UK fixed-line broadband performance, May 2013

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

Research Document

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Section 1

Introduction

Background

Ofcom's primary 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; in particular, the availability of a wide range of electronic communications services, which includes broadband services.[2] We must also have regard to the desirability of encouraging investment and innovation in relevant markets, the availability and use of high-speed data services throughout the UK[3], and the interests of consumers in respect to price, quality of service and value for money.[4]

The Act requires us to make arrangements to find out about the experiences of consumers using electronic communications services and the way they are provided, and we do this by carrying out research into these services.[5] Subject to certain exceptions, we have a duty to publish the results of our research and to take account of it in carrying out our functions.[6]

In order to understand the performance of UK fixed-line residential broadband connections, we commission research to identify the average download speeds that they deliver, along with a number of other metrics which determine the consumer experience of using broadband services. This is the ninth 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 2013, comprising 736 million test results from a panel of 2,218 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 the most robust presentation available of UK fixed-line broadband speeds.

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

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[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

Using this report

While Sections 2 and 3 of this report look at broadband speeds, Section 4 considers the other metrics which affect broadband performance.

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

Further, we use three key terms to describe broadband speeds (the glossary in Annex 4 also has 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.

The report is structured as follows:

- Section 2 looks at residential UK broadband speeds at a national level;

- Sections 3 and 4 set out the performance of individual ISP packages in terms of connection speed and the other metrics which affect broadband performance;

- Annex 1 sets out 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 2

Overview of UK broadband speeds

Average residential fixed-line broadband speeds reached 14.7Mbit/s in May 2013

Our research shows that the average actual download speed of a UK fixed broadband connection was 14.7Mbit/s in May 2013. The average download speed for packages above 'up to' 2Mbit/s and up to and including 10Mbit/s was 3.6Mbit/s, less than a tenth of that for connections with a headline speed of 'up to' 30Mbit/s and higher (45.3Mbit/s). Connections with a headline speed of above 'up to' 10Mbit/s and less than 'up to' 30Mbit/s had average speeds of 8.2Mbit/s in May 2013.

Figure 2.1   Average UK broadband speeds: May 2013
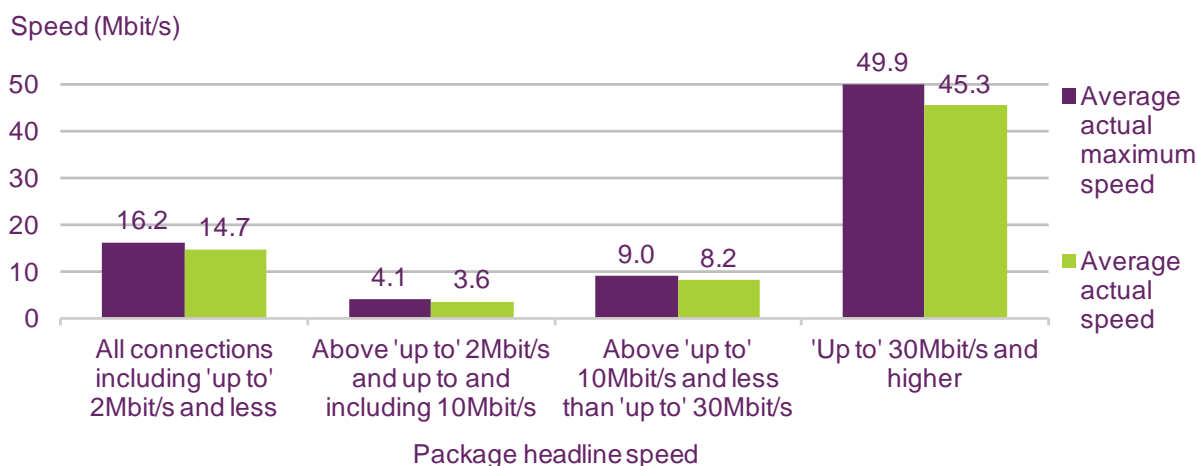
*Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel Base: 1,592
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK 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 2013; (3) Data collected from multi-thread download speed tests; (4) The above 'up to' 10Mbit/s and less than 'up to' 30Mbit/s category includes ADSL2+ connections which are not marketed using a connection speed.*

Average broadband speeds increased by 22% in the six months to May 2013

The average fixed-line broadband download speed provided by UK residential connections has continued to increase. Compared to November 2012, our research shows that average actual download speeds increased by 2.7Mbit/s (22%), to 14.7Mbits. This represents a 64% increase compared to the May 2012 average of 9.0Mbit/s.

For connections of above 'up to' 2Mbit/s and up to and including 10Mbit/s, Figure 2.2 shows that average actual download speeds fell by 0.8Mbit/s. The fall in average speed recorded for this category is likely to be as a result of Virgin Media's 'double speeds' upgrade programme, whereby Virgin Media's 'up to' 10Mbit/s cable customers are being upgraded onto 'up to' 20Mbit/s or 30Mbit/s services. 'Up to' 10Mbit/s cable customers typically have much higher average speeds than the ADSL1 connections which make up the majority of the other connections included in this category (in May 2013 the average speed of an 'up to'

10Mbit/s cable connection was 9.3Mbit/s compared to 3.3Mbit/s for an 'up to' 8Mbit/s ADSL1 connection). Therefore, the fall in the proportion of these connections that are 'up to' 10Mbit/s cable connections has resulted in a fall in average actual download speeds in this category. Another reason is that, as BT continues to upgrade its ADSL network to offer ADSL2+, the ADSL1 connections that remain in this category are likely to be found in more rural areas, where the average length of line from the BT local exchange to the end users' premises is likely to be longer, and average speeds therefore lower.[9]

The average speeds recorded for those on packages of above 'up to' 10Mbit/s and less than 'up to' 30Mbit/s rose slightly, by 0.1Mbit/s to 8.2Mbit/s. The proportion of connections that were 'up to' 20Mbit/s Virgin Media cable connections showed an increase over the period, as a result of Virgin Media's 'double speed' upgrades. The average download speed for these connections was 19.0Mbit/s compared to 6.5Mbit/s for the ADSL2+ connections which make up the majority of the rest of the connections included in this category, so this shift will have an upward effect on the average speed of connections in this category.

The average speed of connections with a headline speed of 'up to' 30Mbit/s or higher continued to increase in the six months to May 2013, up by 2% (0.7Mbit/s) to 45.3Mbit/s. This rate of increase was much lower than the 23% and 6% respective increases in the average speeds of cable and fibre broadband services over the same period (see Figure 2.4).

The main reason for this was that the significant increase in overall actual cable broadband speeds was the result of Virgin Media's 'double-speeds' upgrade programme, which doubled the speeds of most of its broadband connections. However, this did not lead to a significant increase in the proportion of Virgin Media superfast broadband connections that were 'up to' 60Mbit/s or 'up to' 100/120Mbit/s (rather than 'up to' 30Mbit/s), and the average speed of superfast cable connections did not show a similar increase to that of all cable connections.

Figure 2.2   Average broadband speeds: November 2008 to May 2013
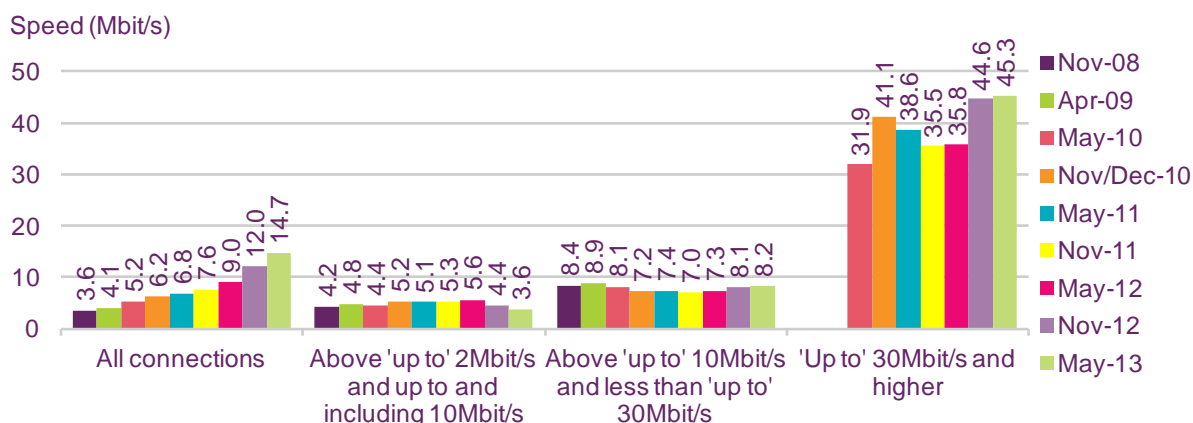
Source: SamKnows measurement data for all panel members
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in May 2013; (3) Data collected from single-thread download speed tests prior to November/December 2010 and multi-thread download speed

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[9] For ADSL broadband, the maximum line speed available is constrained by the length of the copper wire connection between the premises and the local telephone exchange, with speeds slowing down due to increased signal loss as the length of the line increases.

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.

Superfast and ADSL2+ take-up continue to drive increases in average download speeds

A key driver of the increase in average actual fixed broadband download speeds over the past few years has been rising take-up of 'up to' 30Mbit/s and above services (also known as superfast services), a trend which continued in the six months to May 2013. Figure 2.3 shows that 19% of residential fixed broadband connections were classed as being superfast in May 2013, five percentage points higher than in November 2012 and 11 percentage points higher than in May 2012. Eighty-six percent of connections had an advertised speed above 'up to' 10Mbit/s in May 2013, a rise of 18 percentage points since May 2012.

This shift to higher-speed services is partially as a result of Virgin Media's 'double speeds' upgrade programme, which doubled the speeds provided by most of its cable broadband connections. In addition, customers are also choosing to migrate to fibre broadband services, and over the course of the 2012/13 financial year the number of BT retail fibre broadband connections increased from around 550,000[10] to over 1.3 million.[11]

There has also been a reduction in the proportion of connections between 'up to' 8Mbit/s and 'up to' 10Mbit/s, a fall of nine percentage points to 14% in the six months to May 2013. This is likely to be the result of a decline in the number of 'up to' 10Mbit/s cable connections resulting from Virgin Media's continued upgrades. In addition, BT is continuing the upgrade of its ADSL network to offer ADSL2+, which moves connections out of the 'up to' and including 8Mbit/s to 10Mbit/s category. However, the rate at which this is happening is likely to have slowed, as coverage is now widespread.

Figure 2.3   UK residential broadband connections, by headline speed
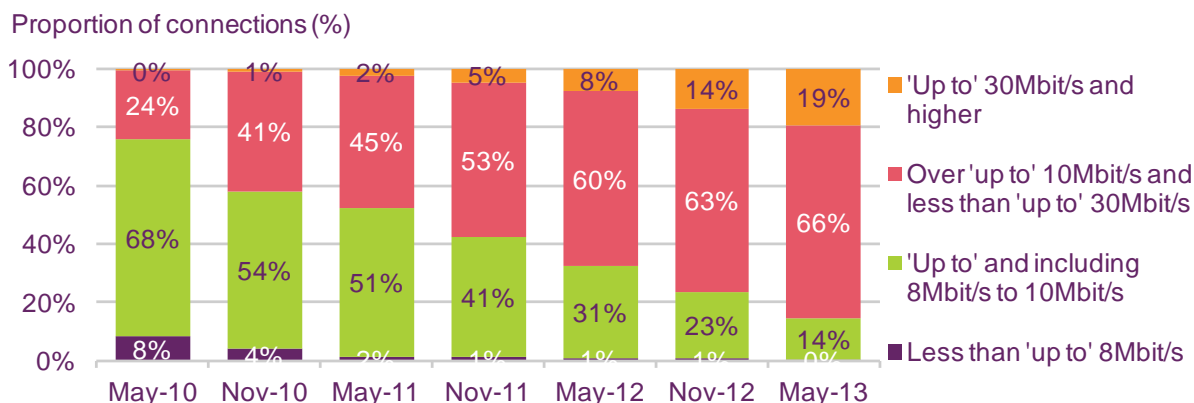
Source: Ofcom, based on data provided by the UK's largest ISPs by retail market share (representing 90% of the total market)
Notes: The above 'up to' 10Mbit/s and lass than 'up to' 30Mbit/s category includes ADSL2+ connections which are not marketed using a connection speed.

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[10] BT's 2012 annual report:
http://www.btplc.com/Sharesandperformance/Annualreportandreview/pdf/BTAnnualReport2012.pdf
[11] BT's 2013 annual report:
http://www.btplc.com/Sharesandperformance/Annualreportandreview/pdf/2013_BT_Annual_Report_smart.pdf

The average download speed for cable is above 'up to' 30Mbit/s

The average download speed for a cable fixed broadband connection was 34.9Mbit/s in May 2013, an increase of 6.6Mbit/s (23%) compared to November 2012 as a result of Virgin Media's 'double speed' upgrade programme (Figure 2.4).

Overall, fibre panellists received the fastest average actual download speeds of the technologies included in this report (43.6Mbit/s), although there has been a marked slowing of the rate of increase. Between May 2012 and November 2012 average actual download speeds for FTTx services increased by 9.5Mbit/s (largely as a result of an increase in the proportion of FTTC connections that were 'up to' 76Mbit/s rather than 'up to' 38Mbit/s), whereas between November 2012 and May 2013 the increase was just 2.5Mbit/s.

Average ADSL speeds remained stable between May 2012 and May 2013.

Figure 2.4   Average actual download speeds for fixed broadband connections, by technology
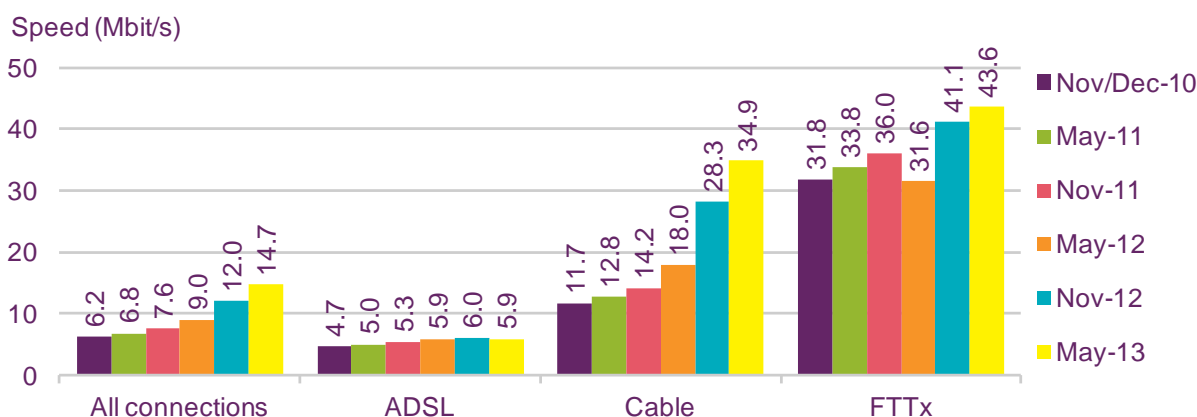
Source: SamKnows measurement data for all panel members with a connection in May 2013
Panel Base: 849
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

The difference between urban and rural average actual speeds is increasing

There are two main reasons why average actual download speeds tend to be higher in urban areas than in rural areas. First, the average line length from the exchange to the end-user's premises is shorter in urban areas, resulting in less signal loss and higher average ADSL broadband speeds. Second, there is lower availability of both fibre and cable broadband in rural areas, as providers tend to concentrate network build in highly populated areas in order to maximise their potential customer bases.

As mentioned previously, growth in superfast broadband take-up has been the main driver of increasing average UK broadband speeds in recent years (see Figure 2.3). However, the impact of increased superfast take-up on average rural broadband speeds has been less pronounced, because fewer consumers have upgraded to these services due to the lower availability of fibre and cable services in rural areas.

Our research shows that while average actual download speeds in urban, suburban and rural areas all increased in the two years to May 2013, the rate of increase has varied widely

across these areas.[12] The average actual download speed in urban areas was 26.4Mbit/s in May 2013, an increase of 12.8Mbit/s (95%) since May 2011. This compares to suburban areas, where average download speeds have increased by 9.1Mbit/s (103%), and rural areas where they have increased by 5.8Mbit/s (141%) over the same time period.

Although the largest Mbit/s increases in average download speeds occurred in urban areas, the percentage increase in rural areas outstripped those in urban and suburban areas. This is because average speeds were lower in rural areas than in urban areas in May 2011, so the (smaller) Mbit/s average increase in rural areas (which was largely the result of upgrades to BT's ADSL1 network to offer ADSL2+ and increasing LLU availability in rural areas) represented a larger proportion of average speeds in May 2011.

The difference between average urban and rural speeds increased from 9.5Mbit/s to 16.5Mbit/s between May 2011 and May 2013, and while this trend is likely to continue in the short term, we expect that it will begin to decline over time, as the availability of superfast broadband (in particular fibre broadband) increases in rural areas.[13]

Figure 2.5   Average download speeds for fixed broadband connections in urban, suburban and rural areas, over time
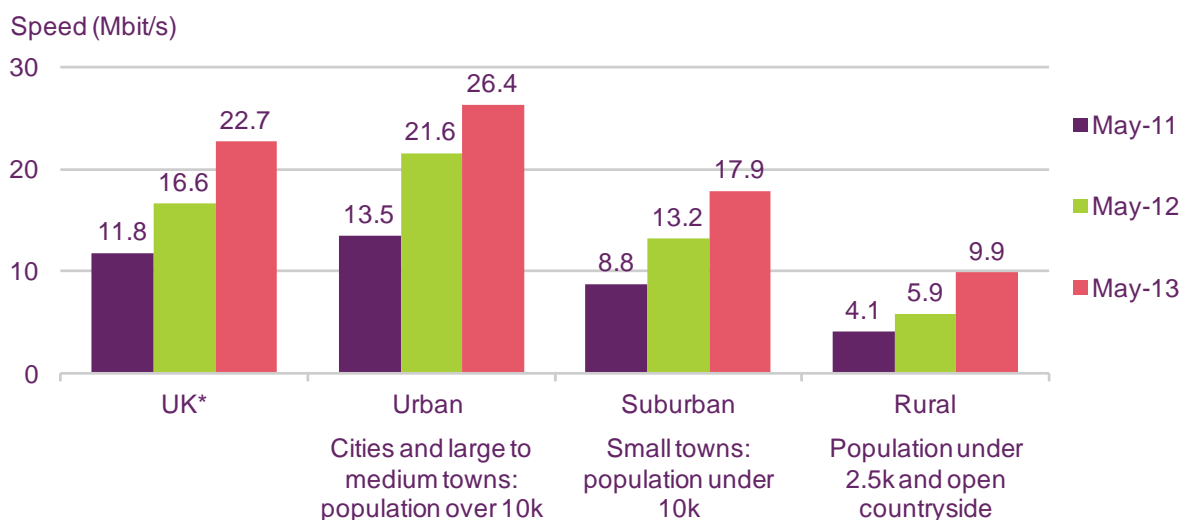
Source: SamKnows measurement data for all panel members
Panel Base: 2011; Urban 999, Suburban 382, Rural 323; 2012 Urban 1099, Suburban 391, Rural 294; and 2013 Urban 1362, Suburban 448, Rural 365
Notes: The UK average above will not match shown elsewhere in this report as different weightings have been used to enable us to provide comparisons by urbanity. Further statistical methodology is provided in Annex 3.

