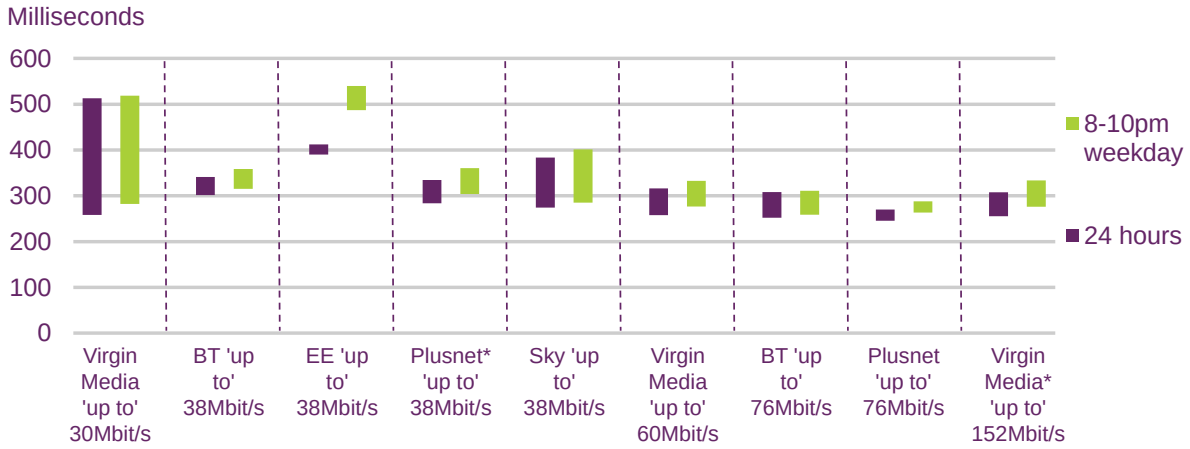
Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Better performance is indicated by a faster loading time, i.e. lower values.

Figure 3.3 **Significant differences, to a 95% level of confidence, between average and peak-time loading of web pages for ADSL2+ ISP packages: May 2014**

	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**
Karoo 20	Plusnet 20, TalkTalk 20, Sky 20	Plusnet 20, TalkTalk 20, Sky 20
EE 20	Plusnet 20, TalkTalk 20, Sky 20	Plusnet 20*, TalkTalk 20, Sky 29
BT 20	TalkTalk 20, Sky 20	TalkTalk 20*, Sky 20

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: May 2014**
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in May 2014.

Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for 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.

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: May 2014**

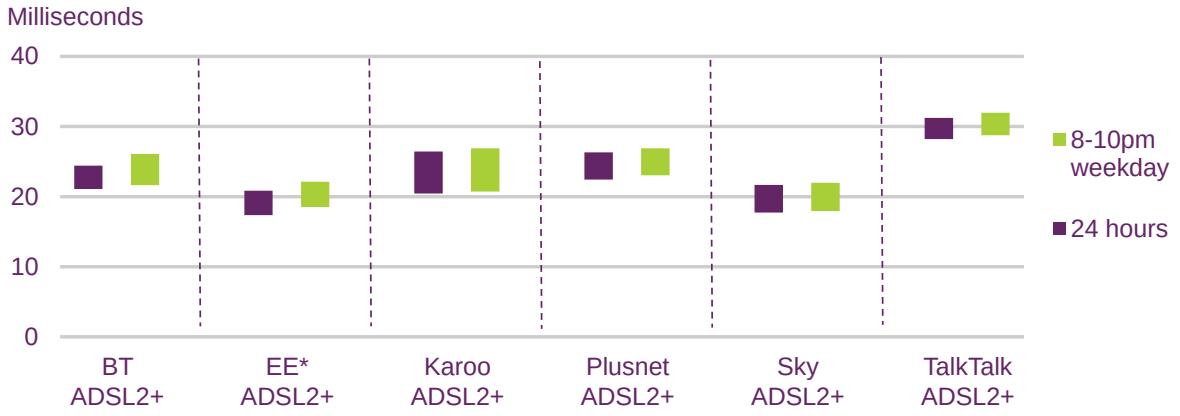
	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**
Plusnet 76	Plusnet 38, BT 38, Sky 38*, EE 38	Plusnet 38, BT 38, EE 38
Virgin Media 152	EE 38	EE 38
BT 76	EE 38	BT 38*, EE 38
Virgin Media 60	EE 38	EE 38
Plusnet 38	EE 38	EE 38
BT 38	EE 38	EE 38
Sky 38	EE 38*	EE 38

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

Latency

Latency is the time that it takes for a single packet of data to travel from a user's PC to a third-party server and back again. The figure is commonly measured in milliseconds, and a connection with low latency will seem more responsive for the delivery of simple tasks such as web browsing. Particular applications also perform significantly better with a low latency, particularly some online games. In Figure 3.6 and Figure 3.8 lower bars indicate better performance.

Figure 3.6 **Average and peak-time latency for ADSL2+ ISP packages: May 2014** (Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been

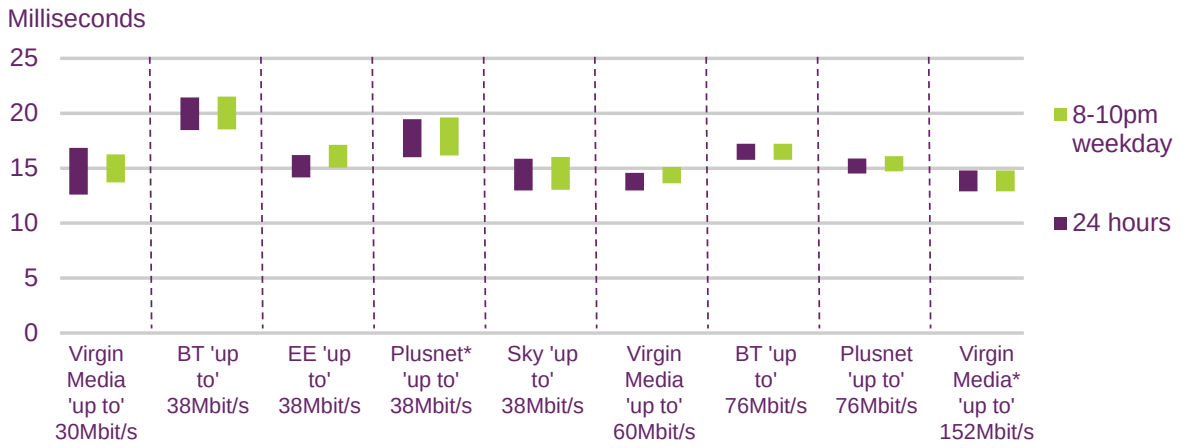
weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Better 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: May 2014**

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
EE 20	BT 20*, Plusnet 20, TalkTalk 20	Plusnet 20*, TalkTalk 20
Sky 20	Plusnet 20*, TalkTalk 20	Plusnet 20*, TalkTalk 20
BT 20	TalkTalk 20	TalkTalk 20
Karoo 20	TalkTalk 20	TalkTalk 20
Plusnet 20	TalkTalk 20*	TalkTalk 20

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: May 2014**
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for 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.

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: May 2014**

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
Virgin Media 152	Plusnet 76*, BT 76, Plusnet 38, BT 38	EE 38*, BT 76, Plusnet 38, BT 38
Virgin Media 60	BT 76, Plusnet 38, BT 38	BT 76, Plusnet 38, BT 38
Sky 38	Plusnet 38*, BT 38	Plusnet 38*, BT 38
Virgin Media 30	BT 38	BT 38
EE 38	BT 38	BT 38
Plusnet 76	BT 38	BT 38
BT 76	No Differences	BT 38

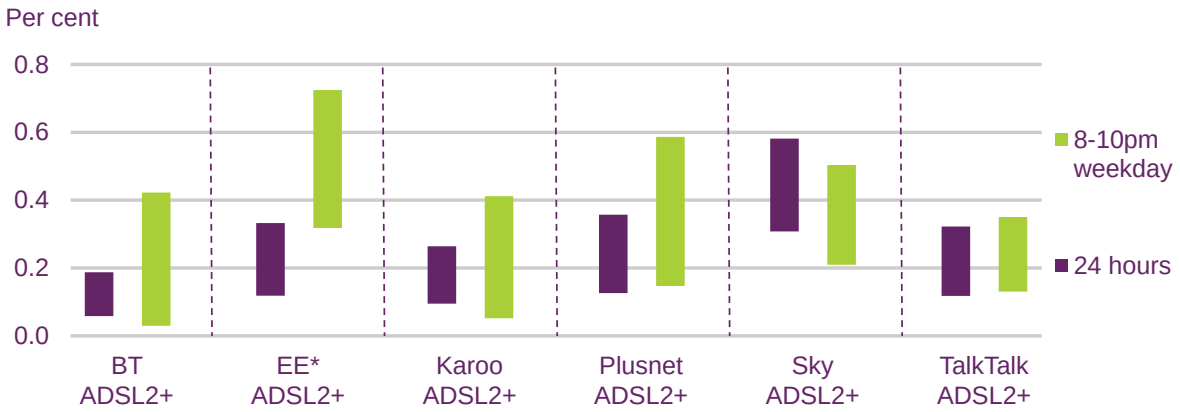
Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

Packet Loss

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

This is of particular concern to online gamers, users of voice over IP (VoIP) telephony as well as those streaming audio or video content (a small number of dropped packets is acceptable as each packet in the test accounts for only 0.2 seconds, but extended periods of loss lead to choppy audio or video content). Note that in Figure 3.14 and Figure 3.16 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: May 2014**
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in May 2014
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread

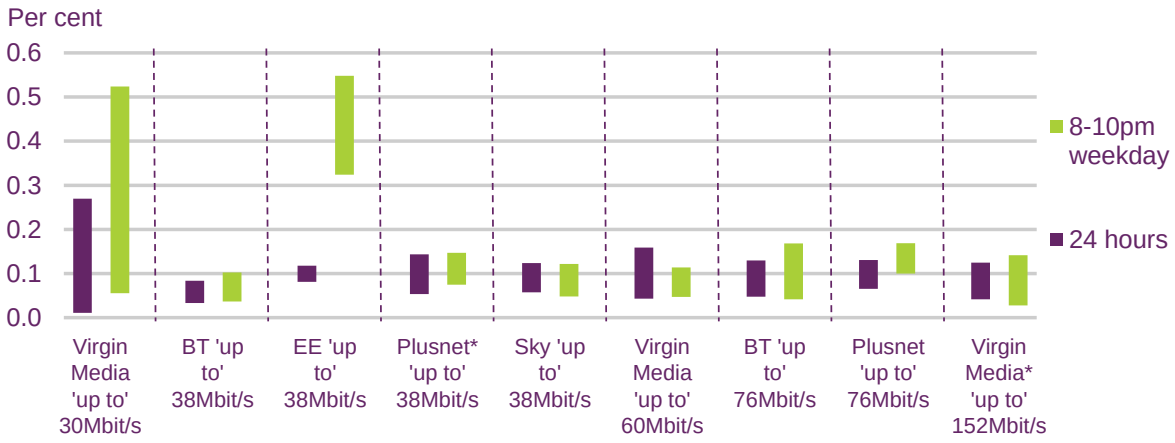
download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Note that better performance is indicated by lower packet loss (i.e. lower values).

Figure 3.11 **Significant differences, to a 95% level of confidence, between average and peak-time packet loss for ADSL2+ ISP packages: May 2014**

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
BT 20	Sky 20	No Differences
Karoo 20	Sky 20*	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: May 2014**
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for 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.

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: May 2014**

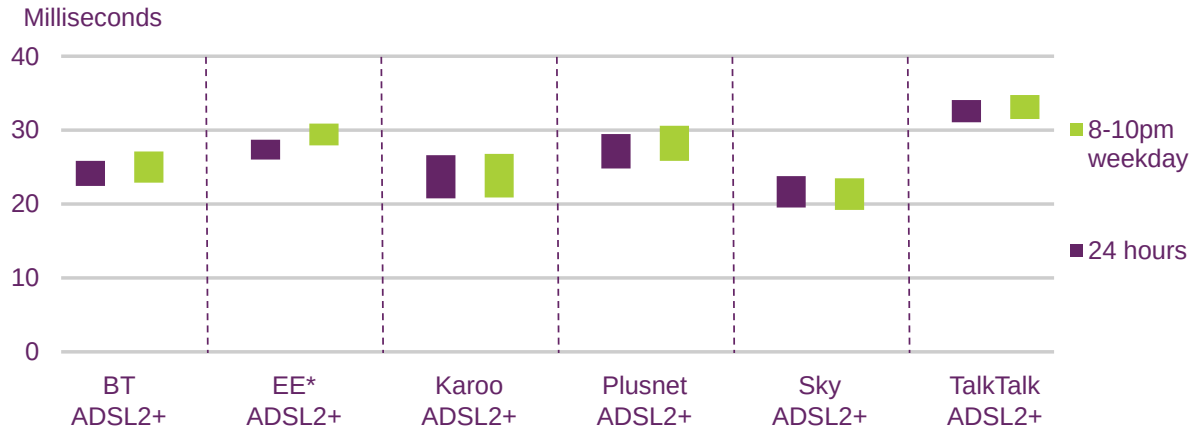
	24 hours	8-10pm weekday
ISP package	Is better than...	Is better than...
BT 38	No Differences	EE 38
Sky 38	No Differences	EE 38
Virgin Media 152	No Differences	EE 38
Plusnet 38	No Differences	EE 38
Virgin Media 60	No Differences	EE 38
BT 76	No Differences	EE 38
Plusnet 76	No Differences	EE 38

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

DNS Resolution

DNS (the domain name service) plays a crucial part in the way the internet operates. This protocol translates domain names (such as ofcom.org.uk) into the IP addresses that are 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 services fail or operate slowly, web browsing and other online activities suffer. A slow DNS does not affect download speed, but can severely affect the responsiveness of the internet while browsing. Note that in Figure 3.18 and Figure 3.20 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: May 2014**
(Lower values indicate better performance)



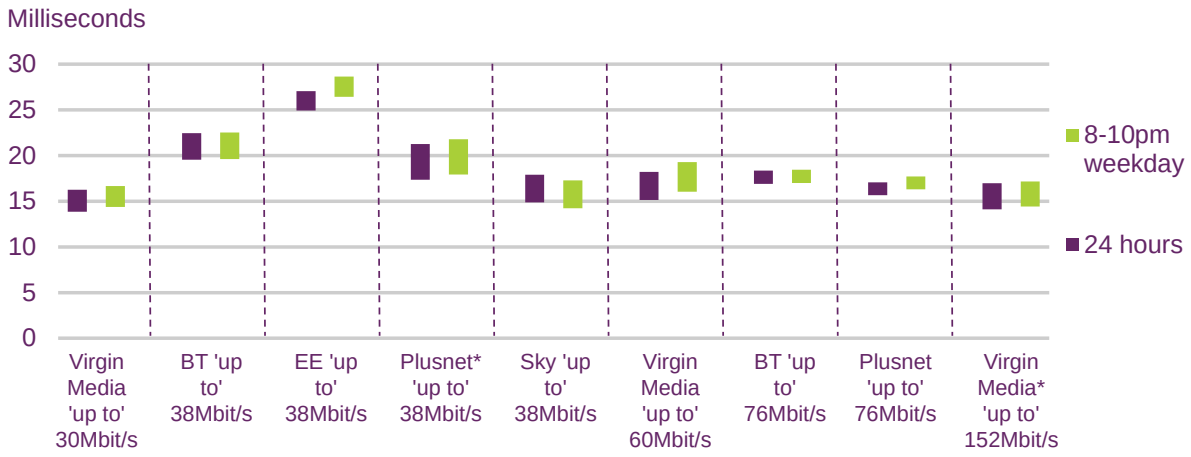
Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (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: May 2014**

	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**
Sky 20	EE 20*, TalkTalk 20	EE 20*, TalkTalk 20
Karoo 20	TalkTalk 20	EE 20*, TalkTalk 20
BT 20	TalkTalk 20	EE 20*, TalkTalk 20
Plusnet 20	TalkTalk 20	TalkTalk 20*

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: May 2014**
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for 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.

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: May 2014**

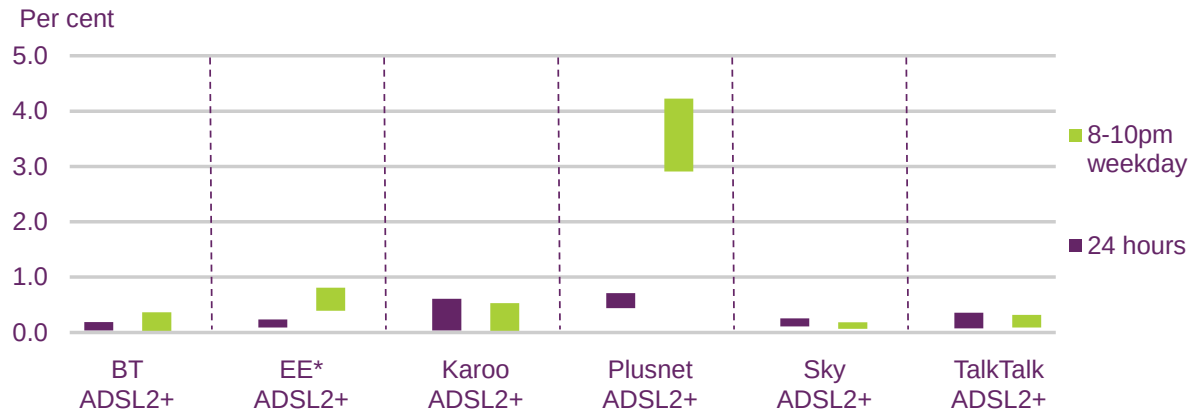
	24 hours	8-10pm weekday
ISP package	Is faster than...	Is faster than...
Virgin Media 30	BT 76*, Plusnet 38*, BT 38, EE 38	BT 76*, Plusnet 76*, Plusnet 38, BT 38, EE 38
Virgin Media 152	Plusnet 38*, BT 38, EE 38	Plusnet 38*, BT 38, EE 38
Sky 38	BT 38, EE 38	Plusnet 38*, BT 38, EE 38
Plusnet 76	Plusnet 38*, BT 38, EE 38	Plusnet 38*, BT 38, EE 38
Virgin Media 60	BT 38, EE 38	BT 38*, EE 38
BT 76	BT 38, EE 38	BT 38, EE 38
Plusnet 38	EE 38	EE 38
BT 38	EE 38	EE 38

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

DNS Failure

DNS failure occurs when an ISP's DNS server is unable to translate a domain name to an IP address in a TCP/IP network. When a DNS failure occurs the user is presented with an error message such as "this server is unavailable" or "host could not be found", and is unable to access the requested page on that occasion. Note that in Figure 3.22 and Figure 3.24 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: May 2014**
(Lower values indicate better performance)