'Up to' 100Mbit/s cable services had the most significant slow-down at peak-times in May 2013

Capacity constraints on ISPs' networks mean that average actual download speeds often fall during busy periods (i.e. when a large number of connections are in use), and our research shows that in May 2013 the average weekday 8pm to 10pm peak-time download speed was 14.2Mbit/s, 97% of the 24-hour average speed (14.7Mbit/s) and 88% of the average maximum speed (16.2Mbit/s).

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[12] The methodology used for this analysis is explained in Annex 3. The figures here should not be compared to other figures in the rest of the report as they were calculated using a different methodology.

[13] Superfast broadband availability is expected to reach 95% of households by 2017.

The 24-hour average and peak-time download speeds recorded in May 2013 were below the maximum speeds for all connection types included in our research (Figure 2.6). 'Up to' 100Mbit/s cable services had the largest percentage difference between average peak-time and average maximum speeds, with the average peak-time download speed (81.0Mbit/s) being 78% of the average maximum speed (104.0Mbit/s). In comparison, 'up to' 38Mbit/s FTTC had the smallest percentage difference between average peak-time and average maximum speeds, with the average peak-time download speed (32.1Mbit/s) being 93% of the average maximum speed (34.5Mbit/s).

Figure 2.6   Variations in download speed, by time of day: May 2013
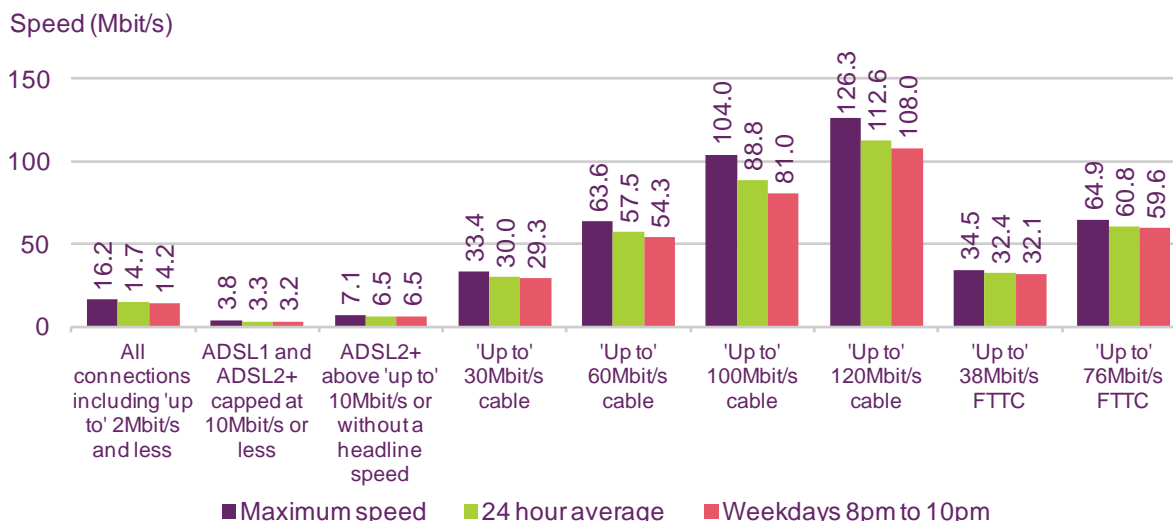
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers 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 2013; (3) Data collected from multi-thread download speed tests.

The average actual upload speed of a UK residential fixed-line broadband connection was 1.8Mbit/s in May 2013

While broadband advertising focuses on download speeds, upload speeds matter to those sharing large files, using real-time two-way video communications, and for some online gaming. Our research shows that average actual upload speeds had increased to 1.8Mbit/s in May 2013, an increase of 0.4Mbit/s from the 1.4Mbit/s average upload speed recorded in November 2012.

Figure 2.7   **Average upstream UK broadband speeds: May 2013**

Speed (Mbit/s)

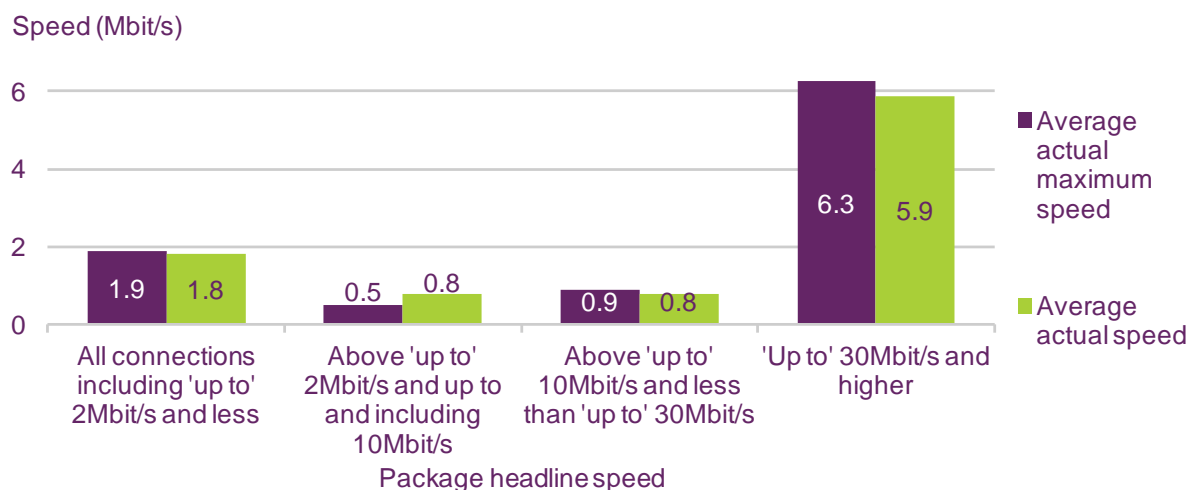Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel Base: 849
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

Section 3

Variations of broadband speeds by internet service provider (ISP)

Introduction

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

- BT retail's ADSL2+ services and its 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC (*BT Infinity*) services;

- EE's ADSL2+ service;

- Karoo's ADSL2+ service;

- Plusnet's ADSL2+ service and its 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC services (although Plusnet is owned by BT, it is considered separately as some aspects of the network are different to those used by BT Retail);

- Sky's on-net ADSL2+ service (this excludes connections that were provided by O2 prior to Sky's acquisition of O2's fixed telecoms business earlier this year);

- TalkTalk's on-net ADSL2+ service; and

- Virgin Media's 'up to' 30Mbit/s, 'up to' 60Mbit/s, 'up to' 100Mbit/s and 'up to' 120Mbit/s cable services (Virgin Media is currently upgrading its cable network to offer 'up to' 120Mbit/s, and offers 'up to' 100Mbit/s services where the upgrade is yet to take place).

These ISP packages accounted for over half of all UK residential broadband connections in May 2013; although consumers should note that there are many other packages and ISPs available, some of which may match or better performance of some of the ISP packages included in this report.

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

The sampling and statistical methodologies have been designed to enable us to report ISP package performance on a like-for-like basis. For example, data for ADSL panellists have been normalised for distance from the exchange, to ensure that there is no bias created by ISPs having customer bases with different distance profiles. For details, see the research methodology set out in Annex 2 and the statistical methodology set out in Annex 3.
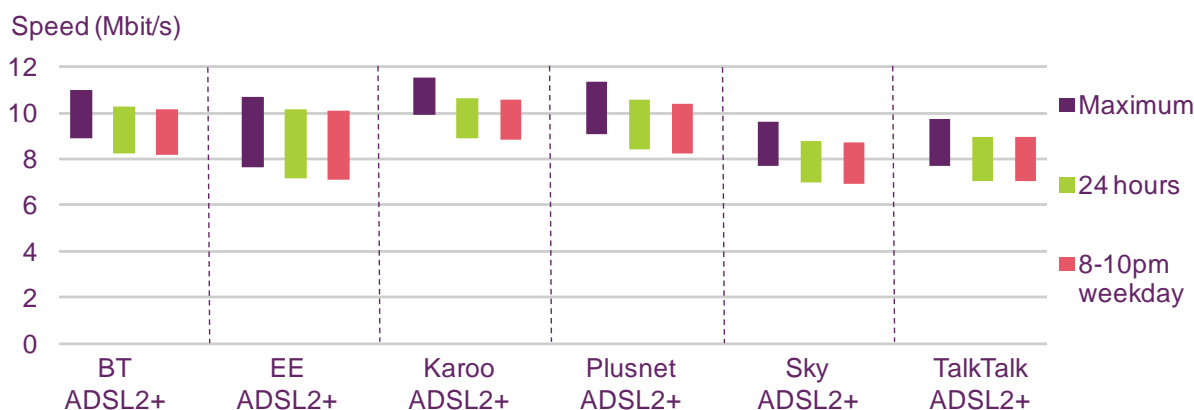
ADSL2+ connections

The main variable affecting the speeds delivered by ADSL2+ services is the distance of the customer's premises to the local exchange, over which the ISP has no control. Therefore, when looking at the fixed-line broadband speeds in Figure 3.1 we have removed those premises over 5km away from their exchange, to be able to more accurately evaluate ISPs' performance.

Figure 3.1 shows that, to a 95% level of confidence, there were no statistically significant differences between the average maximum, average 24-hour and average peak-time download speeds achieved by any of the six individual ADSL2+ ISP packages included in our research in May 2013. [14]

The only statistically significant difference between ISPs' average actual ADSL2+ download speeds in May 2013 were that Karoo's service was faster than Sky's service in terms of the maximum, average and peak-time download speeds (i.e. to a 95% level of confidence, the ADSL2+ service by Karoo was faster than Sky's ADSL2+ service). Across the ADSL2+ ISP packages covered by our research, the proportion of average maximum speeds delivered during the weekday peak period ranged from 90% for Sky connections to 93% for the Karoo ADSL2+ ISP connections covered by our research.

Figure 3.1 Maximum, average and peak-time download speeds for ADSL2+ ISP packages: May 2013

Source: SamKnows measurement data for all panel members with a connection in May 2013
Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Includes only 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 has been weighted for distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 3.2 summarises the statistically significant differences in the download speed performance of the ADSL2+ ISP packages covered in our research.

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[14] A 95% level of confidence means that if we repeated the research again 100 times with 100 different samples assembled in the same way we would expect to see the same difference in at least 95 cases.

Figure 3.2   Significant differences, to a 95% confidence level, between maximum, average and peak download speeds and ADSL2+ ISP packages: May 2013

	Maximum	24 hours	8-10pm weekday
ISP package	Is faster than...	Is faster than...	Is faster than...
Karoo	Sky*	Sky*	Sky*

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

The average download speeds recorded in the previous periods of testing for the ADSL2+ ISP packages included in this report are shown in Figure 3.3 below. This shows that the only statistically significant difference in the performance of any of these packages, between November 2012 and May 2013, was that the average speed of Karoo's service increased from 8.6Mbit/s to 9.8Mbit/s over the period.

Figure 3.3   Average download speeds for ADSL2+ ISP packages: November/December 2010 to May 2013

Source: SamKnows measurement data for all panel members.
Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Only includes customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data has been weighted for distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 3.4 shows the distribution of our ADSL2+ panellists' average speeds during the 8pm to 10pm weekday peak period as a proportion of maximum speed delivered by their connections. The intention of this analysis is to assess whether certain panellists are disproportionately affected by network contention.[15] High levels of network contention, which are most likely to occur at peak-times, limit achievable download speeds. We would therefore expect to see more panellists experiencing low average peak-time speeds compared to maximum speeds, where network contention is higher.

In Figure 3.4, higher lines indicate better performance. Among all of the ADSL2+ ISP packages covered by our research, more than 60% of panellists had average peak-time speeds that were higher than 90% of their maximum speed. Sky's ADSL2+ service had the

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

lowest proportion of panellists receiving an average peak-time speed of 90% or more of their average maximum speed (61%), suggesting that Sky's ADSL2+ network had a higher level of contention than the other ADSL2+ providers included in the analysis during the testing period. In comparison, the best performers were EE and TalkTalk (75%) closely followed by Karoo (74%).

Figure 3.4   Distribution of average peak-time speed as a proportion of maximum speed for ADSL2+ ISP packages: May 2013
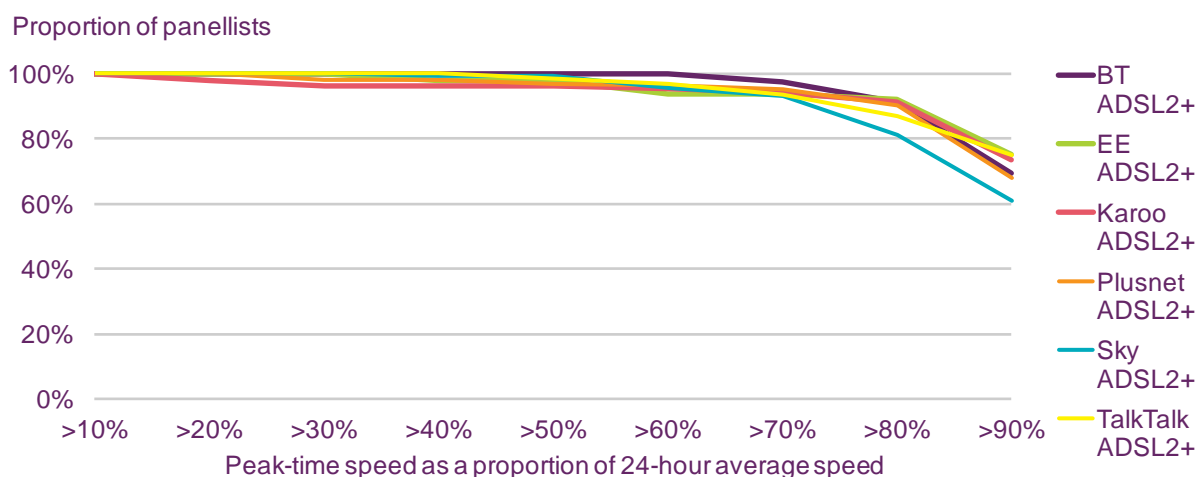
Source: SamKnows measurement data for all panel members
Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
*Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators has been weighted for distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.*

'Up to' 30Mbit/s and higher connections

Virgin Media's 'up to' 120Mbit/s service was the fastest of the ISP packages covered in our research in May 2013 in terms of its average maximum speed (126.3Mbit/s), average download speeds recorded over 24 hours (112.6Mbit/s) and 8pm to 10pm weekday peak-time average speeds (108.0Mbit/s). The relative performance, in terms of maximum, 24 hour average and 8pm to 10pm weekday peak-time speeds of the superfast ISP packages covered by our research generally reflected the speeds at which they were advertised. Average peak-time speeds as a proportion of maximum speeds ranged from 78% for Virgin Media's 'up to' 100Mbit/s cable service to 94% for BT's 'up to' 38Mbit/s FTTC service.

Figure 3.5   Maximum, average and peak-time download speeds 'up to' 30Mbit/s and above ISP packages: May 2013
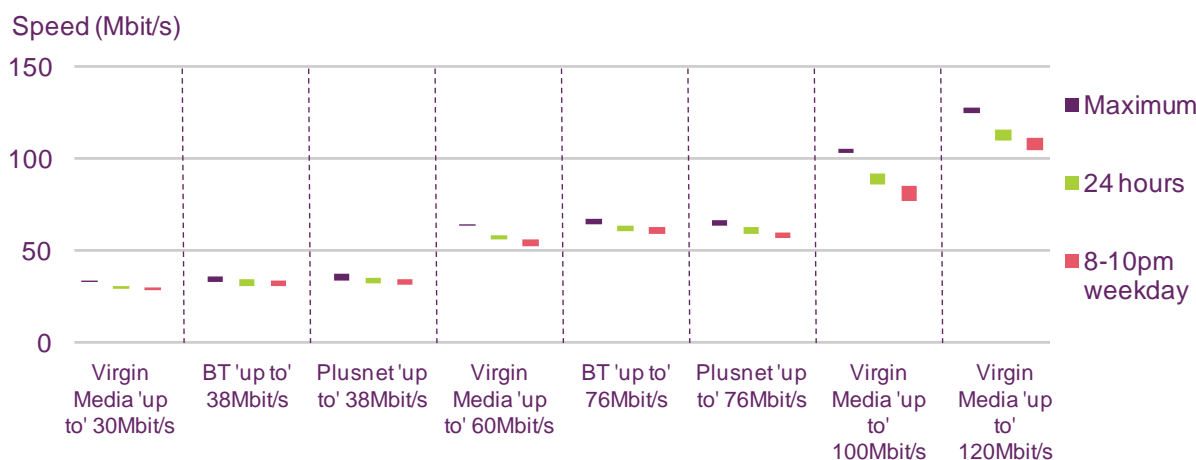
Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: Virgin 'up to 30Mbit/s' 90; BT 'up to 38Mbit/s' 65; Plusnet 'up to 38Mbit/s' 52; Virgin 'up to 60Mbit/s' 134; BT 'up to 76Mbit/s' 203; Plusnet 'up to 76Mbit/s' 186; Virgin 'up to 100Mbit/s' 90; Virgin 'up to' 120Mbit/s 83)
Notes: (1) Data for fibre services and Virgin Media's cable service are not weighted; (2) Data collected from multi-thread download speed tests; (3) The range shown represents a 95% confidence interval around the mean.

Figure 3.6 summarises the statistically significant differences in the average actual download speed performance of the 'up to' 30Mbit/s and above ISP packages covered in our research in May 2013.

In most cases, the 'up to' headline speed dictated which packages were faster, although this was not the case for the average maximum speed of BT's 'up to' 38Mbit/s package, which was not faster (to a 95% confidence level) than the average maximum speed of Virgin Media's 'up to' 30Mbit/s service; and similarly, the average maximum speed of Plusnet's 'up to' 76Mbit/s service was not faster than that of Virgin Media's 'up to' 60Mbit/s service. There were no significant differences between the performance of BT's and Plusnet's FTTC services of the same headline speed.

Figure 3.6 **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 2013**

	Maximum	24 hours	8-10pm weekday
ISP package	Is faster than...	Is faster than...	Is faster than...
Virgin Media 120	Virgin Media 100, BT 76, Plusnet 76, Virgin Media 60, BT 38, Plusnet 38 & Virgin Media 30	Virgin Media 100, BT 76, Plusnet 76, Virgin Media 60, BT 38, Plusnet 38 & Virgin Media 30	Virgin Media 100, BT 76, Plusnet 76, Virgin Media 60, BT 38, Plusnet 38 & Virgin Media 30
Virgin Media 100	BT 76, Plusnet 76, Virgin Media 60, BT 38, Plusnet 38 & Virgin Media 30	BT 76, Plusnet 76, Virgin Media 60, BT 38, Plusnet 38 & Virgin Media 30	BT 76, Plusnet 76, Virgin Media 60, BT 38, Plusnet 38 & Virgin Media 30
Plusnet 76	BT 38, Plusnet 38 & Virgin Media 30	Virgin Media 60*, BT 38, Plusnet 38 & Virgin Media 30	Virgin Media 60*, BT 38, Plusnet 38 & Virgin Media 30
BT 76	Virgin Media 60*, BT 38, Plusnet 38 & Virgin 30	Virgin Media 60*, BT 38, Plusnet 38 & Virgin Media 30	Virgin Media 60, BT 38, Plusnet 38 & Virgin Media 30
Virgin Media 60	BT 38, Plusnet 38 & Virgin Media 30	BT 38, Plusnet 38 & Virgin Media 30	BT 38, Plusnet 38 & Virgin Media 30
Plusnet 38	Virgin Media 30*	Virgin Media 30*	Virgin Media 30*
BT 38	No differences	Virgin Media 30*	Virgin Media 30*

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

Figure 3.7 shows the download speeds recorded for the 'up to' 30Mbit/s and above ISP packages covered in this report over various time periods. This shows that while the average actual speed of Virgin Media 'up to' 30Mbit/s cable service increased in the six months to May 2013, the averages recorded for its 'up to' 60Mbit/s and 100Mbit/s' services both fell during the period.

Figure 3.7 **Average download speeds for 'up to' 30Mbit/s and above ISP packages: November/December 2010 to May 2013**
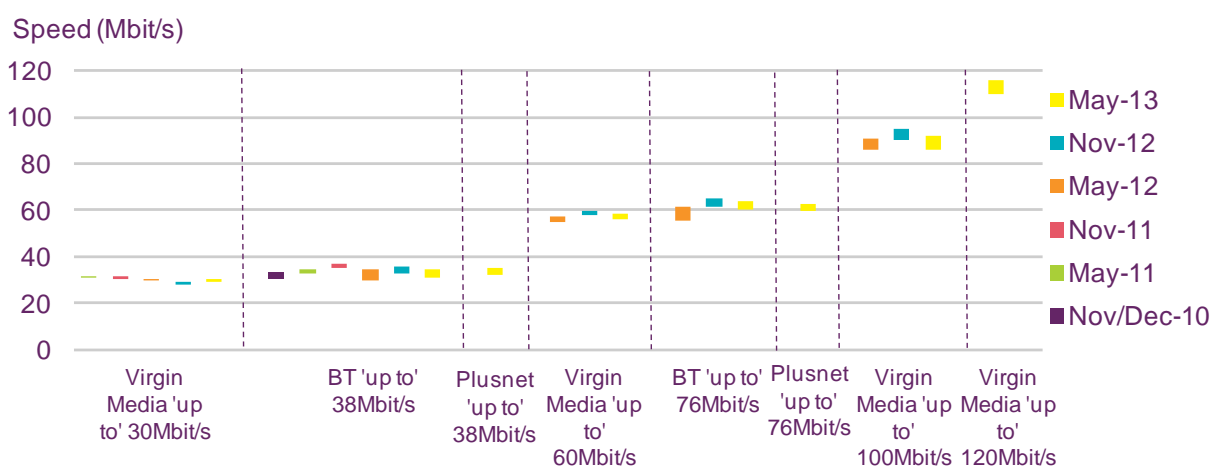
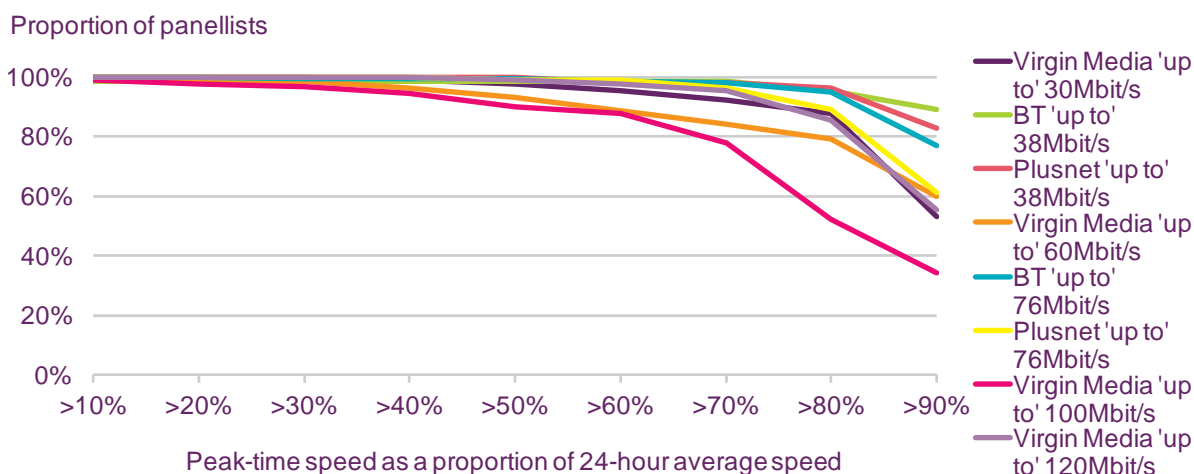*Source: SamKnows measurement data for all panel members with a connection in May 2013.*
Notes: (1) Data for fibre services and Virgin Media's cable service are not weighted; (2) Data collected from multi-thread download speed tests; (3) The range shown represents a 95% confidence interval around the mean.

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The analysis of the distribution of our superfast panellists, in terms of average speeds during the 8pm to 10pm peak period, as a proportion of average maximum speeds, shows that the proportion of panellists who received average peak-time speeds more than 90% of their maximum speed was lower among all the superfast cable packages than among BT and Plusnet's FTTC packages (Figure 3.8). As before, in this analysis higher lines indicate better performance.

In May 2013, the proportion of panellists receiving more than 90% of their maximum speed at peak times among superfast cable services was 60% for Virgin Media's 'up to' 60Mbit/s service, 55% for its 'up to' 120Mbit/s service, 53% for its 'up to' 30Mbit/s service and 34% for its 100Mbit/s service. These proportions were all lower than those of the FTTC ISP packages included in our research, suggesting that levels of contention were higher in Virgin Media's cable network than in Openreach's FTTC network during the period in which the research was carried out.

In May 2013, the proportion of panellists receiving more than 90% of their maximum speed at peak times was 83% for Plusnet's 'up to' 38Mbit/s service and 61% for its 'up to' 76Mbit/s service, compared to 89% for BT's 'up to' 38Mbit/s and 77% for its 'up to' 76Mbit/s service. BT's retail FTTC services therefore achieved higher proportions of panellists receiving more than 90% of their maximum speed at peak times than did Plusnet's comparable services.

Figure 3.8   Distribution of average peak-time speed as a proportion of maximum speed for 'up to' 30Mbit/s and above ISP packages: May 2013

Source: SamKnows measurement data for all panel members.
Panel size: Virgin 'up to' 30Mbit/s 90; BT 'up to' 38Mbit/s 65; Plusnet 'up to' 38Mbit/s 52; Virgin 'up to' 60Mbit/s 134; BT 'up to' 76Mbit/s 203; Plusnet 'up to' 76Mbit/s 186; Virgin 'up to' 100Mbit/s 90; Virgin 'up to' 120Mbit/s 83)
Notes: (1) Data for fibre services Virgin Media's cable service are not weighted; (2) Data collected from multi-thread download speed tests.

Summary of average download speeds of all ISP packages

Figure 3.9 summarises the average maximum, 24-hour and weekday peak period download speeds achieved by all of the ISP packages included in our research in May 2013. As previously, it shows the 95% confidence interval around the mean. This is not necessarily the average speed achieved across all UK customers using each package, but we can say, with a 95% confidence level, that the average speed of these packages falls somewhere in the stated range.

Figure 3.9   Summary of average download speed by ISP package: May 2013

	Average download speed during period		
	Maximum	**24 hours**	**8-10pm weekdays**
BT ADSL2+	8.9Mbit/s to 11.0Mbit/s	8.2Mbit/s to 10.2Mbit/s	8.2Mbit/s to 10.1Mbit/s
EE ADSL2+	7.7Mbit/s to 10.7Mbit/s	7.1Mbit/s to 10.1Mbit/s	7.1Mbit/s to 10.1Mbit/s
Karoo ADSL2+	9.9Mbit/s to 11.5Mbit/s	8.9Mbit/s to 10.6Mbit/s	8.8Mbit/s to 10.6Mbit/s
Plusnet ADSL2+	9.1Mbit/s to 11.3Mbit/s	8.4Mbit/s to 10.6Mbit/s	8.2Mbit/s to 10.4Mbit/s
Sky ADSL2+	7.7Mbit/s to 9.6Mbit/s	7.0Mbit/s to 8.8Mbit/s	6.9Mbit/s to 8.7Mbit/s
TalkTalk ADSL2+	7.7Mbit/s to 9.7Mbit/s	7.1Mbit/s to 9.0Mbit/s	7.1Mbit/s to 9.0Mbit/s
Virgin Media 'up to' 30Mbit/s	33.0Mbit/s to 33.7Mbit/s	29.4Mbit/s to 30.6Mbit/s	28.4Mbit/s to 30.1Mbit/s
BT 'up to' 38Mbit/s	33.1Mbit/s to 36.1Mbit/s	30.9Mbit/s to 34.4Mbit/s	30.6Mbit/s to 34.1Mbit/s
Plusnet 'up to' 38Mbit/s	33.9Mbit/s to 37.4Mbit/s	31.9Mbit/s to 35.4Mbit/s	31.3Mbit/s to 34.7Mbit/s
Virgin Media 'up to' 60Mbit/s	63.4Mbit/s to 63.8Mbit/s	56.4Mbit/s to 58.6Mbit/s	52.4Mbit/s to 56.2Mbit/s
BT 'up to' 76Mbit/s	64.2Mbit/s to 67.5Mbit/s	60.4Mbit/s to 63.9Mbit/s	59.3Mbit/s to 62.7Mbit/s
Plusnet 'up to' 76Mbit/s	63.4Mbit/s to 66.4Mbit/s	59.5Mbit/s to 62.6Mbit/s	56.8Mbit/s to 59.8Mbit/s
Virgin Media 'up to' 100Mbit/s	102.9Mbit/s to 105.2Mbit/s	85.9Mbit/s to 91.7Mbit/s	76.9Mbit/s to 85.2Mbit/s
Virgin Media 'up to' 120Mbit/s	125.1Mbit/s to 127.5Mbit/s	109.7Mbit/s to 115.6Mbit/s	104.5Mbit/s to 111.4Mbit/s

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel Base: 1,592
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 for distance from exchange; data for fibre services and Virgin Media's cable service are not weighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Upload speeds

As mentioned previously, broadband connections work both ways, with upload speeds important to those looking to share large files, engage in real-time video communications (e.g. Skype) and for some online gaming.

ADSL2+ connections

Figure 3.10 and Figure 3.11 show that EE and Karoo provided faster average maximum, 24-hour speed and weekday 8pm to 10pm peak period ADSL2+ upload speeds, to at least a 95% confidence level, than Plusnet, Sky and TalkTalk in May 2013. BT's average maximum, 24-hour and peak-time speeds were also faster than Plusnet and TalkTalk's, and its maximum average speed was faster than that of Sky's ADSL2+ service.

Figure 3.10   Maximum, average and peak-time upload speeds for ADSL2+ ISP packages: May 2013
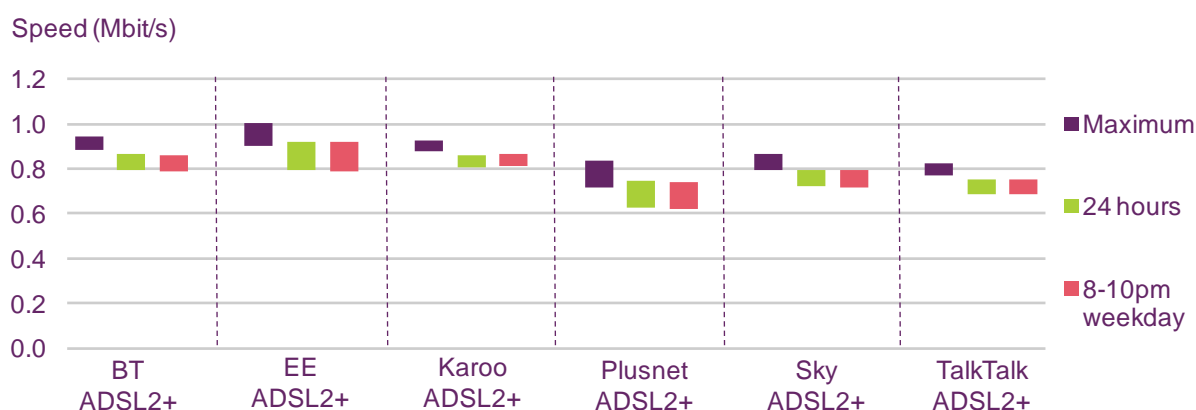
Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Includes only customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data have been weighted for distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 3.11   Significant differences, to a 95% level of confidence, between maximum, average and peak-time upload speeds for ADSL2+ ISP packages: May 2013

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

Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*
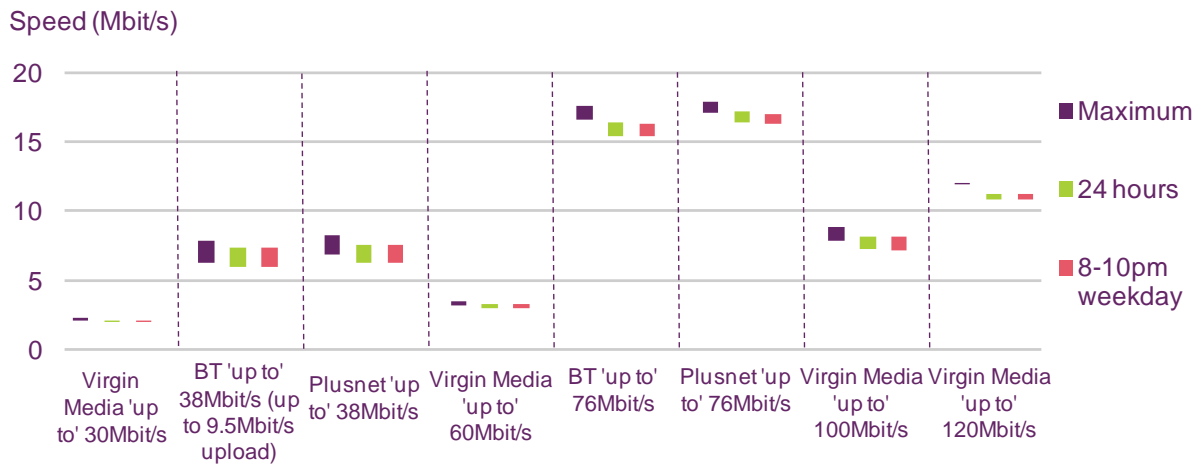
'Up to' 30Mbit/s and higher connections

BT's and Plusnet's 'up to' 76Mbit/s FTTC services (which have an advertised upload speed of 'up to' 19Mbit/s and 'up to' 19.5Mbit/s respectively) achieved the highest average upload speeds among the superfast ISP packages included in our research, with Plusnet panellists achieving 16.8Mbit/s and BT panellists 15.9Mbit/s. This was over twice as fast as the upload speeds provided by Plusnet and BT's 'up to' 38Mbit/s services (which have an advertised headline speed of 9.5Mbit/s), with Plusnet panellists achieving 6.9Mbit/s and BT panellists achieving 6.6Mbit/s.

The headline upload speeds of Virgin Media's cable packages are 10% of their download speeds, and in May 2013 the average actual upload speeds provided by the Virgin Media ISP packages included in our analysis ranged from 2.0Mbit/s for its 'up to' 30Mbit/s service to 11.1Mbit/s for its 120Mbit/s service. Virgin Media is currently upgrading the upstream and downstream speeds offered by its cable broadband connections, with the upload speed

increase for a particular customer typically taking place a few months after the downstream speed upgrade.

In our research we classify panellists' connections according to their download speed, so some Virgin Media panellists who have been recently upgraded to a higher downstream speed will not yet have had their upload speeds upgraded. As a result, although the Virgin Media upload speed figures shown in Figure 3.12 below are representative of performance in May 2013, they do not necessarily reflect future upstream connection performance.

Figure 3.12   Maximum, average and peak-time upload speeds for 'up to' 30Mbit/s and above ISP packages: May 2013

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: Virgin 'up to' 30Mbit/s 90; BT 'up to' 38Mbit/s 65; Plusnet 'up to' 38Mbit/s 52; Virgin 'up to' 60Mbit/s 134; BT 'up to' 76Mbit/s 203; Plusnet 'up to' 76Mbit/s 186; Virgin 'up to' 100Mbit/s 90; Virgin 'up to' 120Mbit/s 83)
Notes: (1) Data for fibre services Virgin Media's cable service are not weighted; (2) Data collected from multi-thread download speed tests; (3) The range shown represents a 95% confidence interval around the mean.

Figure 3.13   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 2013

ISP package	Maximum Is faster than...	24 hours Is faster than...	8-10pm weekday Is faster than...
Virgin Media 120	Virgin Media 100, Virgin Media 60, BT 38, Plusnet 38 & Virgin Media 30	Virgin Media 100, Virgin Media 60, BT 38, Plusnet 38 & Virgin Media 30	Virgin Media 100, Virgin Media 60, BT 38, Plusnet 38 & Virgin Media 30
Virgin Media 100	Virgin Media 60, BT 38* & Virgin Media 30	Virgin Media 60 & Virgin Media 30	Virgin Media 60 & Virgin Media 30
Plusnet 76	Virgin Media 120, Virgin Media 100, Virgin Media 60, BT 38, Plusnet 38 & Virgin Media 30	Virgin Media 120, Virgin Media 100, Virgin Media 60, BT 76*, BT 38, Plusnet 38 & Virgin Media 30	Virgin Media 120, Virgin Media 100, Virgin Media 60, BT 38, Plusnet 38 & Virgin Media 30
BT 76	Virgin Media 120, Virgin Media 100, Virgin Media 60, BT 38, Plusnet 38 & Virgin Media 30	Virgin Media 120, Virgin Media 100, Virgin Media 60, BT 38, Plusnet 38 & Virgin Media 30	Virgin Media 120, Virgin Media 100, Virgin Media 60, BT 38, Plusnet 38 & Virgin Media 30
Virgin Media 60	Virgin Media 30	Virgin Media 30	Virgin Media 30
Plusnet 38	Virgin Media 60 & Virgin Media 30	Virgin Media 60 & Virgin Media 30	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

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

Section 4

Other measures of performance

There are a number of other metrics that can be used to evaluate fixed-line broadband performance, and the most important of these are outlined below in Figure 4.1. As the technologies and providers which deliver the highest connection speeds do not necessarily deliver the best performance with regard to these other measures, it is important that both sets of performance measurements are taken into consideration to understand overall performance. In this section we compare the performance of different ISP packages with respect to these metrics.