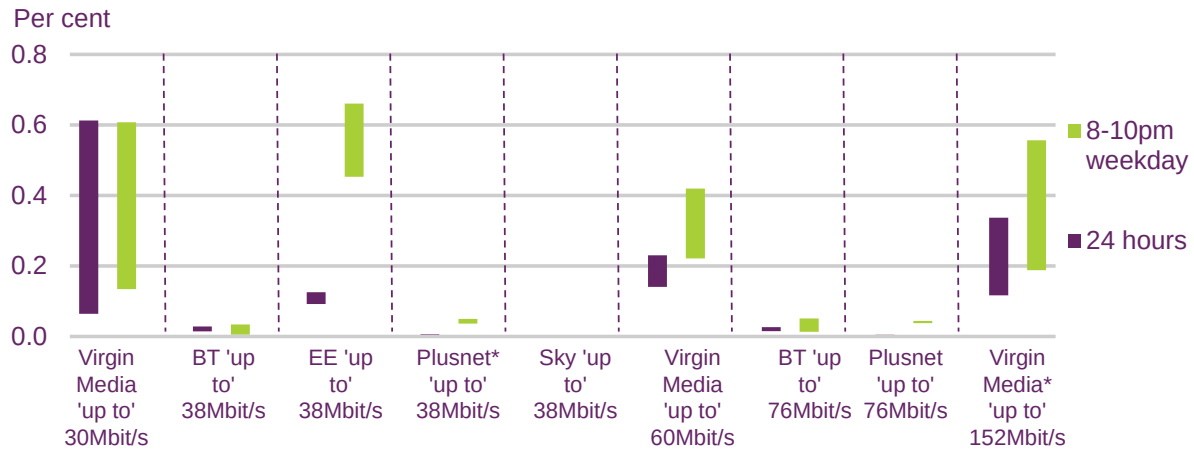
Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (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: May 2014**

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
Sky 20	Plusnet 20	EE 20, Plusnet 20
BT 20	Plusnet 20	Plusnet 20
TalkTalk 20	Plusnet 20	Plusnet 20
EE 20	Plusnet 20	Plusnet 20
Karoo 20	No Differences	Plusnet 20

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: May 2014**
(Lower values indicate better performance)



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

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: May 2014**

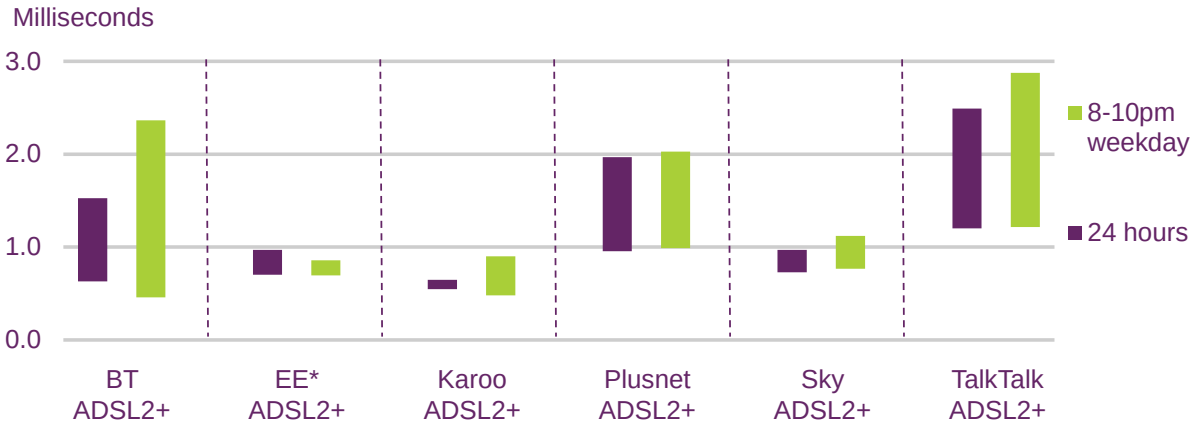
	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
BT 38	EE 38, Virgin Media 60, Virgin Media 152, BT 76, Virgin Media 30*, Plusnet 76, Plusnet 38	Virgin Media 60, Virgin Media 30*, Virgin Media 152, EE 38, Plusnet 76, Plusnet 38
Sky 38	EE 38*, Virgin Media 60, Virgin Media 152, BT 76, Plusnet 76, Plusnet 38	Virgin Media 60, Virgin Media 30*, Virgin Media 152, EE 38, Plusnet 76, Plusnet 38
EE 38	BT 76, Plusnet 76, Plusnet 38	Plusnet 76, Plusnet 38
Virgin Media 60	Plusnet 76, Plusnet 38	Plusnet 76, Plusnet 38
Virgin Media 152	Plusnet 76, Plusnet 38	Plusnet 76, Plusnet 38
BT 76	Plusnet 76, Plusnet 38	Virgin Media 60, Virgin Media 30*, Virgin Media 152, EE 38, Plusnet 76, Plusnet 38
Virgin Media 30	Plusnet 76, Plusnet 38	Plusnet 76, Plusnet 38

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

Jitter

'Jitter' is defined as the rate of change of latency. The lower the measure of jitter, the more stable 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. The effectively allows for up to a 20 millisecond jitter with no noticeable effect for the end-user. Note that in Figure 3.26, Figure 3.28, Figure 3.30 and Figure 3.32 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: May 2014**
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in May 2014.

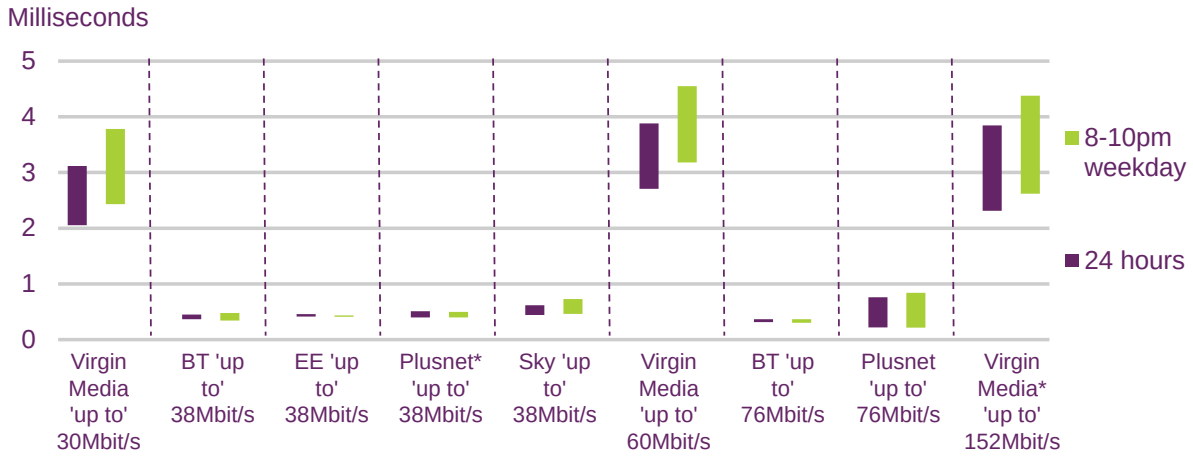
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (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: May 2014**

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
Karoo 20	EE 20*, Sky 20, Plusnet 20, TalkTalk 20	Plusnet 20*
EE 20	No Differences	Plusnet 20*

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: May 2014**
(Lower values indicate better performance)



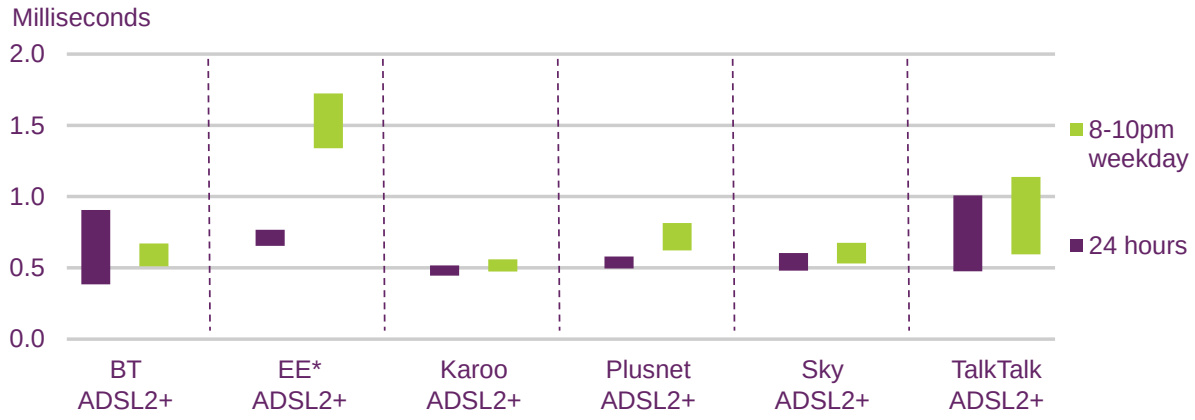
Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL 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.

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: May 2014**

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
BT 76	BT 38*, EE 38, Plusnet 38, Virgin Media 30, Virgin Media 60, Virgin Media 152	EE 38, Plusnet 38, Virgin Media 30, Virgin Media 60, Virgin Media 152
BT 38	Virgin Media 30, Virgin Media 60, Virgin Media 152	Virgin Media 30, Virgin Media 60, Virgin Media 152
EE 38	Virgin Media 30, Virgin Media 60, Virgin Media 152	Virgin Media 30, Virgin Media 60, Virgin Media 152
Plusnet 38	Virgin Media 30, Virgin Media 60, Virgin Media 152	Virgin Media 30, Virgin Media 60, Virgin Media 152
Plusnet 76	Virgin Media 30, Virgin Media 60, Virgin Media 152	Virgin Media 30, Virgin Media 60, Virgin Media 152
Sky 38	Virgin Media 30, Virgin Media 60, Virgin Media 152	Virgin Media 30, Virgin Media 60, Virgin Media 152

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

Figure 3.26 **Average and peak-time downstream jitter for ADSL2+ ISP packages: May 2014**
(Lower values indicate better performance)



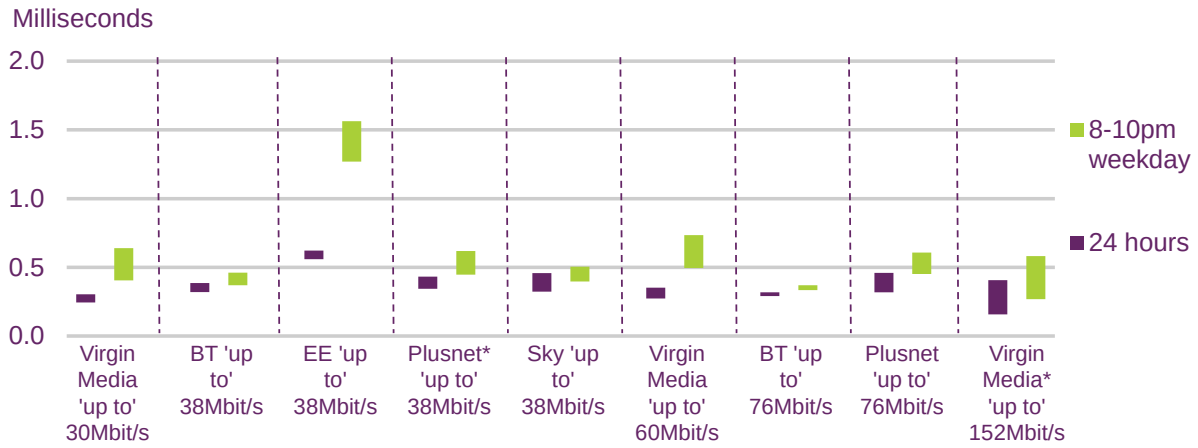
Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (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+ packages: May 2014**

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
Karoo 20	EE 20	TalkTalk 20*, Plusnet 20, EE 20
Plusnet 20	EE 20	EE 20
Sky 20	EE 20*	EE 20
TalkTalk 20	No Differences	EE 20
BT 20	No Differences	EE 20

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: May 2014**
(Lower values indicate better performance)



Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for 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.

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: May 2014**

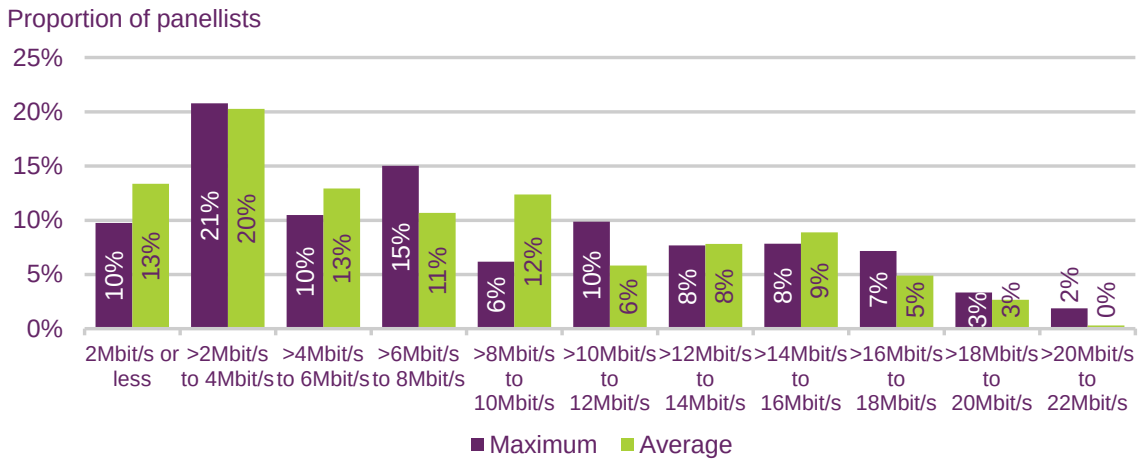
	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
Virgin Media 30	BT 38*, Plusnet 76*, Plusnet 38, EE 38	EE 38
BT 76	Plusnet 38, EE 38	BT 38*, Virgin Media 30*, Virgin Media 120*, Plusnet 76, Plusnet 38, EE 38
Virgin Media 152	EE 38	EE 38
Virgin Media 60	EE 38	EE 38
BT 38	EE 38	EE 38
Plusnet 38	EE 38	EE 38
Plusnet 76	EE 38	EE 38
Sky 38	No Differences	EE 38

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

Annex 1

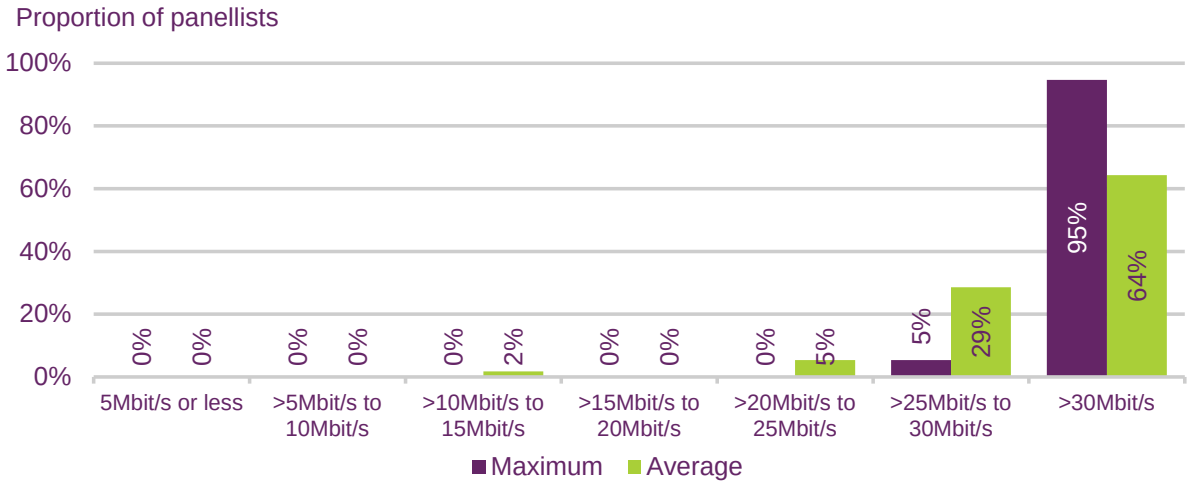
Additional analysis

Figure 4.1 **Distribution of maximum and average download speeds for ADSL2+ ISP packages: May 2014**



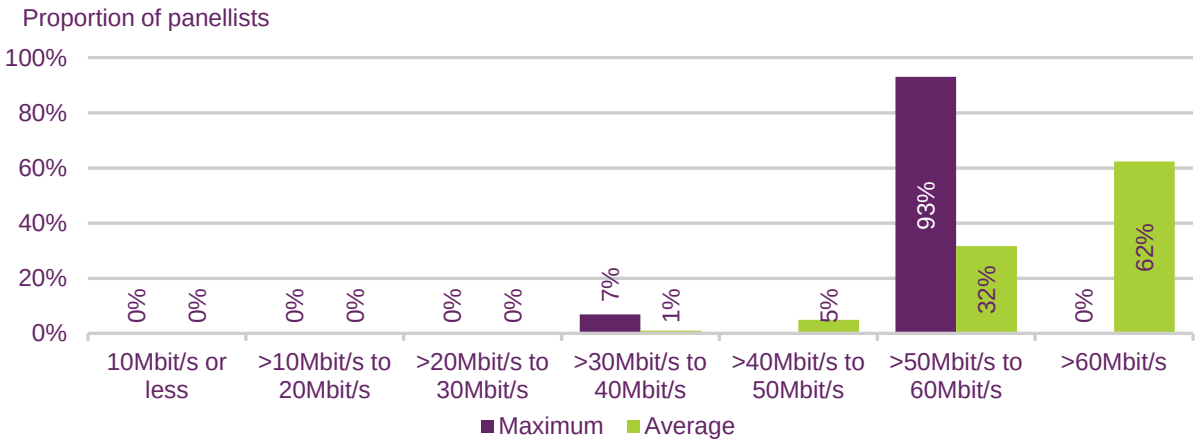
Source: SamKnows measurement data for panel members with a connection in May 2014.
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK ADSL2+ residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 4.2 **Distribution of maximum and average download speeds for 'up to' 30Mbit/s cable packages: May 2014**



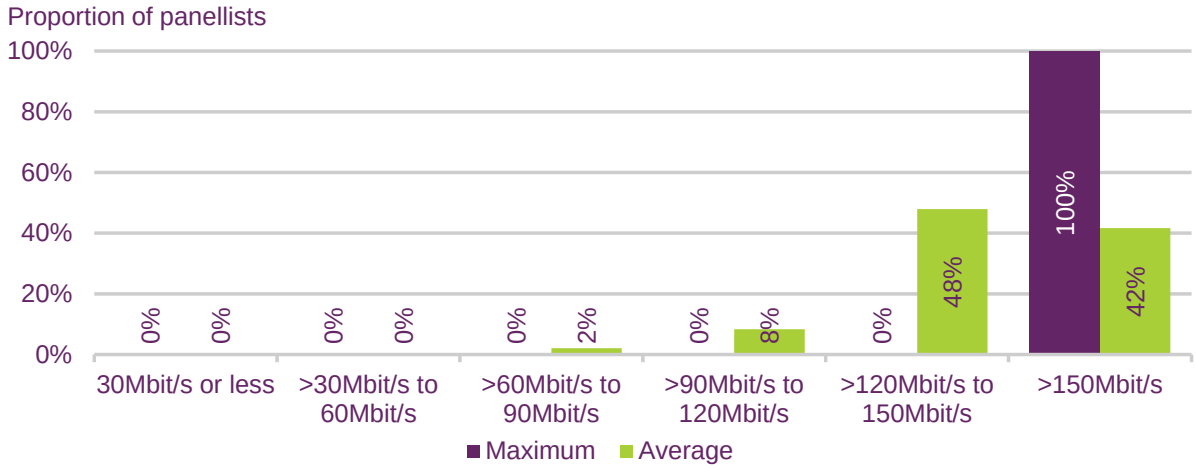
Source: SamKnows measurement data for panel members with a connection in May 2014.
Notes: (1) Data have been weighted to regional coverage to ensure that they are representative of UK cable 'up to' 30Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 4.3 **Distribution of maximum and average download speeds for 'up to' 60Mbit/s cable packages: May 2014**