Figure 4.1   Summary of additional metrics

| 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.*

In Figures 4.2 and 4.3 below we chart the average packet loss and latency of the ISP packages covered by our research, two metrics which affect the quality of experience when undertaking online activities. In particular, high packet loss and latency can result in effects such as slow performance of tasks such as file downloads, lack of responsiveness when navigating websites, effects on sound quality when using VoIP and/or visual 'glitches' when streaming video content. High packet loss has a bigger impact on those with lower connection speeds, as a slower connection cannot replace any missing data packets quickly.

Figure 4.2 shows average packet loss and latency for the ADSL2+ ISP packages covered by our research. Among the ADSL2+ services, EE performed particularly well with low levels of packet loss and latency. Karoo had relatively high levels of packet loss with TalkTalk having the highest levels of latency.

Figure 4.2   Average 24-hour latency and packet loss for ADSL2+ ISP packages: May 2013
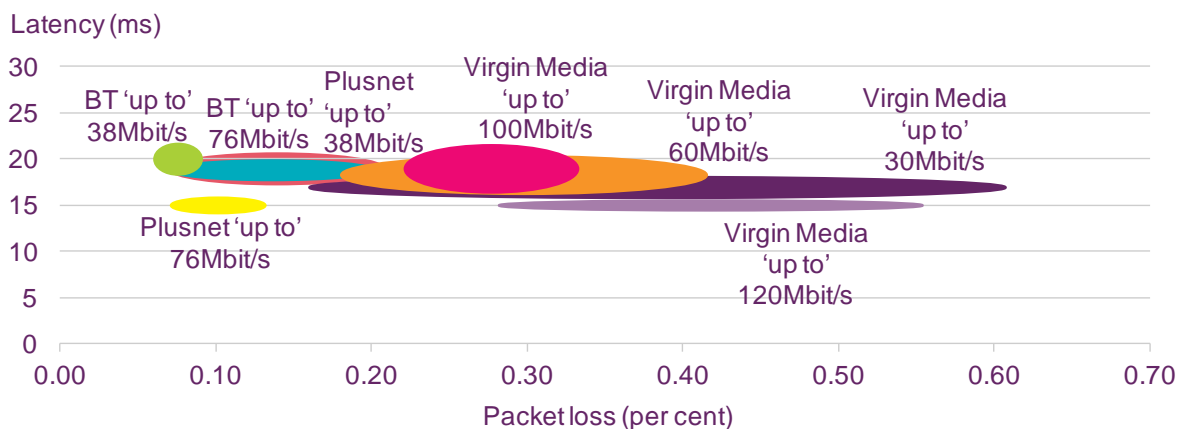
(lower levels indicate better performance)
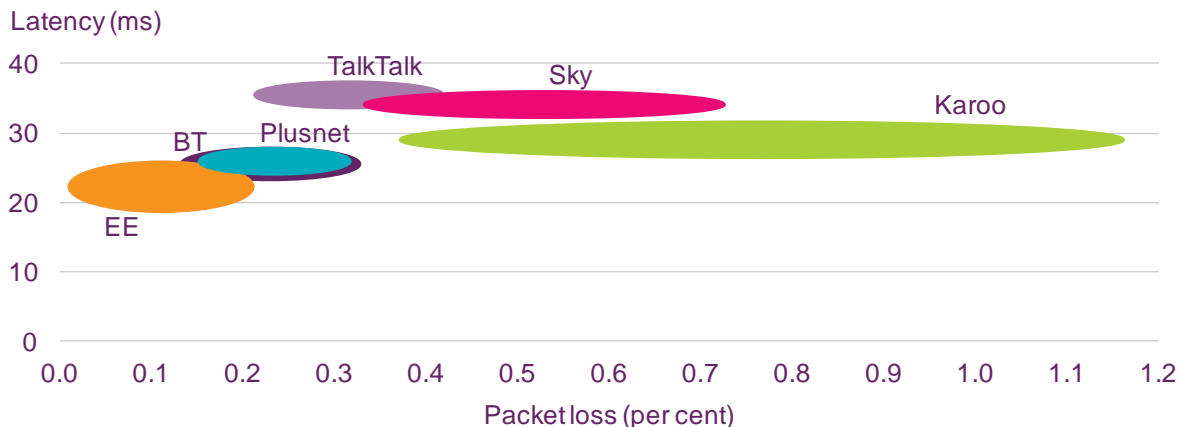
*Source: SamKnows measurement data for all panel members with a connection in May 2013
Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Includes only customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data have been weighted for distance from exchange; (4) Better performance is indicated by low latency and packet loss (i.e. lower values).*

Figure 4.3 shows that latency was lower for the superfast ISP packages covered by our research than it was for the ADSL2+ services, with packet loss being similar across all ISP packages. Average latency levels were similar across all of the superfast packages included in our research, clustered between 15 and 20ms. However our research indicates that packet loss tended to be lower on BT and Plusnet's FTTC services than on Virgin Media's superfast cable services, although it is unlikely that any of the levels of packet loss and latency observed among the superfast ISP packages covered in our research would have a noticeable impact on the consumers' experiences of undertaking most online tasks.

Figure 4.3   Average 24-hour latency and packet loss for 'up to' 30Mbit/s and above ISP packages: May 2013

(Lower bars indicate better performance)

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

Panel size: Virgin 'up to' 30Mbit/s 90; BT 'up to' 38Mbit/s 65; Plusnet 'up to' 38Mbit/s 52; Virgin 'up to' 60Mbit/s 134; BT 'up to' 76Mbit/s 203; Plusnet 'up to' 76Mbit/s 186; Virgin 'up to' 100Mbit/s 90; Virgin 'up to' 120Mbit/s 83)
Notes: (1) Data for fibre services and Virgin Media's cable service are not weighted; (2) Better performance is indicated by low latency and packet loss (i.e. lower values).

Web browsing

In order to assess the basic web browsing performance of packages with different headline speeds, we measured the time in milliseconds to fetch the main HTML and assets (i.e. text, basic code and content files) from three test pages. Note that in figures 4.4 and 4.6 better performance equates to faster loading times, which are shown by lower bars.

Figure 4.4   Average and peak-time loading of web pages for ADSL2+ ISP packages: May 2013

(Lower bars indicate better performance)

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators has been weighted for distance from exchange; (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 4.5   Significant differences, to a 95% level of confidence, between average and peak-time loading of web pages for ADSL2+ ISP packages: May 2013
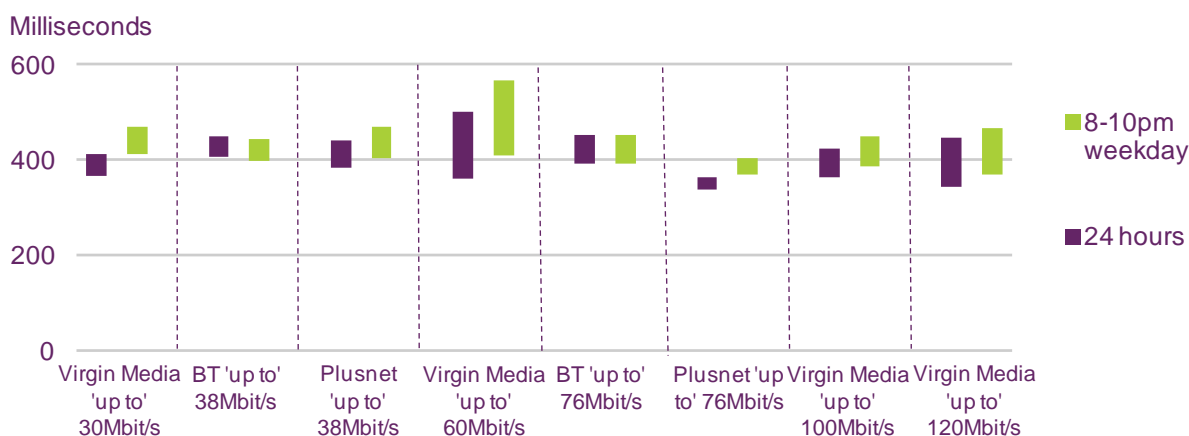
ISP package	24 hours Is faster than...	8-10pm weekday Is faster than...
BT	Sky*	Sky*
Karoo	Sky & TalkTalk	Sky & TalkTalk
EE	Sky*	No differences
Plusnet	Sky & TalkTalk*	Sky & TalkTalk*

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

Figure 4.6   Average and peak-time loading of web pages for 'up to' 30Mbit/s and above ISP packages: May 2013

(Lower bars indicate better performance)

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: Virgin 'up to' 30Mbit/s 90; BT 'up to' 38Mbit/s 65; Plusnet 'up to' 38Mbit/s 52; Virgin 'up to' 60Mbit/s 134; BT 'up to' 76Mbit/s 203; Plusnet 'up to' 76Mbit/s 186; Virgin 'up to' 100Mbit/s 90; Virgin 'up to' 120Mbit/s 83)
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 for 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) Better performance is indicated by a faster loading time, i.e. lower values.

Figure 4.7   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 2013

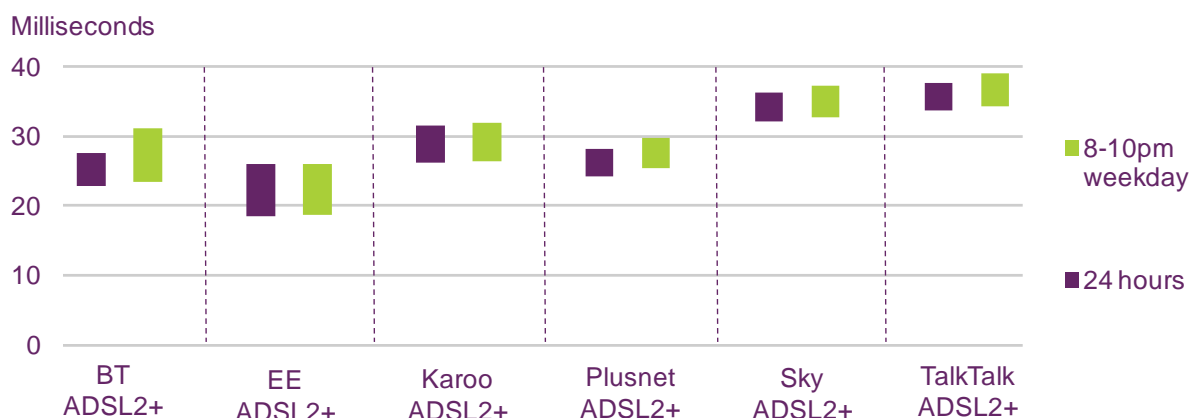|	24 hours	8-10pm weekday
ISP package	Is faster than...	Is faster than...
Plusnet 76	Virgin Media 100*, BT 76, BT 38, Plusnet 38 & Virgin Media 30*	No differences

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

Latency

Latency is the time 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. Certain applications, particularly some games, perform far better with lower latency. Note that in Figures 4.8 and 4.10, better performance equals lower latency, which is indicated by lower bars.

Figure 4.8   Average and peak-time latency for ADSL2+ ISP packages: May 2013

(Lower bars indicate better performance)

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Includes only ADSL customers within 5km of the 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 for 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) Better performance is indicated by a faster loading time, i.e. lower values.

Figure 4.9   Significant differences, to a 95% level of confidence, between average and peak-time latency for ADSL2+ ISP packages: May 2013
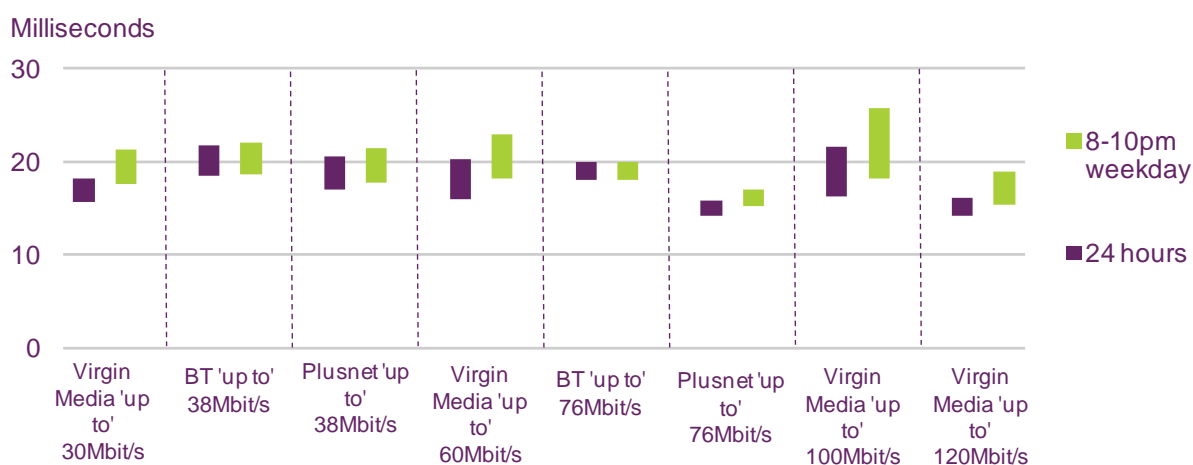
	24 hours	8-10pm weekday
ISP package	Is better than...	Is better than...
EE	Karoo*, Sky and TalkTalk	Karoo*, Sky and TalkTalk
Karoo	Sky* and TalkTalk	Sky* and TalkTalk
Plusnet	Sky and TalkTalk	Sky and TalkTalk
BT	Sky and TalkTalk	Sky* and TalkTalk

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

Figure 4.10   Average and peak-time latency for 'up to' 30Mbit/s and above ISP packages: May 2013

(Lower bars indicate better performance)

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: Virgin 'up to' 30Mbit/s 90; BT 'up to' 38Mbit/s 65; Plusnet 'up to' 38Mbit/s 52; Virgin 'up to' 60Mbit/s 134; BT 'up to' 76Mbit/s 203; Plusnet 'up to' 76Mbit/s 186; Virgin 'up to' 100Mbit/s 90; Virgin 'up to' 120Mbit/s 83)
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 for 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) Better performance is indicated by a faster loading time, i.e. lower values.

Figure 4.11   Significant differences, to a 95% level of confidence, between average and peak-time latency for 'up to' 30Mbit/s and above ISP packages: May 2013

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
Virgin Media 120	Virgin Media 100*, BT 76, BT 38 & Plusnet 38	No differences
Plusnet 76	Virgin Media 100*, BT 76, Virgin Media 60*, BT 38 & Plusnet 38	Virgin Media 100*, BT 76*, Virgin Media 60, BT 38, Plusnet 38* & Virgin Media 30*
Virgin Media 30	BT 38	No differences

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 considerably degrade the performance of real-time applications, and although network protocols such as transmission control protocol (TCP) automatically deal with packet loss to minimise the impact to the end-user, there may still be a temporary slow-down.

This can be a major concern for online gamers, users of voice over IP (VoIP) telephony and those streaming audio or video content (a small number of dropped packets is generally

acceptable, as each packet in the test accounts for only 0.2 seconds, but extended periods of loss lead to choppy and broken-up video and audio). Note that in figure 4.12 and figure 4.14 better performance equates to lower packet loss, which is indicated by lower bars.

Figure 4.12   Average and peak-time packet loss for ADSL2+ ISP packages: May 2013

(Lower bars indicate better performance)
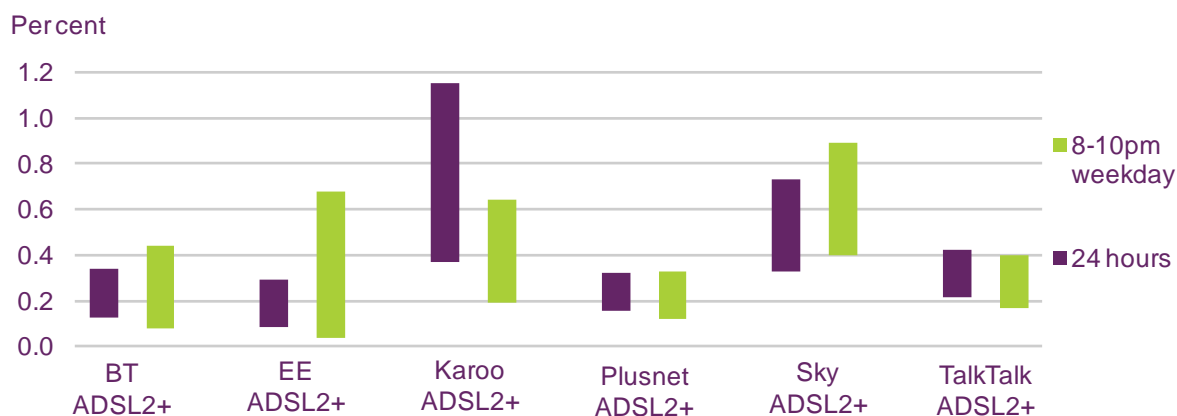
Source: SamKnows measurement data for all panel members with a connection in May 2013. Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to for 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) Better performance is indicated by a faster loading time, i.e. lower values.

Figure 4.13   Significant differences, to a 95% level of confidence, between average and peak-time packet loss for ADSL2+ ISP packages: May 2013

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

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

**Figure 4.14   Average and peak-time packet loss for 'up to' 30Mbit/s and above ISP packages: May 2013**

(Lower bars indicate better performance)

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: Virgin 'up to' 30Mbit/s 90; BT 'up to' 38Mbit/s 65; Plusnet 'up to' 38Mbit/s 52; Virgin 'up to' 60Mbit/s 134; BT 'up to' 76Mbit/s 203; Plusnet 'up to' 76Mbit/s 186; Virgin 'up to' 100Mbit/s 90; Virgin 'up to' 120Mbit/s 83)
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 for distance from exchange; data for fibre services and Virgin Media's cable service is not weighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Better performance is indicated by a faster loading time, i.e. lower values.