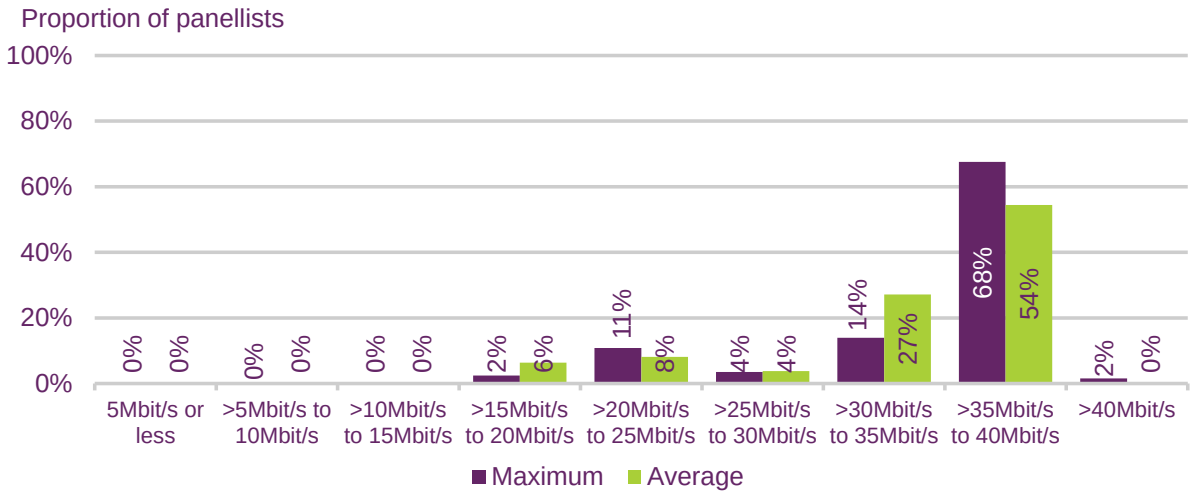
Source: SamKnows measurement data for panel members with a connection in May 2014.
Notes: (1) Data have been weighted to regional coverage to ensure that they are representative of UK cable 'up to' 60Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 4.4 **Distribution of maximum and average download speeds for 'up to' 152Mbit/s cable packages: May 2014**



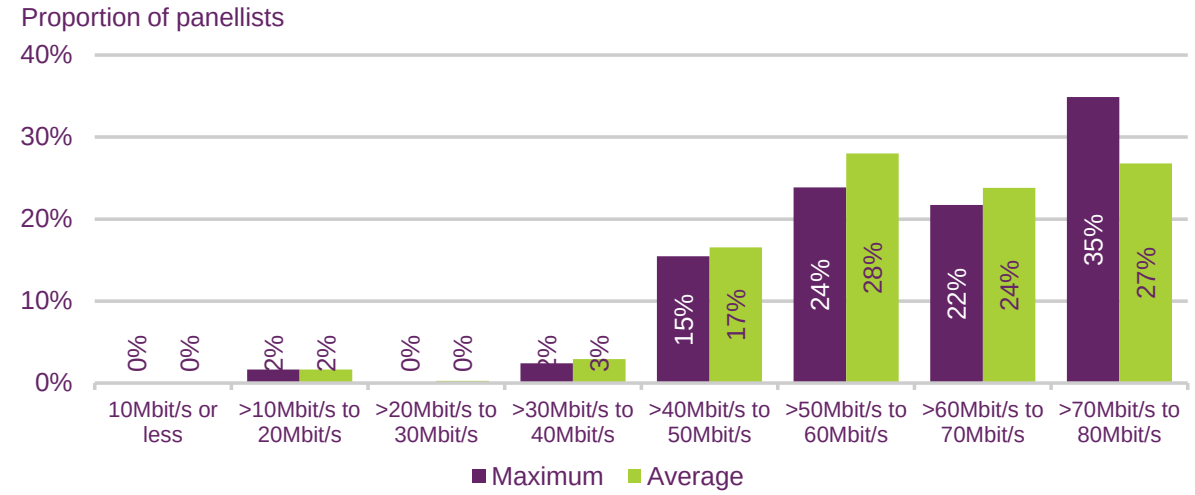
Source: SamKnows measurement data for panel members with a connection in May 2014.
Notes: (1) Data have been weighted to regional coverage to ensure that they are representative of UK cable 'up to' 100Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 4.5 **Distribution of maximum and average download speeds for 'up to' 38Mbit/s FTTC packages: May 2014**



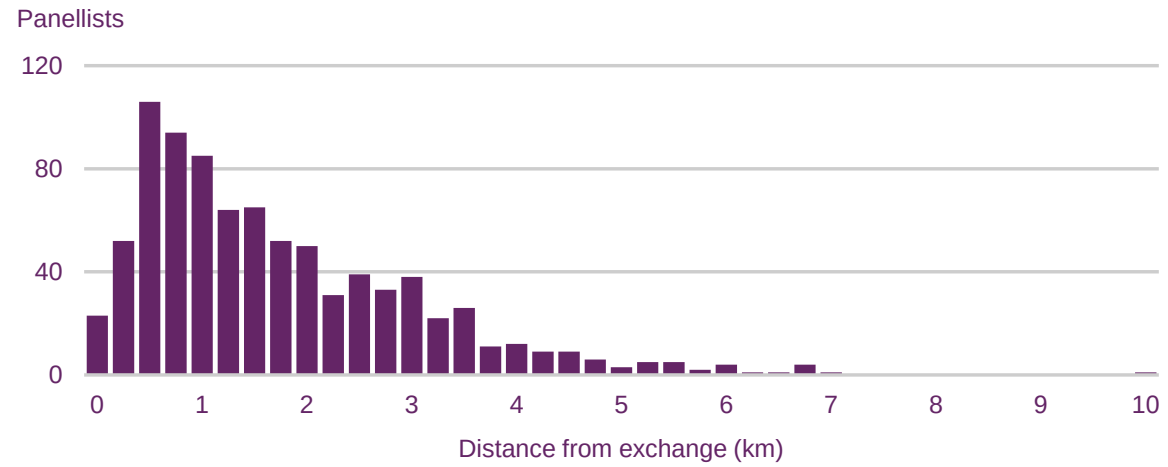
Source: SamKnows measurement data for panel members with a connection in May 2014.
Notes: (1) Data collected from multi-thread download speed tests.

Figure 4.6 **Distribution of maximum and average download speeds for 'up to' 76Mbit/s FTTC packages: May 2014**



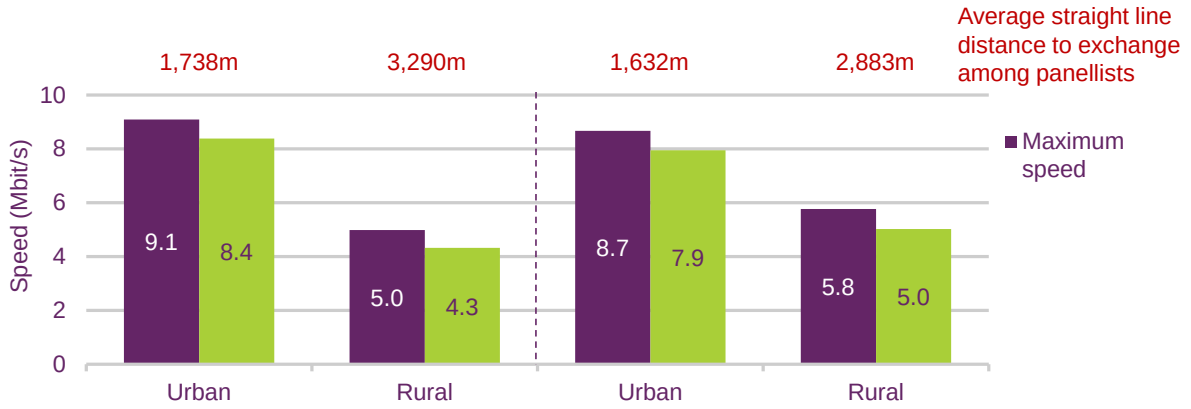
Source: SamKnows measurement data for panel members with a connection in May 2014.
Notes: (1) Data collected from multi-thread download speed tests.

Figure 4.7 **Distribution of panellists, by distance from exchange**



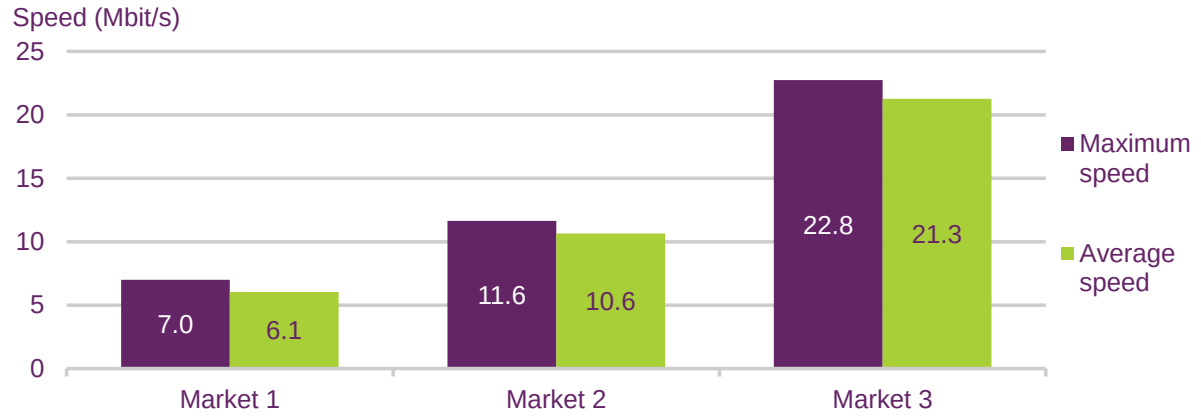
Source: Ofcom, using data supplied by SamKnows

Figure 4.8 **Average and maximum download speeds for ADSL broadband connections in rural & urban areas: May 2014**



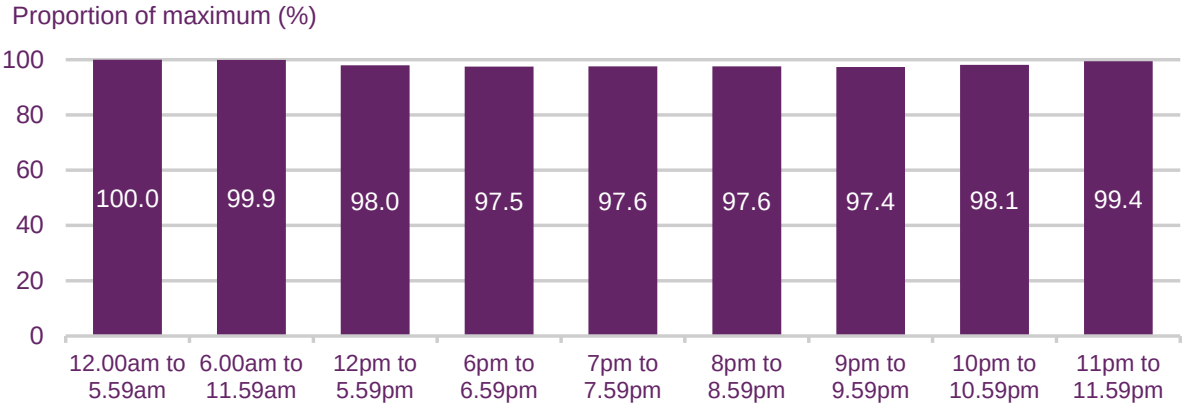
Source: SamKnows measurement data for all panel members with a connection in May 2014,
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests

Figure 4.9 **Average and maximum download speeds, by geographic market: May 2014**



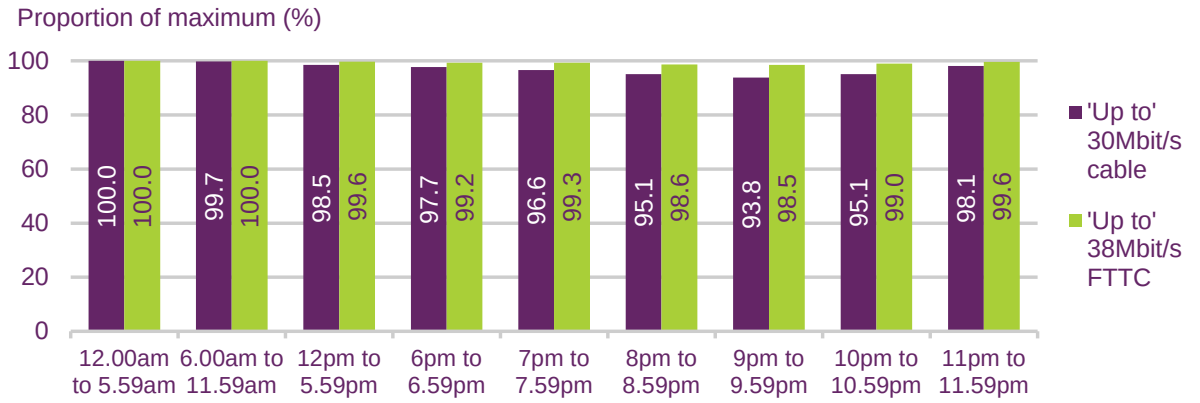
Source: SamKnows measurement data for all panel members with a connection in May 2014. Panel Base: 956
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential 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 May 2014 and an estimated split between rural and urban areas; (3) Data collected from multi-thread download speed tests.

Figure 4.10 **Average download speed as a proportion of maximum speed by time of day for ADSL2+ ISP packages: May 2014**



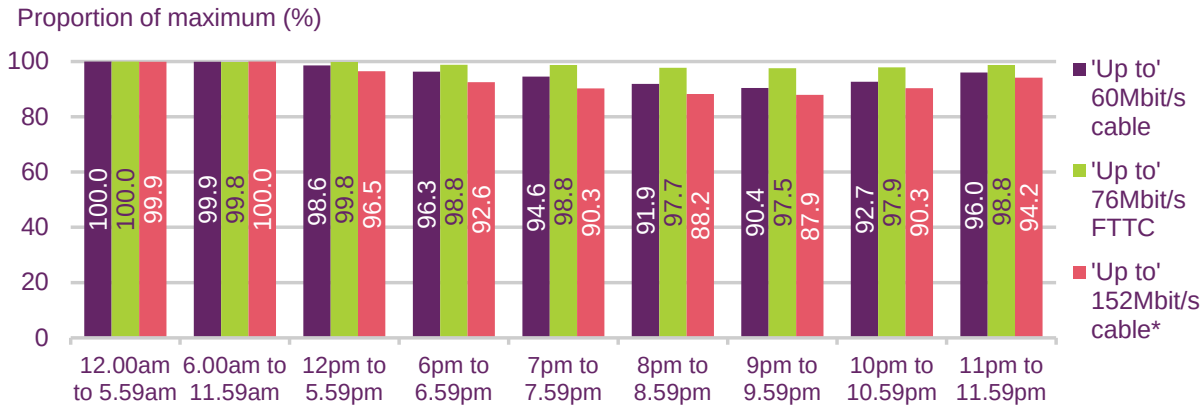
Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK ADSL2+ residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 4.11 **Average download speed as a proportion of maximum speed, by time of day for 'up to' 30Mbit/s and 'up to 38Mbit/s ISP packages: May 2014**



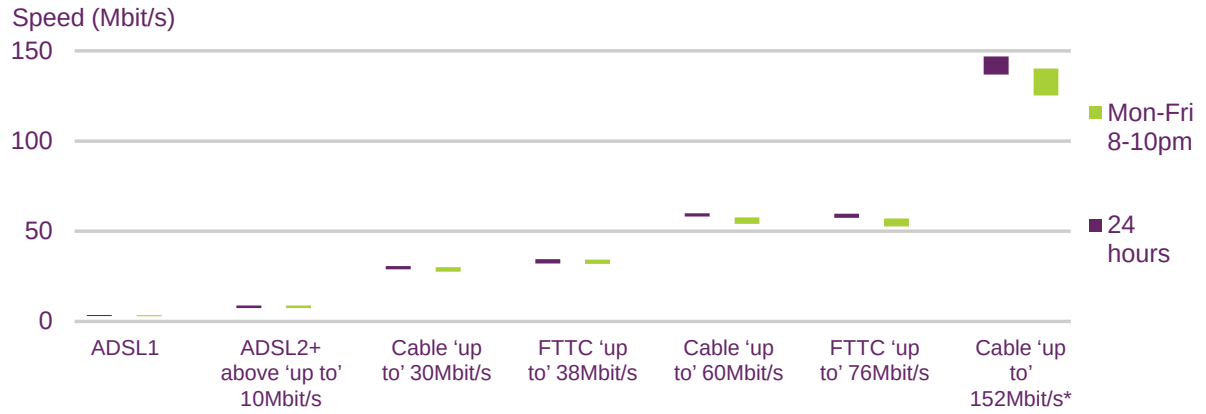
Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK 'up to' 30Mbit/s cable and 'up to' 38Mbit/s FTTC residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 4.12 **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' 152Mbit/s ISP packages: May 2014**



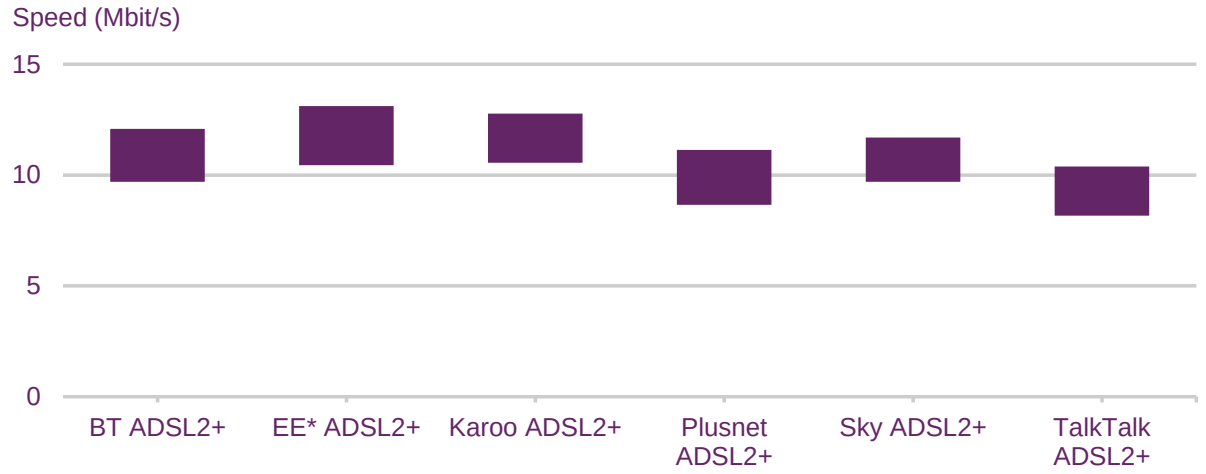
Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Data have been weighted by ISP package, rural/urban and Geographic Market classification to ensure that they are representative of UK 'up to' 60Mbit/s cable, 'up to' 76Mbit/s FTTC and 'up to' 100Mbit/s cable residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 4.13 **Average download speeds, by technology and headline speed: May 2014**