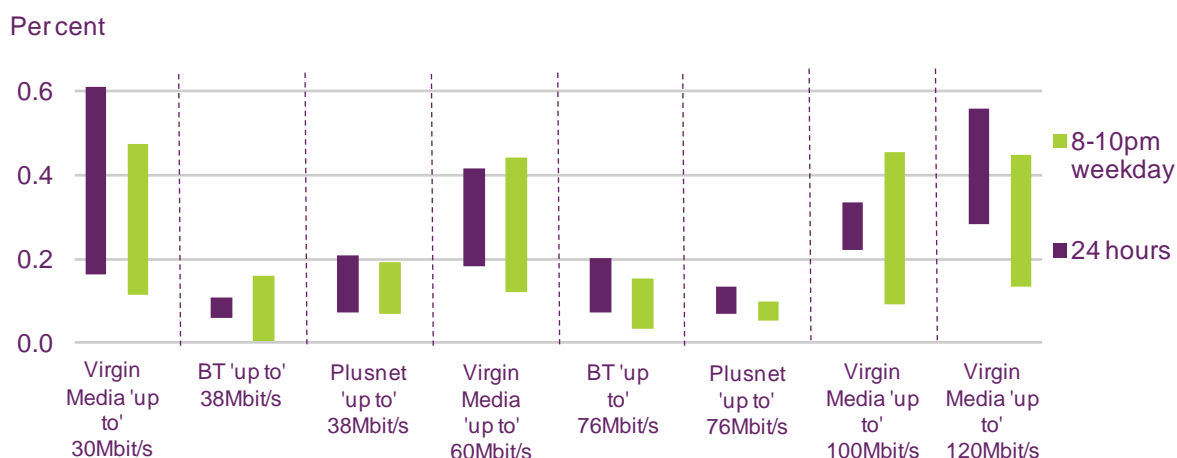**Figure 4.15   Significant differences, to a 95% level of confidence, between average and peak-time packet loss for 'up to' 30Mbit/s and above ISP packages: May 2013**

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
Plusnet 76	Virgin Media 120, Virgin Media 100, Virgin Media 60* & Virgin Media 30*	Virgin Media 120*, Virgin Meida 60* & Virgin Media 30*
BT 76	Virgin Media 120 & Virgin Media 100*	No differences
Plusnet 38	Virgin Media 120 & Virgin Media 100*	No differences
BT 38	Virgin Media 120 , Virgin Media 100, Virgin Media 60 & Virgin Media 30*	No differences

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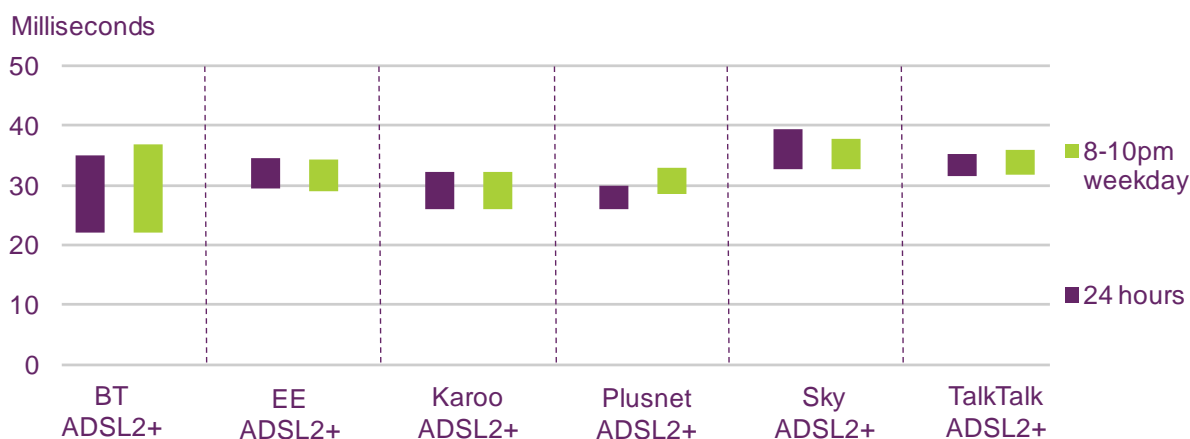
DNS resolution

DNS (the domain name service) plays a crucial role in the internet. This protocol translates domain names (such as ofcom.org.uk) into the IP addresses that are actually used to route traffic (e.g. 194.33.179.25). Every ISP maintains its own DNS servers through which

customers' computers issue queries to translate names into IP addresses. When these servers fail or operate slowly, web browsing and other online activities suffer. A slow DNS time does not affect download speed, but can severely affect the responsiveness of the internet while browsing. Note that in figures 4.16 and 4.18 better performance equates to faster resolution times, which are indicated by lower bars.

Figure 4.16   Average and peak-time DNS resolution time for ADSL2+ ISP packages: May 2013

(Lower bars indicate better performance)

Source: SamKnows measurement data for all panel members with a connection in May 2013. Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Includes only ADSL customers within 5km of the 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 for distance from exchange; data for Virgin Media's cable service are not weighted; (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 4.17   Significant differences, to a 95% level of confidence, between average and peak-time DNS resolution time for ADSL2+ ISP packages: May 2013

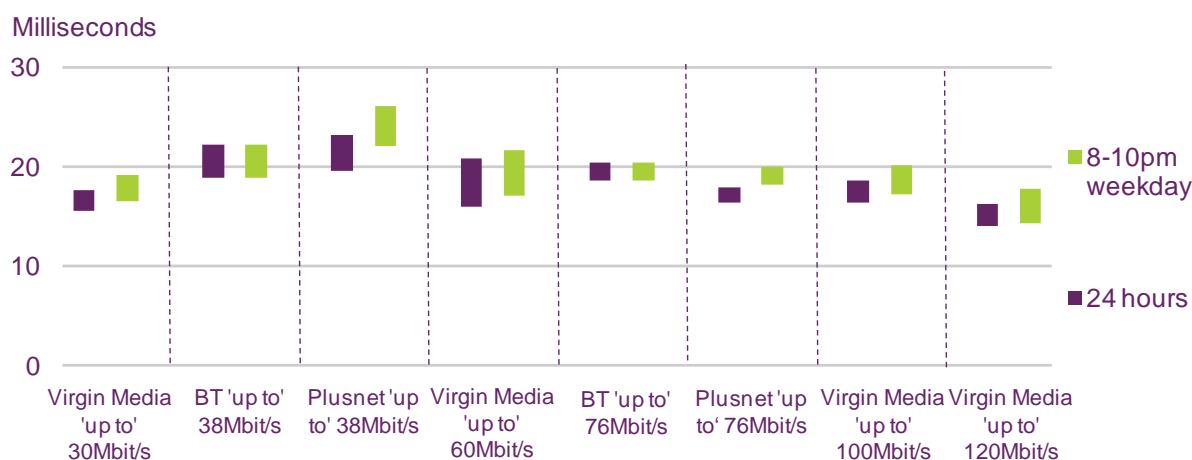|	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**
Karoo	Sky*	Sky*
Plusnet	TalkTalk and Sky	No differences

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

Figure 4.18   Average and peak-time DNS resolution time for 'up to' 30Mbit/s and above ISP packages: May 2013

(Lower bars indicate better performance)

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: Virgin 'up to' 30Mbit/s 90; BT 'up to' 38Mbit/s 65; Plusnet 'up to' 38Mbit/s 52; Virgin 'up to' 60Mbit/s 134; BT 'up to' 76Mbit/s 203; Plusnet 'up to' 76Mbit/s 186; Virgin 'up to' 100Mbit/s 90; Virgin 'up to' 120Mbit/s 83)
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 for distance from exchange; data for Virgin Media's cable service are not weighted; (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 4.19   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 2013

	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**
Virgin Media 120	Virgin Media 100*, BT 76, Plusnet 76*, BT 38 & Plusnet 38	BT 76*, Plusnet 76*, BT 38 & Plusnet 38
Virgin Media 100	BT 38* & Plusnet 38	Plusnet 38
Plusnet 76	BT 76, BT 38 & Plusnet 38	Plusnet 38
BT 76	No difference	Plusnet 38
Virgin Media 60	No differences	Plusnet 38*
Virgin Media 30	BT 76, BT 38 & Plusnet 38	Plusnet 38

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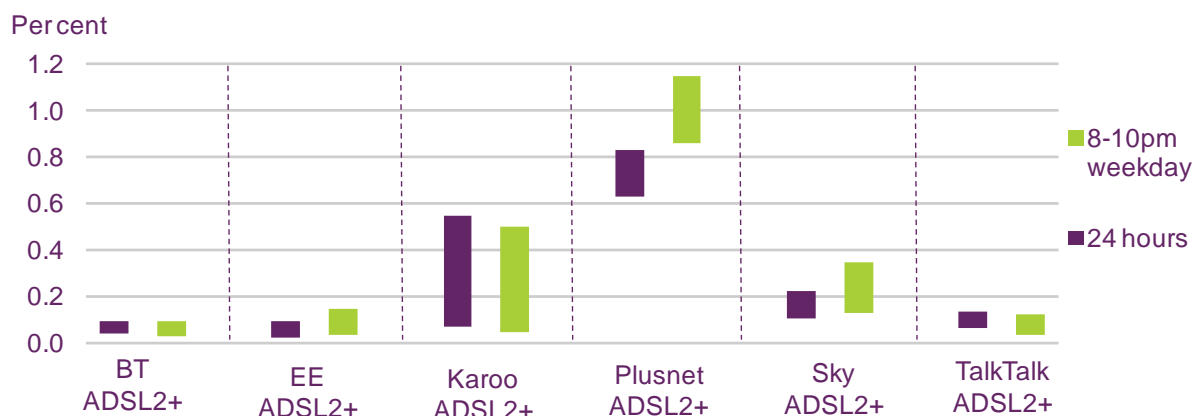
DNS failure

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 be found"*, and is unable to

access the requested page on that occasion. Note that in figures 4.20 and 4.22 better performance equates to short times, which are indicated by lower bars.

Figure 4.20   Average and peak-time DNS failure rates for ADSL2+ ISP packages: May 2013

(Lower bars indicate better performance)

*Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Includes only ADSL customers within 5km of the 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 for distance from exchange; data for Virgin Media's cable service are not weighted; (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 4.21   Significant differences, to a 95% level of confidence, between average and peak-time DNS failure rates for ADSL2+ ISP packages: May 2013

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

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

Figure 4.22   Average and peak-time DNS failure rates for 'up to' 30Mbit/s and above ISP packages: May 2013

(Lower bars indicate better performance)

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: Virgin 'up to' 30Mbit/s 90; BT 'up to' 38Mbit/s 65; Plusnet 'up to' 38Mbit/s 52; Virgin 'up to' 60Mbit/s 134; BT 'up to' 76Mbit/s 203; Plusnet 'up to' 76Mbit/s 186; Virgin 'up to' 100Mbit/s 90; Virgin 'up to' 120Mbit/s 83)
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 for distance from exchange; data for fibre services Virgin Media's cable service are not weighted; (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.

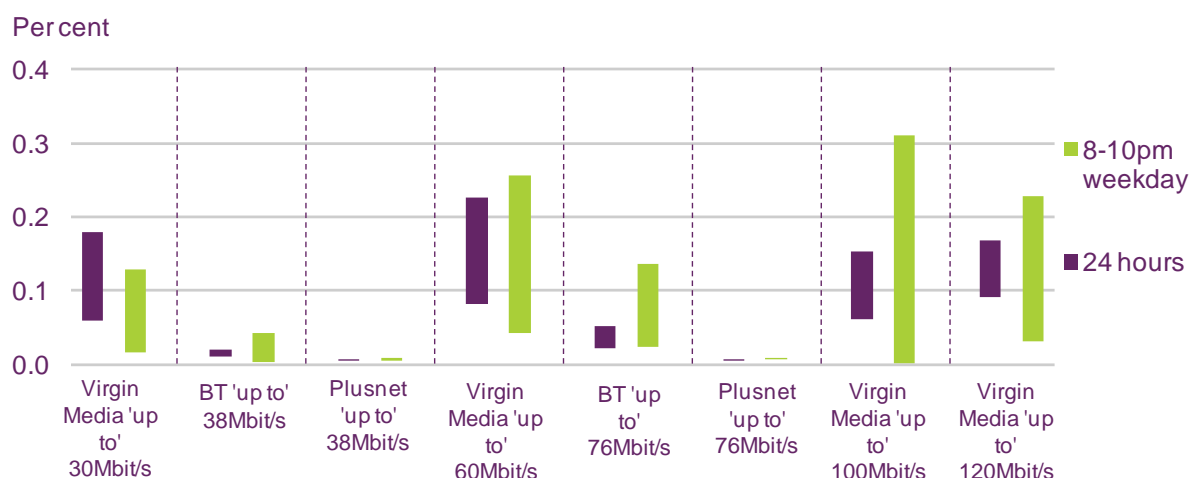**Figure 4.23   Significant differences, to a 95% level of confidence, between average and peak-time DNS failure rates for 'up to' 30Mbit/s and above ISP packages: May 2013**

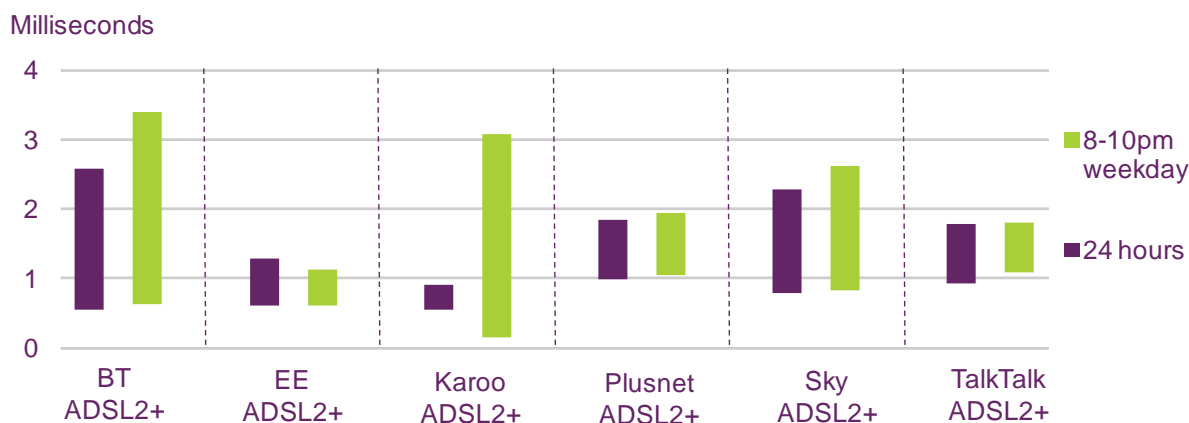| ISP package	24 hours Is better than...	8-10pm weekday Is better than...
Virgin Media 120	Plusnet 76 & Plusnet 38	Plusnet 76 & Plusnet 38
Virgin Media 100	Plusnet 76 & Plusnet 38	Plusnet 76 & Plusnet 38
BT 76	Virgin Media 120, Virgin Media 100*, Virgin Media 60*, Plusnet 76, Plusnet 38 & Virgin Media 30*	Plusnet 76 & Plusnet 38
Virgin Media 60	Plusnet 76 & Plusnet 38	Plusnet 76 & Plusnet 38
BT 38	Virgin 120, Virgin 100, Plusnet 76, BT 76*, Virgin Media 60, Plusnet 38 & Virgin Media 30	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. This effectively allows for up to a 20 millisecond jitter, with no noticeable effect for the end-user. Note that in figures 4.24, 4.26, 4.28 and 4.30 better performance equates to shorter times, which are indicated by lower bars.

Figure 4.24   Average and peak-time upstream jitter for ADSL2+ ISP packages: May 2013

(Lower bars indicate better performance)

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Includes only ADSL customers within 5km of the 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 for distance from exchange; data for Virgin Media's cable service are not weighted; (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 4.25   Significant differences, to a 95% level of confidence, between average and peak-time upstream jitter for ADSL2+ ISP packages: May 2013

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

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

Figure 4.26   Average and peak-time upstream jitter for 'up to' 30Mbit/s and above ISP packages: May 2013

(Lower bars indicate better performance)

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: Virgin 'up to' 30Mbit/s 90; BT 'up to' 38Mbit/s 65; Plusnet 'up to' 38Mbit/s 52; Virgin 'up to' 60Mbit/s 134; BT 'up to' 76Mbit/s 203; Plusnet 'up to' 76Mbit/s 186; Virgin 'up to' 100Mbit/s 90; Virgin 'up to' 120Mbit/s 83)
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 fibre and cable services are not weighted; (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.