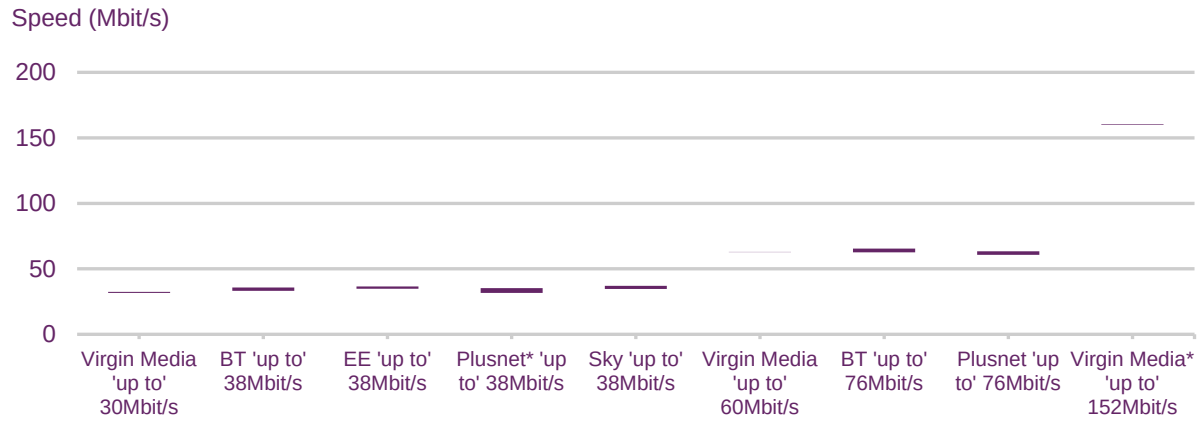
Source: SamKnows measurement data for all panel members with a connection in May 2014. Panel Base: 956
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential 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 May 2014; (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean.

Figure 4.14 **Maximum download speeds for ADSL2+ ISP packages: May 2014**



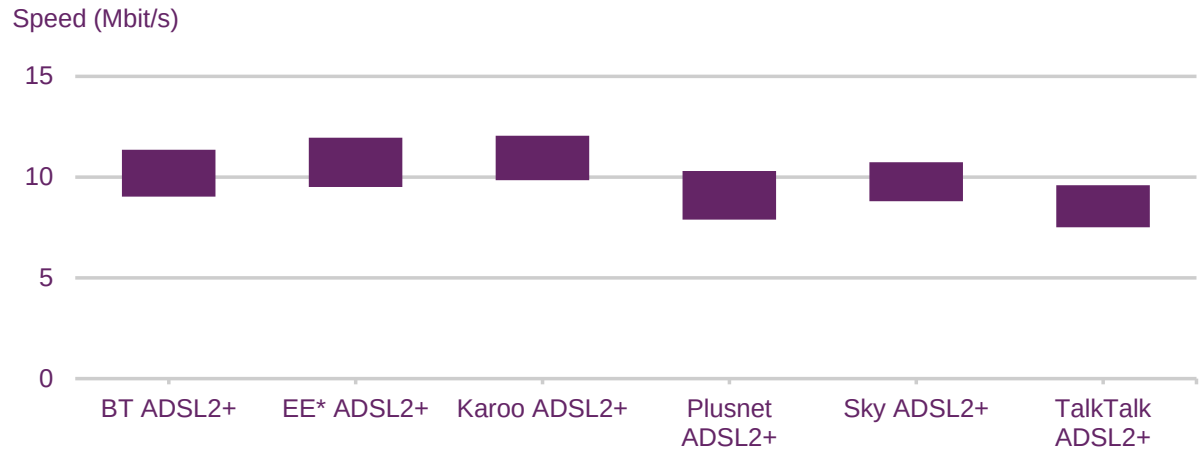
Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 4.15 **Maximum download speeds for 'up to' 30Mbit/s and above ISP packages: May 2014**



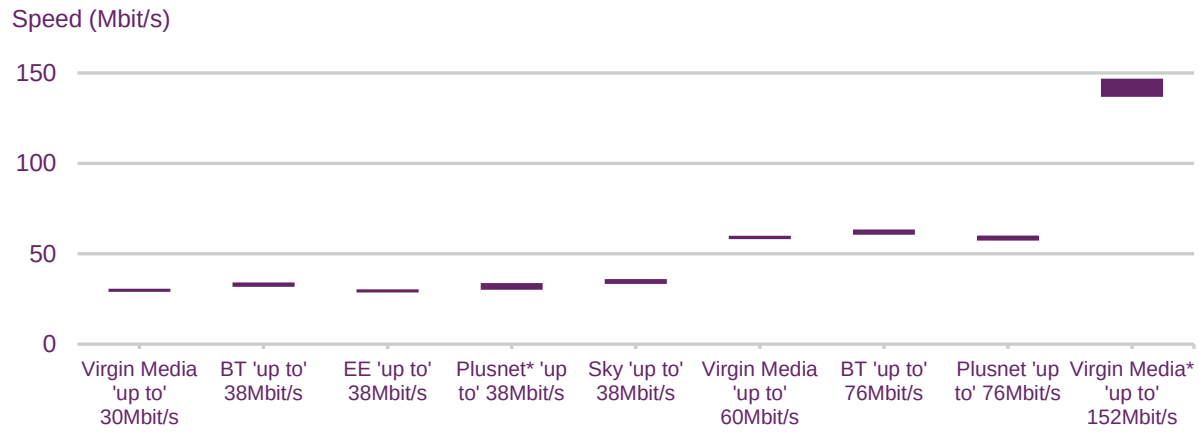
Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL 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.

Figure 4.16 **Average download speeds for ADSL2+ ISP packages, 24 hours: May 2014**



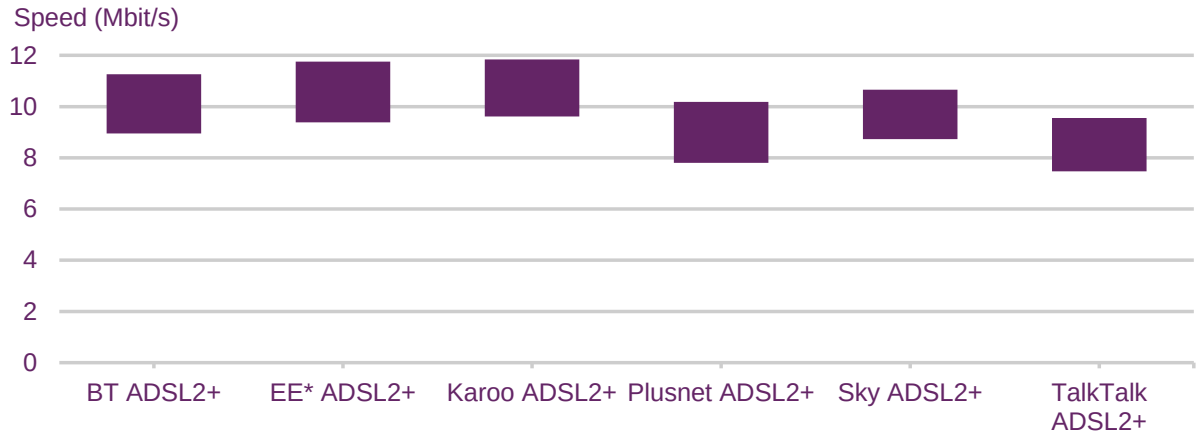
Source: SamKnows measurement data for all panel members with a connection in May 2014
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

Figure 4.17 **Average download speeds for 'up to' 30Mbit/s and above ISP packages, 24 hours: May 2014**



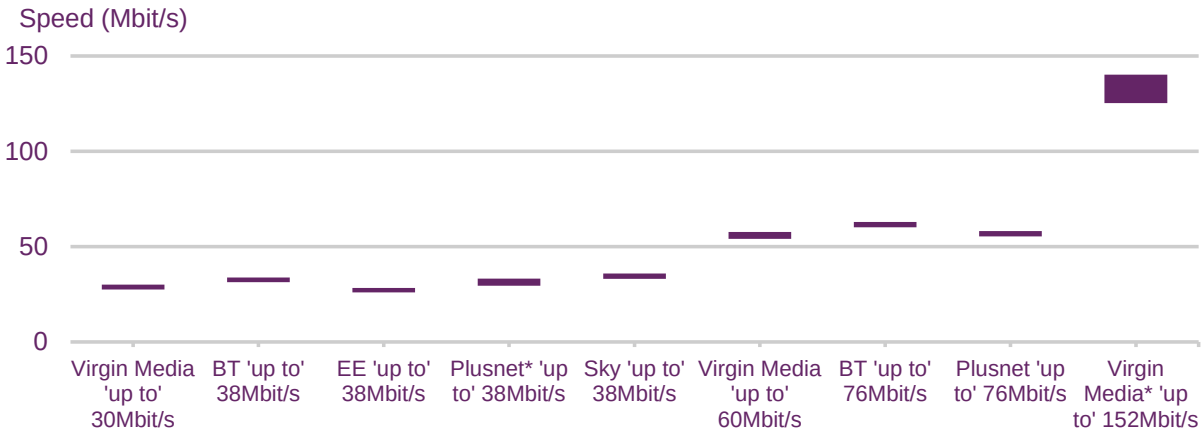
Source: SamKnows measurement data for all panel members with a connection in May 2014
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 4.18 **Average download speeds for ADSL2+ ISP packages, 8pm to 10pm weekdays: May 2014**