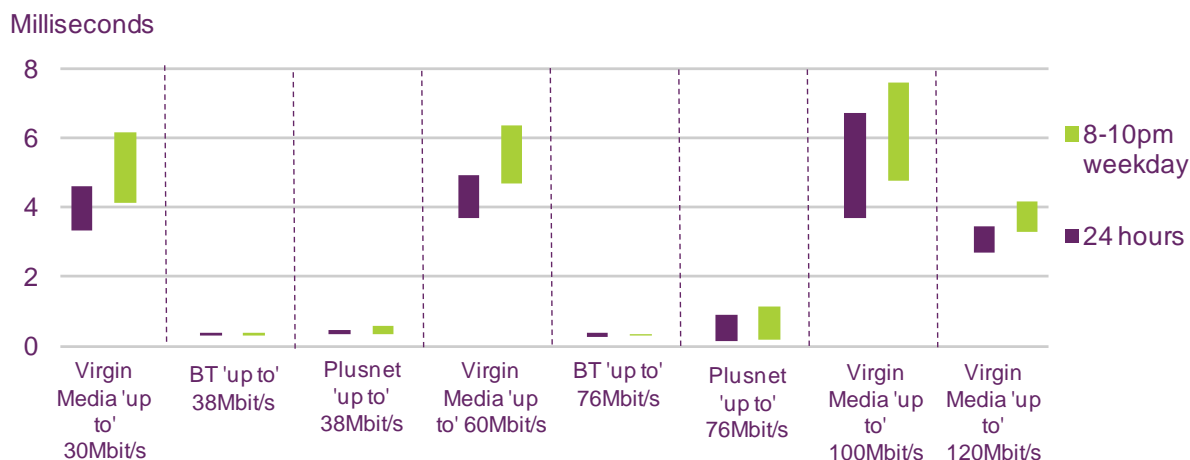**Figure 4.27   Significant differences, to a 95% level of confidence, between average and peak-time upstream jitter for 'up to' 30Mbit/s and above ISP packages: May 2013**

	24 hours	8-10pm weekday
ISP package	Is better than...	Is better than...
Virgin Media 120	Virgin Media 100* & Virgin Media 60*	Virgin Media 100* & Virgin Media 60
Plusnet 76	Virgin Media 120, Virgin Media 100, Virgin Media 60 & Virgin Media 30	Virgin Media 120, Virgin Media 100, Virgin Media 60 & Virgin Media 30
BT 76	Virgin Media 120, Virgin Media 100, Virgin Media 60 & Virgin Media 30	Virgin Media 120, Virgin Media 100, Virgin Media 60 & Virgin Media 30
Plusnet 38	Virgin Media 120, Virgin Media 100, Virgin Media 60 & Virgin Media 30	Virgin Media 120, Virgin Media 100, Virgin Media 60 & Virgin Media 30
BT 38	Virgin Media 120, Virgin Media 100, Virgin Media 60 & Virgin Media 30	Virgin Media 120, Virgin Media 100, Virgin Media 60 & Virgin Media 30

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

Figure 4.28   Average and peak-time downstream jitter for ADSL2+ ISP packages: May 2013

(Lower bars indicate better performance)

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Includes only ADSL customers within 5km of the 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 for distance from exchange; data for Virgin Media's cable service are not weighted; (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 4.29   Significant differences, to a 95% level of confidence, between average and peak-time downstream jitter for ADSL2+ ISP packages: May 2013
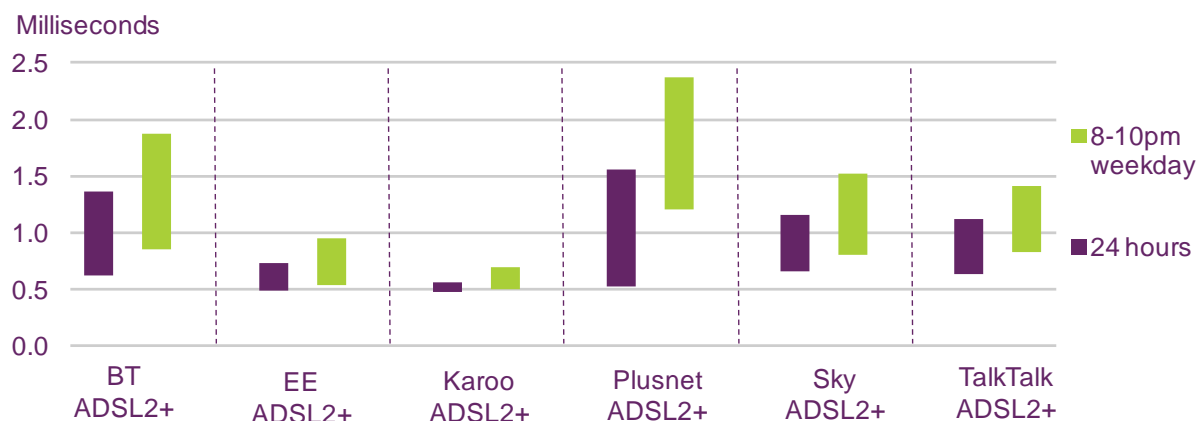
	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
EE	No differences	Plusnet*
Karoo	BT*, Sky & TalkTalk*	BT*, Plusnet, Sky* & TalkTalk

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

Figure 4.30   Average and peak-time downstream jitter for 'up to' 30Mbit/s and above ISP packages: May 2013

(Lower bars indicate better performance)

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: Virgin 'up to' 30Mbit/s 90; BT 'up to' 38Mbit/s 65; Plusnet 'up to' 38Mbit/s 52; Virgin 'up to' 60Mbit/s 134; BT 'up to' 76Mbit/s 203; Plusnet 'up to' 76Mbit/s 186; Virgin 'up to' 100Mbit/s 90; Virgin 'up to' 120Mbit/s 83)
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 fibre and cable services are not weighted; (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.

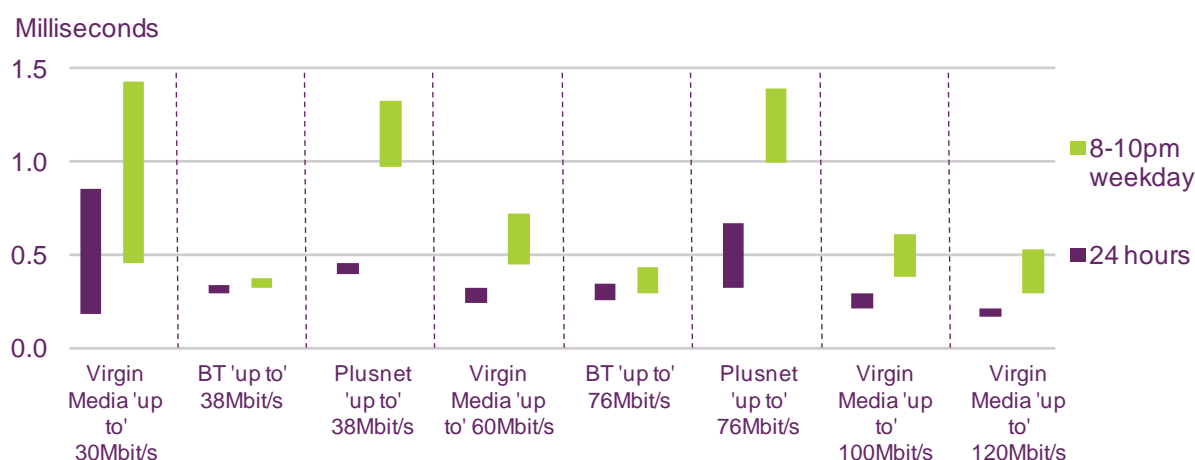**Figure 4.31   Significant differences, to a 95% level of confidence, between average and peak-time downstream jitter for 'up to' 30Mbit/s and above ISP packages: May 2013**

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
Virgin Media 120	Virgin Media 100*, BT 76, Plusnet 76, Virgin Media 60, BT 38 & Plusnet 38	Plusnet 76 & Plusnet 38
Virgin Media 100	Plusnet 76* & Plusnet 38	Plusnet 76 & Plusnet 38
BT 76	Plusnet 38	Plusnet 76, Virgin Media 60*, Plusnet 38 & Virgin Media 30*
Virgin Media 60	Plusnet 38	Plusnet 76 & Plusnet 38
BT 38	Plusnet 38	Virgin Media 100*, Plusnet 76, Virgin Media 60, Plusnet 38 & Virgin Media 30*

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

Conclusion and next steps

This report represents a snapshot of the average performance of fixed-line residential UK broadband connections and of the individual ISP packages included in the research in May 2013. The broadband market is changing rapidly as operators invest in order to make faster broadband available, and the results set out in this report will therefore not necessarily reflect the future performance of networks and providers.

Despite these anticipated changes, and in order to help ISPs' current and new customers to make better informed purchasing decisions based on their individual needs, it is important that consumers understand that there are significant variations in the performance of ISP packages, and that these are largely attributable to the technology used by the ISP. This information is particularly relevant for users of high-bandwidth services such as high-definition video and some online gaming.

We plan to publish the next UK fixed-line broadband performance report in early 2014, using data collected from tests run in November 2013.

Annex 1

Additional analysis

The distribution of actual broadband speeds

Figure 1 **Distribution of maximum and average download speeds for ADSL2+ packages: May 2013**
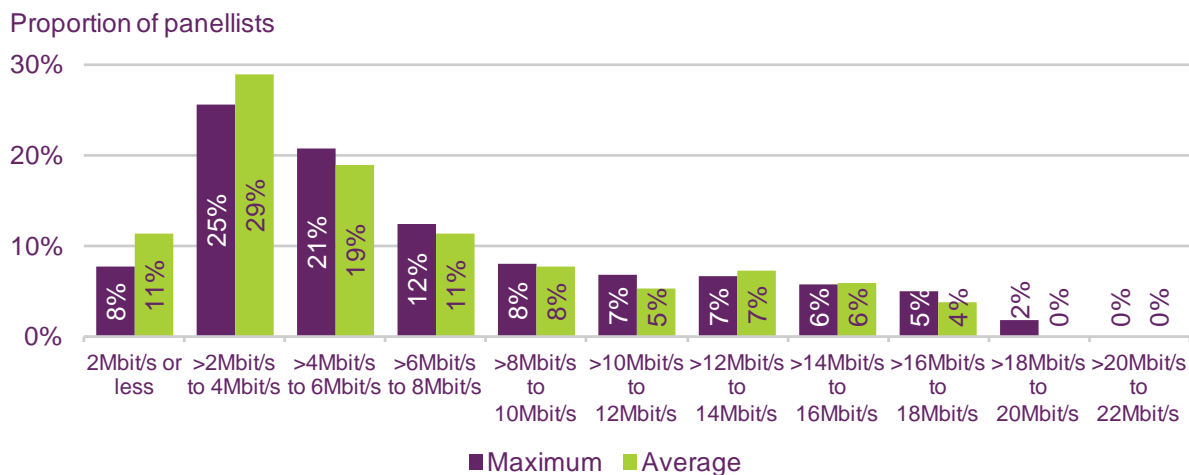
Proportion of panellists

Source: SamKnows measurement data for panel members with a connection in May 2013.
Panel size: 849
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK ADSL2+ residential customers as a whole; (2) Data collected from multi-thread download speed tests.

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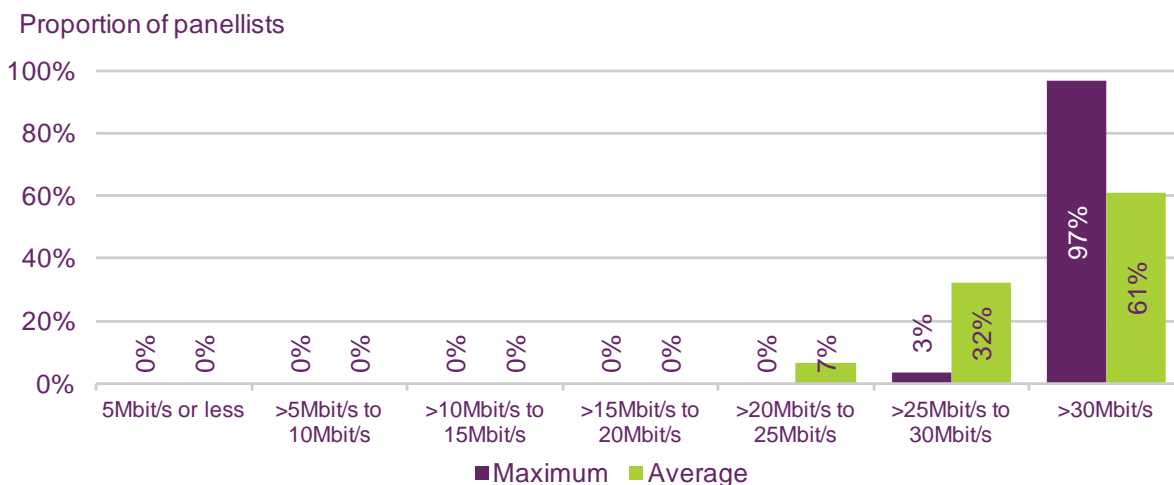
Proportion of panellists

Source: SamKnows measurement data for panel members with a connection in May 2013.
Panel size: 90
Notes: (1) Data collected from multi-thread download speed tests.

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

Proportion of panellists

Source: SamKnows measurement data for panel members with a connection in May 2013.
Panel size: 134
Notes: (1) Data collected from multi-thread download speed tests.

Figure 4   Distribution of maximum and average download speeds for 'up to' 100Mbit/s cable packages: May 2013

Proportion of panellists

Source: SamKnows measurement data for panel members with a connection in May 2013.
Panel size: 40
Notes: (1) Data collected from multi-thread download speed tests.

Figure 5   Distribution of maximum and average download speeds for 'up to' 120Mbit/s cable packages: May 2013

Proportion of panellists

■ Maximum ■ Average

Source: SamKnows measurement data for panel members with a connection in May 2013.
Panel size: 83
Notes: (1) Data collected from multi-thread download speed tests.

Figure 6   Distribution of maximum and average download speeds for 'up to' 38Mbit/s FTTC packages: May 2013

Proportion of panellists

■ Maximum ■ Average

Source: SamKnows measurement data for panel members with a connection in May 2013.
Panel size: 170
Notes: (1) Data collected from multi-thread download speed tests.

Figure 7　　　Distribution of maximum and average download speeds for 'up to' 76Mbit/s FTTC packages: May 2013
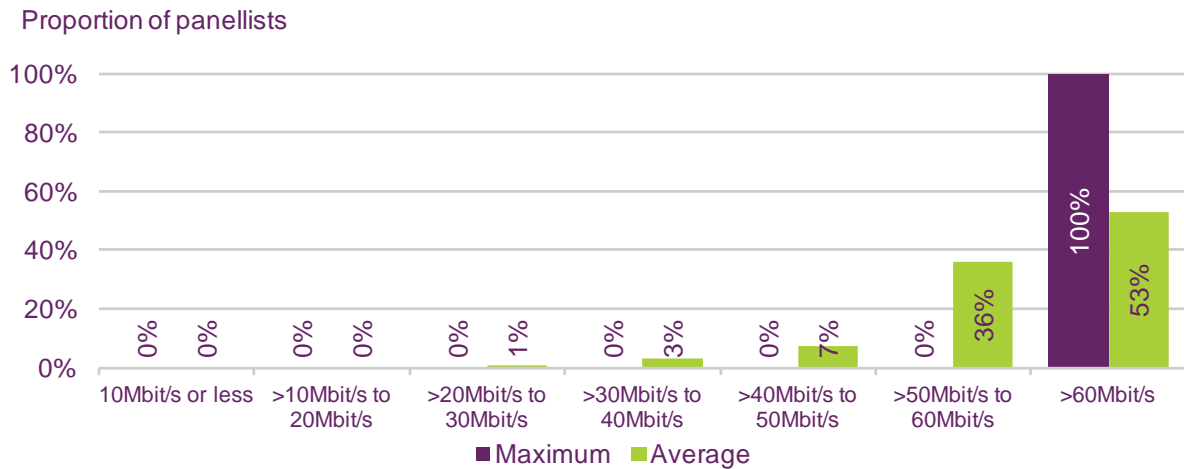
Proportion of panellists

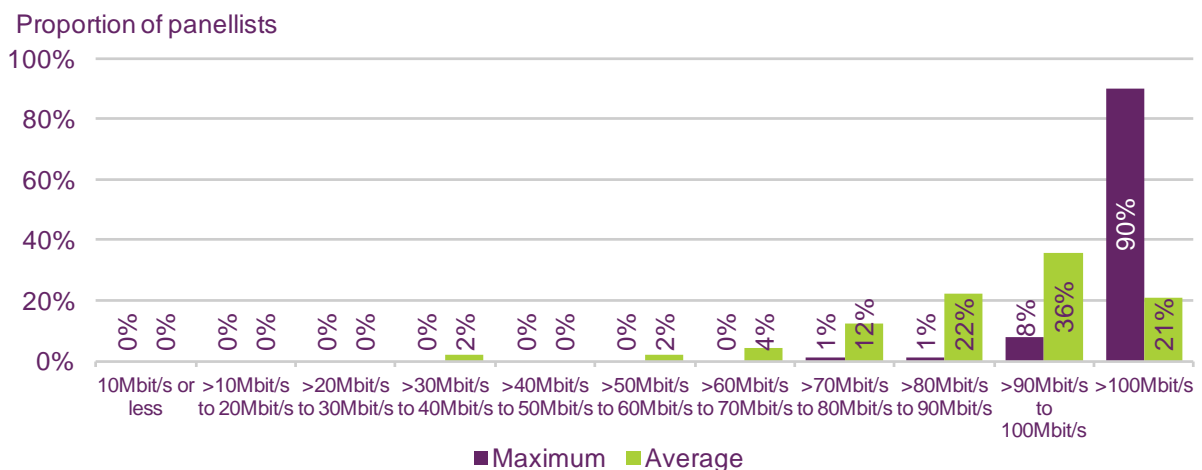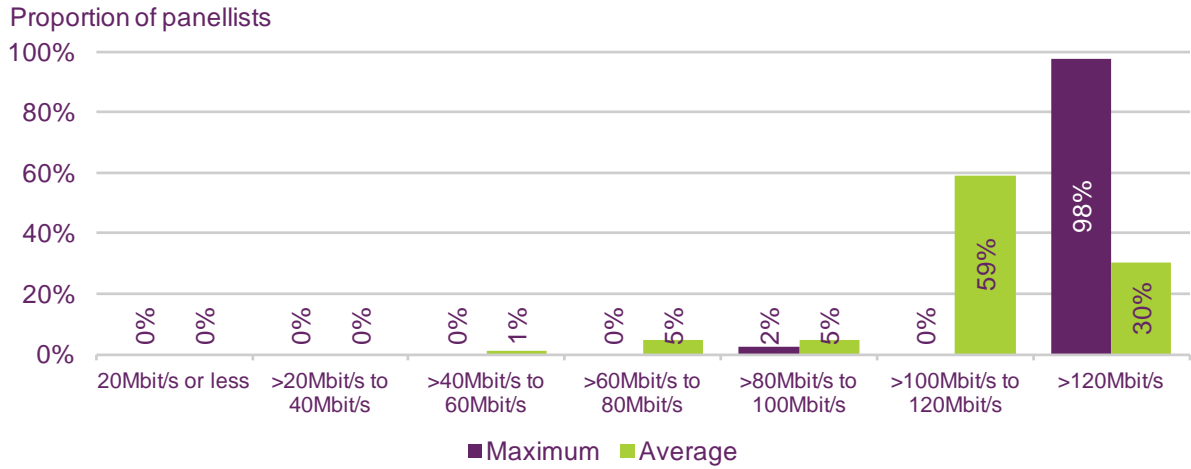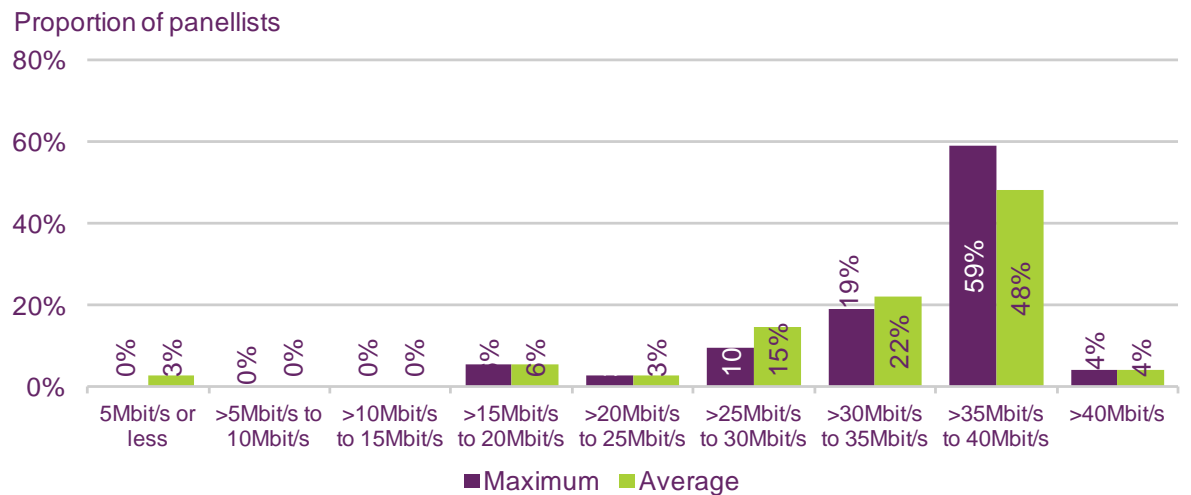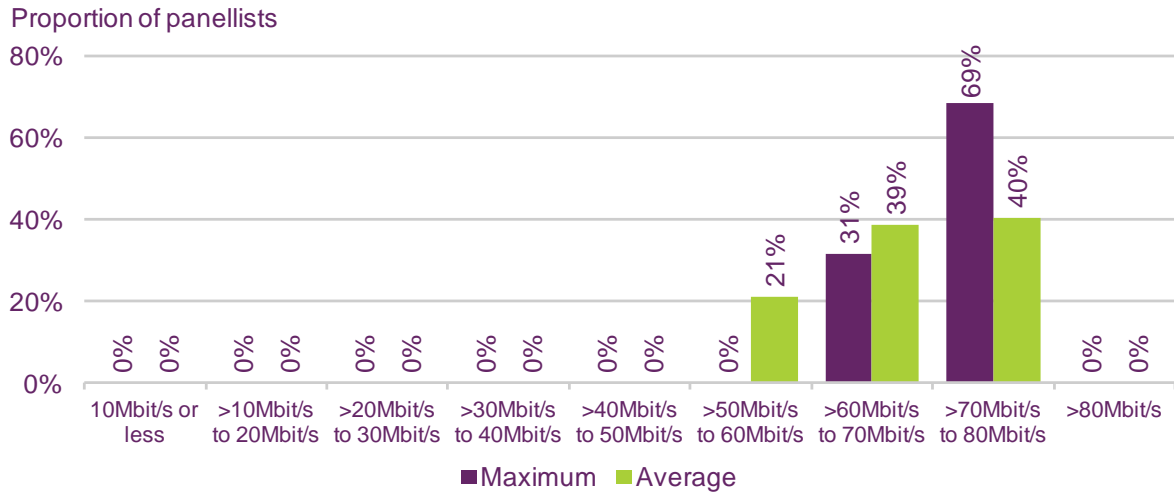*Source: SamKnows measurement data for panel members with a connection in May 2013.*
Panel size: 413
Notes: (1) Data collected from multi-thread download speed tests.