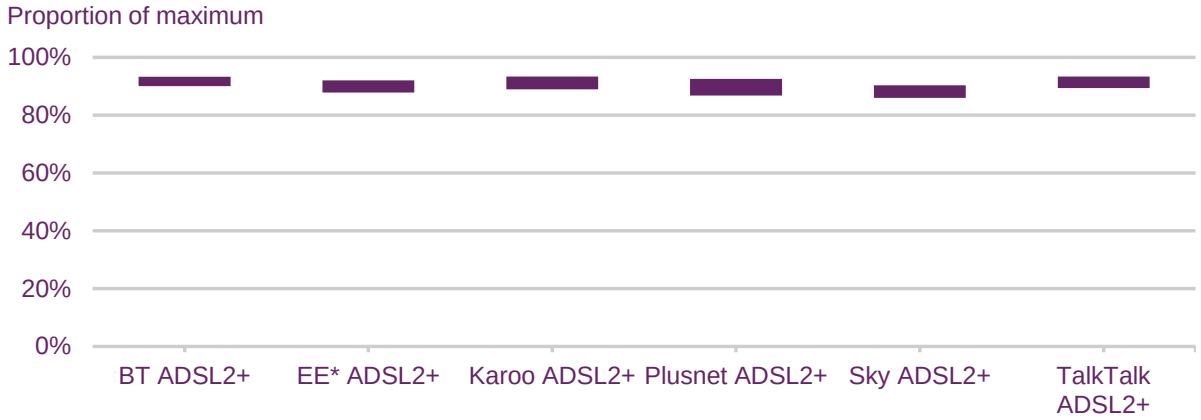
Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL 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.

Figure 4.19 **Average download speeds for 'up to' 30Mbit/s and above packages, 8pm to 10pm weekdays: May 2014**



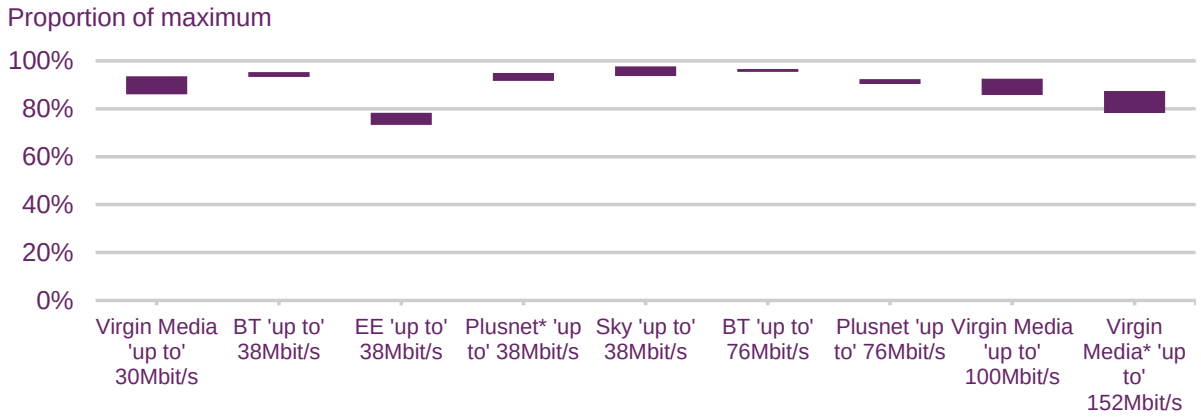
Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5)The range shown represents a 95% confidence interval around the mean.

Figure 4.20 **Peak-time (8pm to 10pm weekday) speeds as a proportion of maximum speeds for ADSL2+ ISP packages: May 2014**



Source: SamKnows measurement data for all panel members with a connection in May 2014.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

Figure 4.21 **Peak-time (8pm to 10pm weekday) speeds as a proportion of maximum speeds for 'up to' 30Mbit/s and above ISP packages: May 2014**



Source: SamKnows measurement data for all panel members with a connection in May 2014
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

Annex 2

Technical and research methodologies

Technical methodologies

This report is Ofcom's eleventh fixed-line residential broadband speeds report and the ninth 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.

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

Testing recursive DNS resolver responsiveness and failures

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

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

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

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 5.1 sets out Ofcom's definitions of geographic broadband markets (based on the definitions for the wholesale broadband access (WBA) market[10]). These were an important consideration in recruiting our panel and applying statistical analysis, because they enabled us to ensure that our panel was representative of the UK residential broadband market as a whole, and facilitated like-for-like comparison between ISP packages:

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

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

Figure 5.1 **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

[10] 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).

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[11] 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[12].

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

[12] 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 2699 million data points. It has been a complex process, both technically and statistically.

The glossary in Annex 4 provides definitions of the technical terms we use throughout the report. However, knowledge of the following is important in order to understand how we have analysed the performance data collected.

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

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

- In order to ensure that the national data we present are representative of UK residential broadband users as a whole, we have weighted the data by ISP package, technology (LLU, non-LLU and cable), rural/urban split, 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 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. 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.

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, 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 3,445 measurement units have been despatched since October 2008. Of the 1,178 which no longer provide data, 600 were phased out as not capable of reporting packages with speeds over 20Mbit/s. 2,391 of these were connected by panellists between 1st and 30th May 2014. Of these, 956 supplied data to the UK average, and 1,711 to the named ISP package comparisons.

Figure 6.1 **Panellist numbers**

Sample set		Number
Total number of boxes dispatched		**3,445 (600 phased out)**
Total number of boxes connected		**2,391**
	Excluded because of missing data, (i.e. measurements, packages, distance)	92
	Excluded 'up to' 2Mbit/s	5
	Other Exclusions to improve UK sample weighting (i.e. distance, market classification, region, ISP)	9
Total participants included in UK Analysis		**956**
Total participants included in ISP Package Analysis		**1,711**

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 238, 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 2,175 panellists' measurement results were divided into two separate datasets, each weighted to targets.

- **National panel** (over 'up to' 2Mbit/s packages): 956 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**: 1,711 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 6.2 **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 6.3 **National panel range of weights**

Range	Count	Column N%
Less than 0.5	331	35%
0.5 to 1	272	29%
1 to 1.5	180	19%
1.5 to 2	56	6%
2 to 3	76	8%
3 to 4	29	3%
5+	12	1%

Source: Ofcom

Overall, against the entire weight frame, the ISP package panel achieved a weighting efficiency of 92%. This is because Virgin Media cable packages and BT FTTC are not weighted as distance from exchange does not impair download speeds.

Figure 6.4 **ISP package panel range of weights**

Range	Count	Column N%
Less than 0.5	34	2%
0.5 to 1	232	14%
1 to 1.5	1368	80%
1.5 to 2	62	4%
2 to 3	12	1%

Source: Ofcom

Figure 6.5 **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%
BT 'up to' 38Mbit/s	100%
EE 'up to' 38Mbit/s	100%
Plusnet 'up to' 38Mbit/s	100%
Sky 'up to' 38Mbit/s	100%
Virgin Media 'up to' 50Mbit/s	100%
Virgin Media 'up to' 60Mbit/s	100%
BT 'up to' 76Mbit/s	100%
Plusnet 'up to' 76Mbit/s	100%
Virgin Media 'up to' 120Mbit/s	100%
Virgin Media 'up to' 152Mbit/s	100%

Source: Ofcom

Weighted and unweighted measurement data for ADSL2+ ISP packages

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

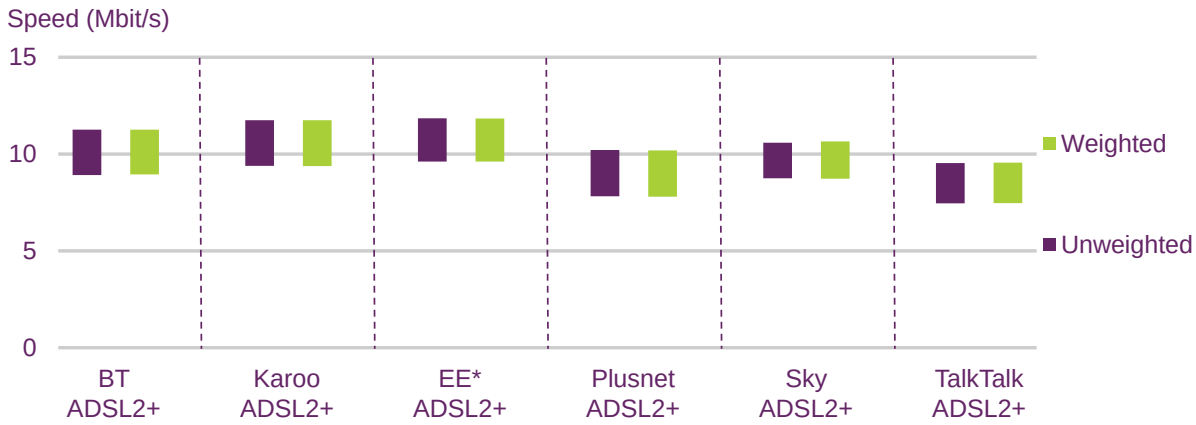
Figure 6.6 **Maximum download speeds for ADSL2+ ISP packages, weighted and unweighted figures: May 2014**

Source: SamKnows measurement data for all panel members with a connection in May 2014. 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 6.7 **Average download speeds for ADSL2+ ISP packages, 24 hours, weighted and unweighted figures: May 2014**

Source: SamKnows measurement data for all panel members with a connection in May 2014. 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 6.8 **Peak-time download speeds for ADSL2+ ISP packages, 8 to 10pm weekdays, weighted and unweighted figures: May 2014**



Source: SamKnows measurement data for all panel members with a connection in May 2014. 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.

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'

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.