Variation of speeds by geographic location

Figure 8　　　Distribution of panellists, by distance from exchange

Panellists

Distance from exchange (km)
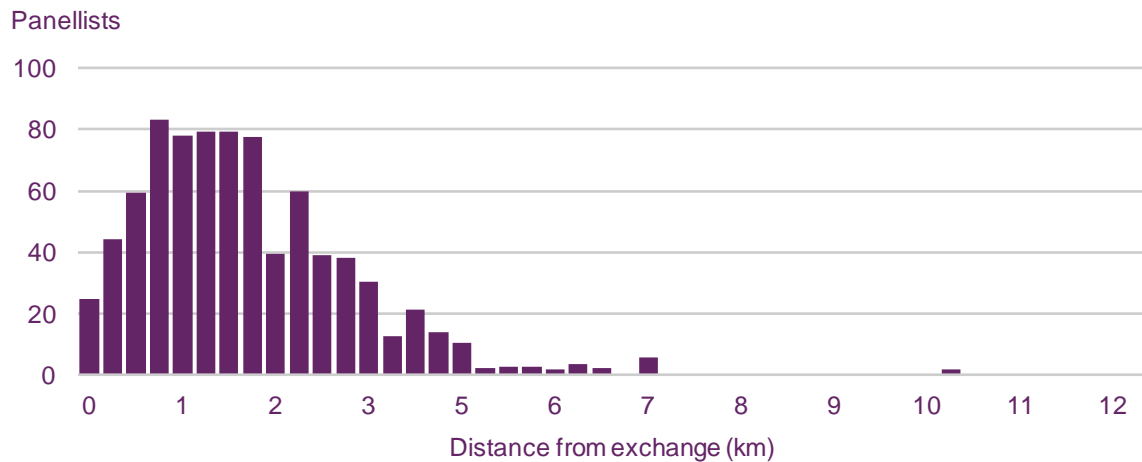
Source: Ofcom, using data supplied by SamKnows
Panel size: 2,173

Figure 9   Average and maximum download speeds for ADSL broadband connections in rural and urban areas: May 2013
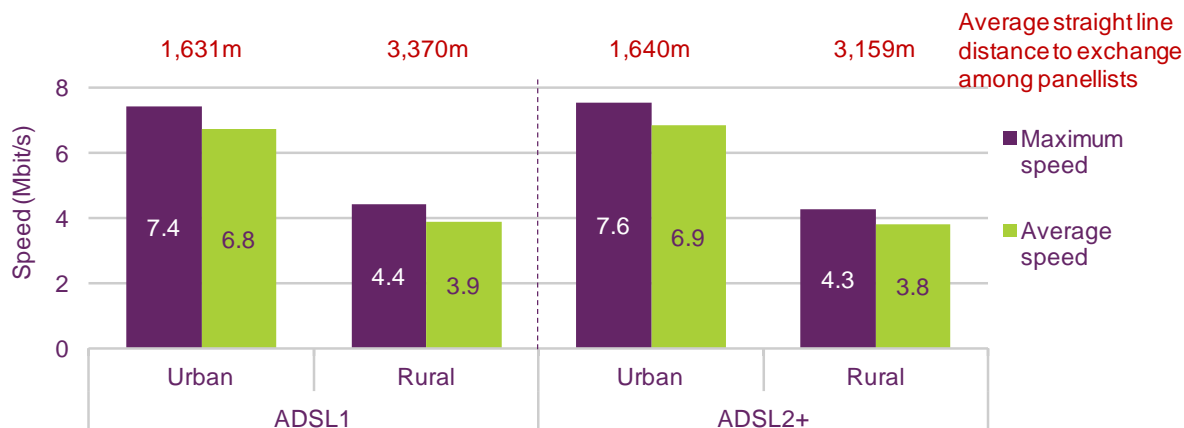
Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: 849
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests

Geographic market situation[16]

Figure 10   Average and maximum download speeds, by geographic market: May 2013

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: 849

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[16] The geographic markets used are those identified by Ofcom in the *Review of the wholesale access markets: Statement on market definition, market power determinations and remedies,* 3 December 2010 (http://stakeholders.ofcom.org.uk/binaries/consultations/wba/statement/wbastatement.pdf). These are:
Market 1: exchanges where only BT is present or forecast to be present;
Market 2: exchanges where two Principal Operators (operators capable of providing a material constraint in the market) are present or forecast and exchanges where three Principal Operators are present or forecast but where BT's share is greater than or equal to 50%; and
Market 3: exchanges where four or more Principal Operators are present or forecast and exchanges where three Principal Operators are present or forecast but where BT's share is less than 50%.

Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) 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 2013 and an estimated split between rural and urban areas; (3) Data collected from multi-thread download speed tests.

Figure 11   Average download speed as a proportion of maximum speed, by time of day for ADSL2+ ISP packages: May 2013
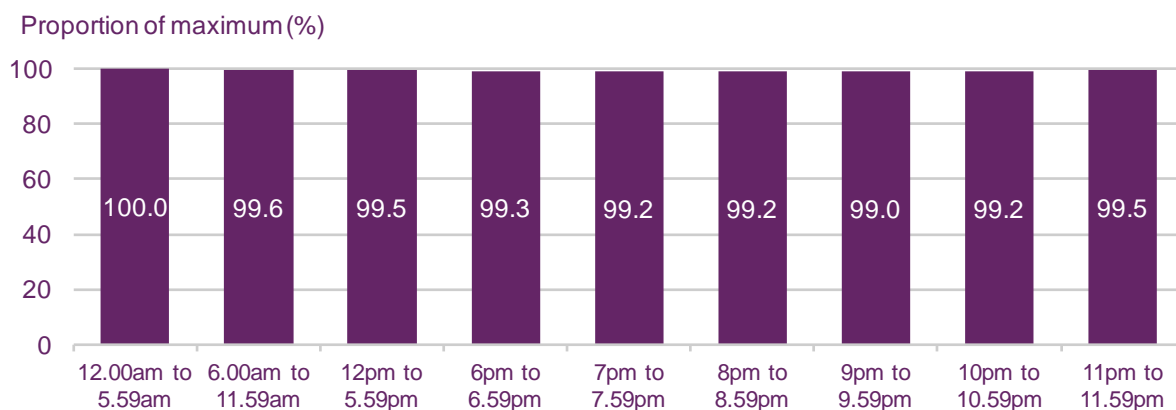
Proportion of maximum (%)

12.00am to 5.59am	6.00am to 11.59am	12pm to 5.59pm	6pm to 6.59pm	7pm to 7.59pm	8pm to 8.59pm	9pm to 9.59pm	10pm to 10.59pm	11pm to 11.59pm
100.0	99.6	99.5	99.3	99.2	99.2	99.0	99.2	99.5

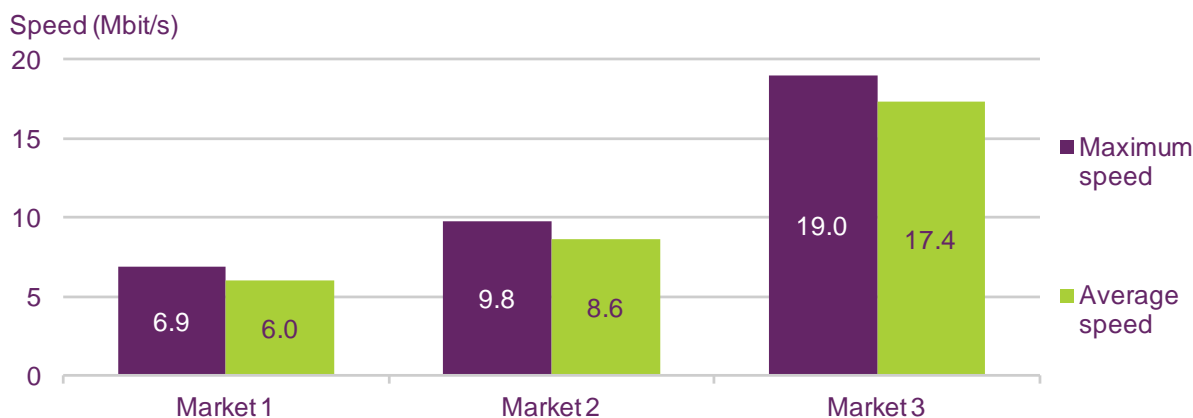*Source: SamKnows measurement data for all panel members with a connection in May 2013.*
Panel size: 616
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK ADSL2+ residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 12   Average download speed as a proportion of maximum speeds, by time of day for 'up to' 30Mbit/s and 'up to' 38Mbit/s ISP packages: May 2013

Proportion of maximum (%)

	12.00am to 5.59am	6.00am to 11.59am	12pm to 5.59pm	6pm to 6.59pm	7pm to 7.59pm	8pm to 8.59pm	9pm to 9.59pm	10pm to 10.59pm	11pm to 11.59pm
'Up to' 30Mbit/s cable	99.8	100.0	99.5	97.9	95.5	95.6	95.6	97.1	98.2
'Up to' 38Mbit/s FTTC	99.8	99.6	99.2	98.4	98.2	97.4	98.6	99.9	100.0

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: Virgin Media 'up to' 30Mbit/s 90, BT 'up to' 38Mbit/s 65 and Plusnet 'up to' 38Mbit/s 52
Notes: (1) Data collected from multi-thread download speed tests.

Figure 13   Average download speed as a proportion of maximum speed, by time of day for above 'up to' 60Mbit/s and 'up to' 76Mbit/s ISP packages: May 2013

Proportion of maximum (%)

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: Virgin Media 'up to 60 Mbit/s" 134, BT 'up to' 76Mbit/s 203 and Plusnet 'up to' 76Mbit/s 186.
Notes: (1) Data collected from multi-thread download speed tests.

Figure 14   Average download speeds as a proportion of maximum speed, by time of day for above 'up to' 100Mbit/s and 'up to' 120Mbit/s ISP packages: May 2013
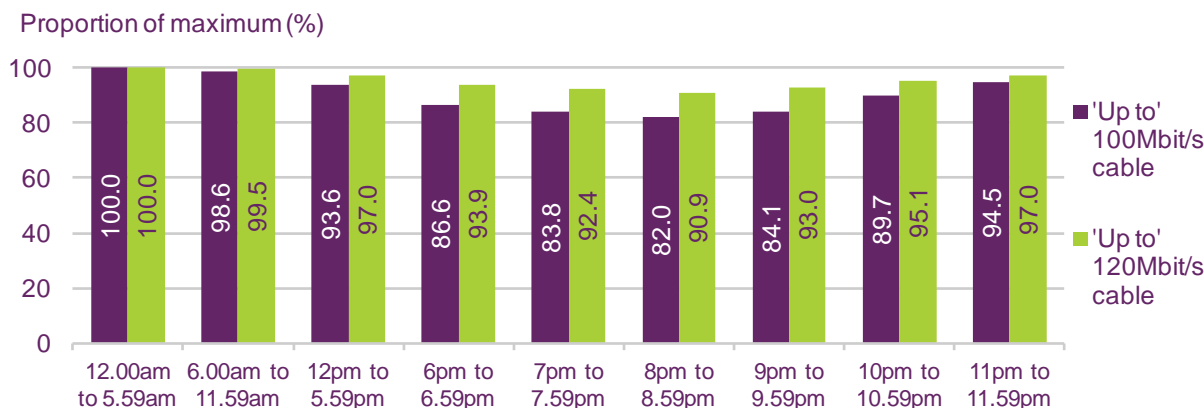
Proportion of maximum (%)

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: Virgin Media 'up to' 100Mbit/s 90 and Virgin Media 'up to 120 Mbits' 83.
Notes: (1) Data collected from multi-thread download speed tests.

Variation in speeds, by access technology

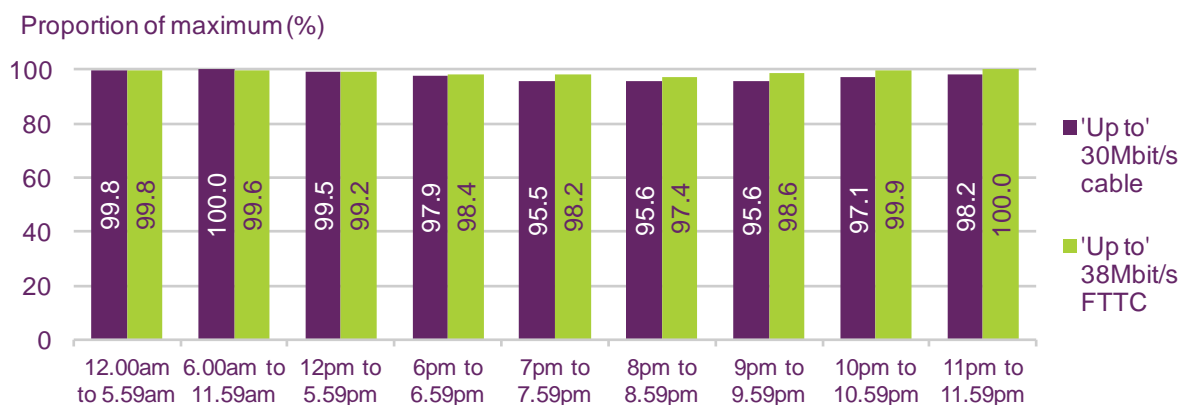**Figure 15**   **Average download speeds, by technology and headline speed: May 2013**

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: 849
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in May 2013; (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean.

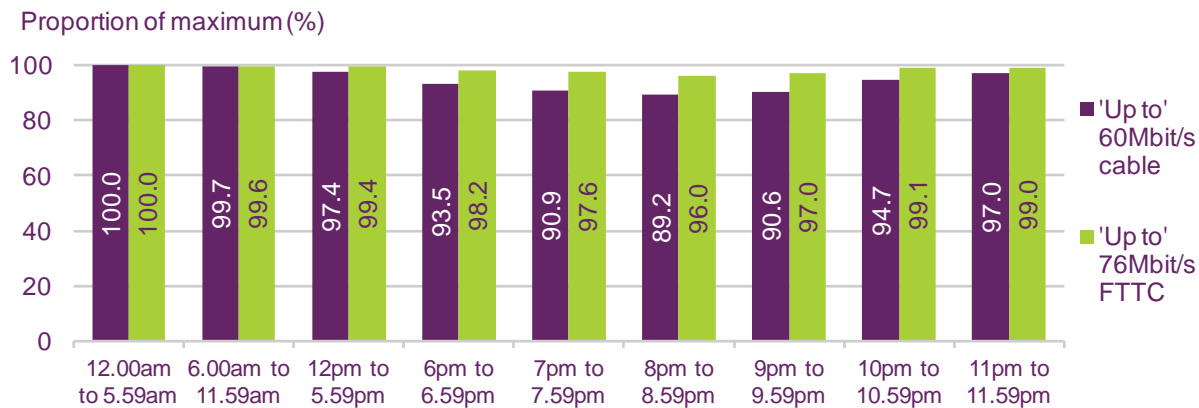**Figure 16**   **Maximum download speeds for ADSL2+ ISP packages: May 2013**
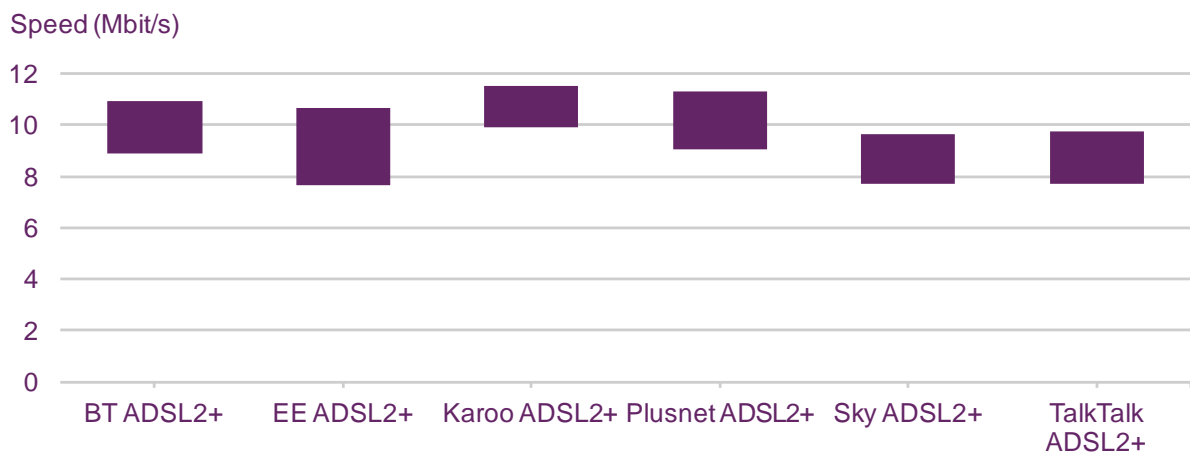
Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: Virgin Media 'up to' 100Mbit/s 90 and Virgin Media 'up to 120 Mbits' 83.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted for distance from exchange; data for Virgin Media's cable service are not weighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

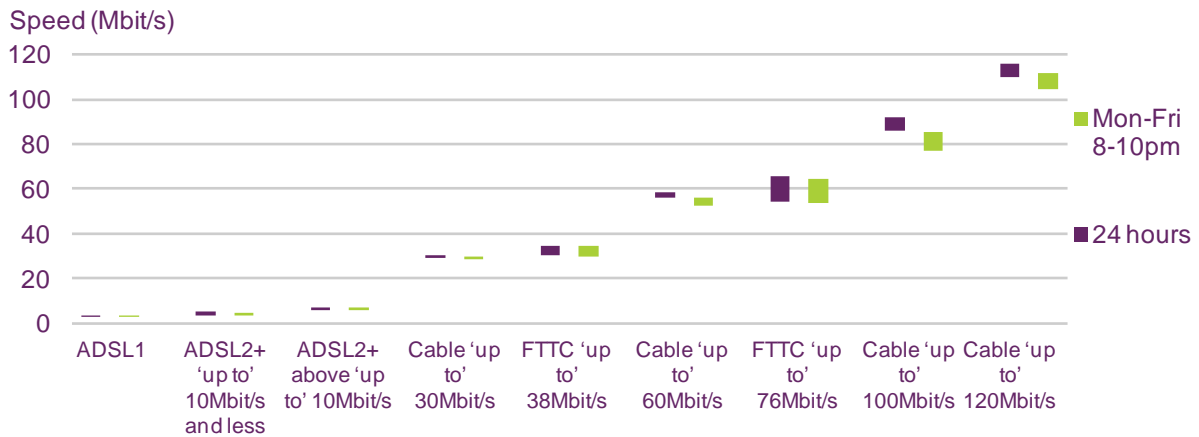**Figure 17   Maximum download speeds for 'up to' 30Mbit/s and above ISP packages: May 2013**

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: Virgin 'up to' 30Mbit/s 90; BT 'up to' 38Mbit/s 65; Plusnet 'up to' 38Mbit/s 52; Virgin 'up to' 60Mbit/s 134; BT 'up to' 76Mbit/s 203; Plusnet 'up to' 76Mbit/s 186; Virgin 'up to' 100Mbit/s 90; Virgin 'up to' 120Mbit/s 83)
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) Data for fibre and cable services are not weighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 18   Average download speeds for ADSL2+ ISP packages, 24 hours: May 2013

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

Figure 19   Average download speeds for 'up to' 30Mbit/s and above ISP packages, 24 hours: May 2013

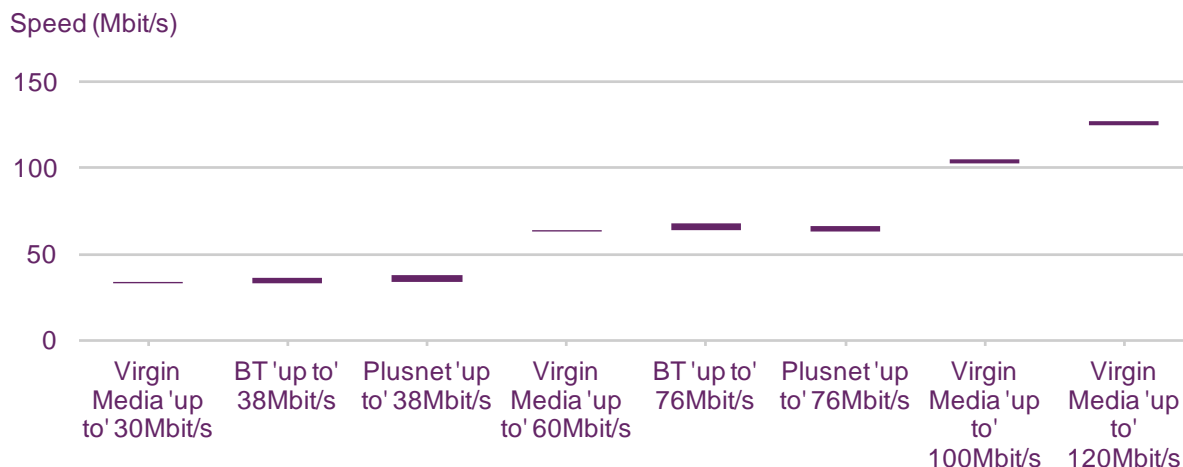*Source: SamKnows measurement data for all panel members with a connection in May 2013*
Panel size: Virgin 'up to' 30Mbit/s 90; BT 'up to' 38Mbit/s 65; Plusnet 'up to' 38Mbit/s 52; Virgin 'up to' 60Mbit/s 134; BT 'up to' 76Mbit/s 203; Plusnet 'up to' 76Mbit/s 186; Virgin 'up to' 100Mbit/s 90; Virgin 'up to' 120Mbit/s 83)
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 fibre and cable services are not weighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.
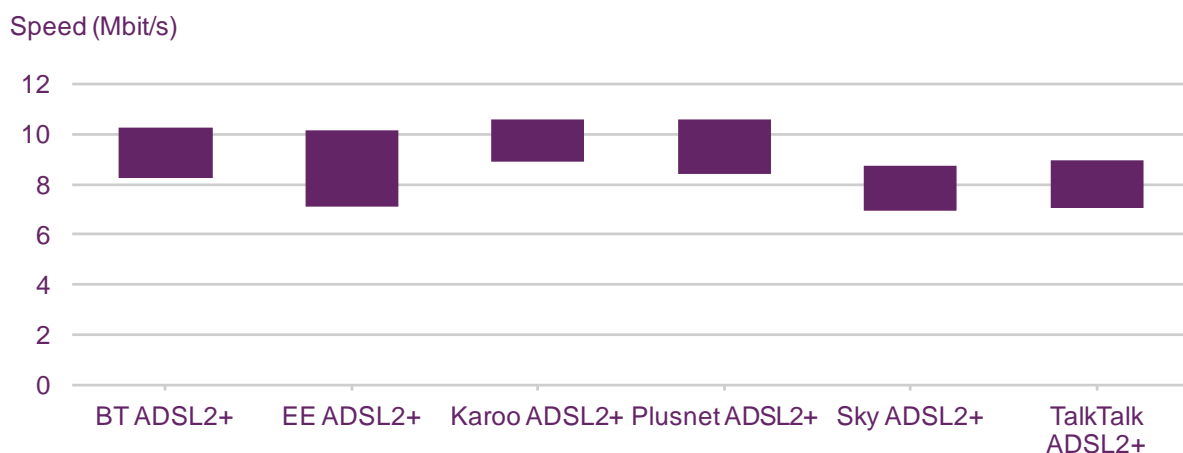
Figure 20   Average download speeds for ADSL2+ ISP packages, 8pm to 10pm weekdays: May 2013

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted for distance from exchange; data for Virgin Media's cable service are not weighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.
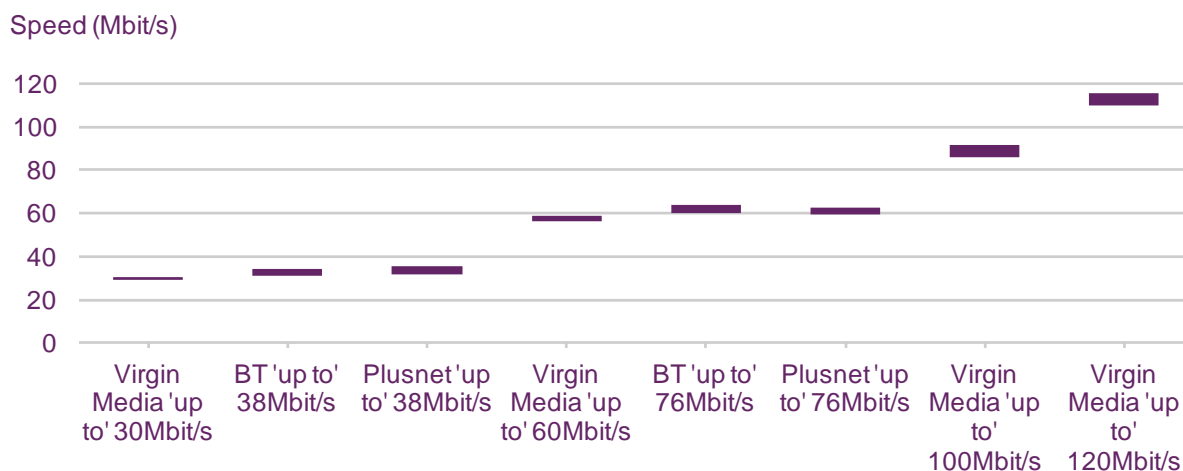
Figure 21   Average download speeds for 'up to' 30Mbit/s and above ISP packages, 8pm to 10pm weekdays: May 2013

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: Virgin 'up to' 30Mbit/s 90; BT 'up to' 38Mbit/s 65; Plusnet 'up to' 38Mbit/s 52; Virgin 'up to' 60Mbit/s 134; BT 'up to' 76Mbit/s 203; Plusnet 'up to' 76Mbit/s 186; Virgin 'up to' 100Mbit/s 90; Virgin 'up to' 120Mbit/s 83)
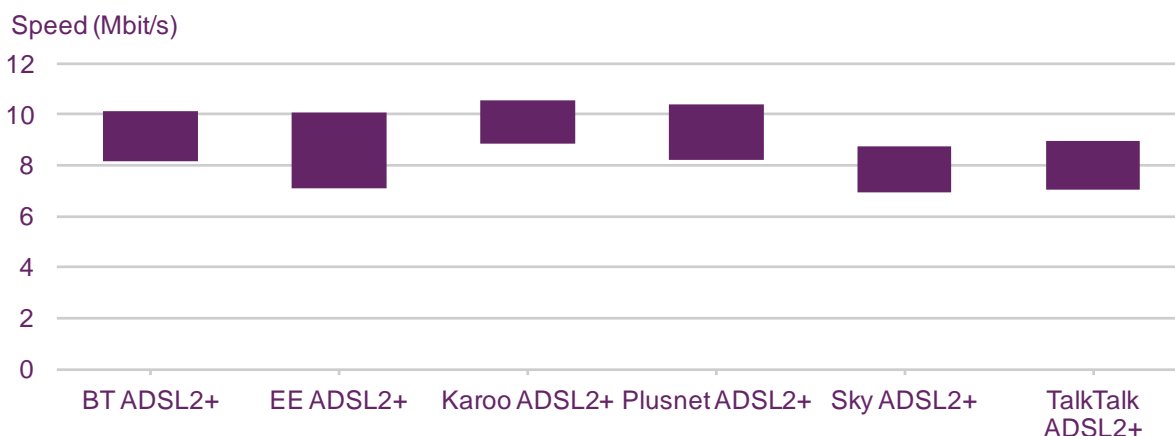*Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for fibre and cable services is not weighted; (4) Data collected from multi-thread download speed tests; (5)The range shown represents a 95% confidence interval around the mean.*

Peak download speeds as a proportion of maximum line speeds

Figure 22   Peak-time (8pm to 10pm weekdays) speeds as a proportion of maximum speeds for ADSL2+ ISP packages: May 2013
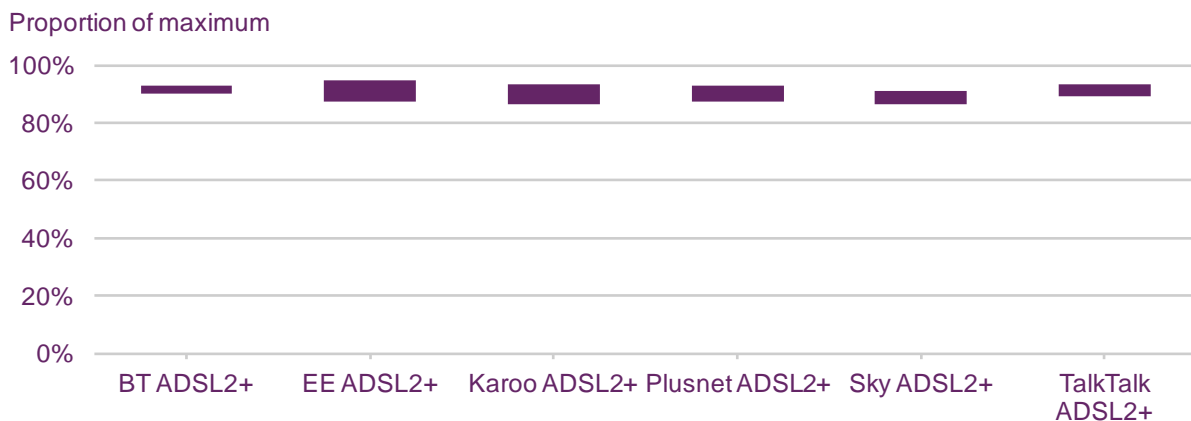
Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted for distance from exchange; data for Virgin Media's cable service are not weighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 23   Peak-time (8pm to 10pm weekdays) speeds as a proportion of maximum speeds for 'up to' 30Mbit/s and above ISP packages: May 2013
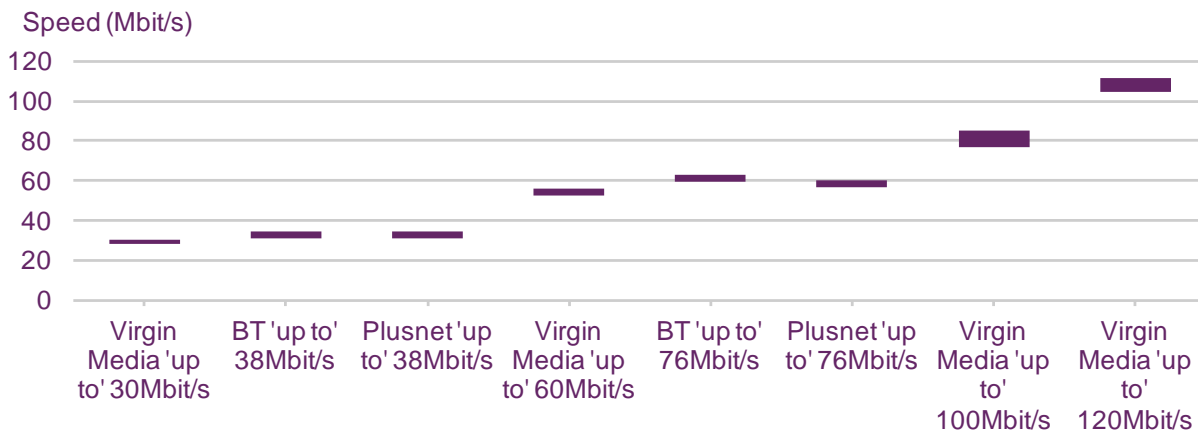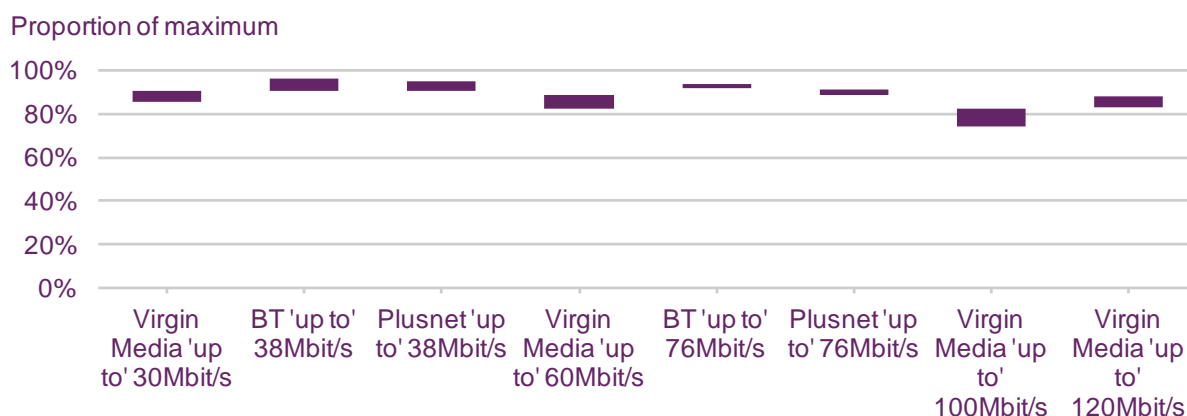

Source: SamKnows measurement data for all panel members with a connection in May 2013
Panel size: Virgin 'up to' 30Mbit/s 90; BT 'up to' 38Mbit/s 65; Plusnet 'up to' 38Mbit/s 52; Virgin 'up to' 60Mbit/s 134; BT 'up to' 76Mbit/s 203; Plusnet 'up to' 76Mbit/s 186; Virgin 'up to' 100Mbit/s 90; Virgin 'up to' 120Mbit/s 83)
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 fibre and cable services is not weighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Annex 2

Technical and research methodologies

Technical methodologies

This report is Ofcom's ninth fixed-line residential broadband speeds report and the seventh 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; apart from a single script that checks for the availability of the software component at boot-up, the physical unit contains no additional software. 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. 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 52Mbit/s will transfer an increased amount during the downstream throughput test. This amount is up to 21MB or 10 seconds (whichever is reached first). 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.

Five 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.

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 2,218 panellists who had a broadband monitoring unit connected to their routers in May 2013. Figure 1 sets out Ofcom's definitions of geographic broadband markets (based on the definitions for the wholesale broadband access (WBA) market[17]). 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).

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[17] 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).

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

Figure 1   Ofcom definitions of geographic broadband markets

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

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

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

All weightings applied have been developed by market research company Saville Rossiter-Base[18] 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

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

had expert review by econometrician Professor Andrew Chesher of University College London.[19]

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[19] 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 643 million[20] 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

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[20] 525 million of these were to test connection latency/packet loss.

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

o 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[21]. 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.

o 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.

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

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.

Quotas were set by geographic market classification, LLU, ISP market and package shares, rural/urban and straight line ('as the crow flies') distance from exchange. In, addition restrictions were placed on the number of respondents per ISP allowed on any exchange.

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

The panel is currently over-representative of the higher-speed packages, with 50% 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 (1% of the total in November 2012, and a reduction from 1.1% since May 2012). In our first round of research conducted between October 2008 and April 2009[22], 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 o regarding which package they were using on the sampling.

In total 3,160 measurement units have been despatched since October 2008. Of the 1,296 which no longer provide data, 600 were phased out as not capable of reporting packages with speeds over 20Mbit/s. 2,019 of these were connected by panellists between 1st and 30th November 2012. Of these, 1,291 supplied data to the UK average, and 1,221 to the named ISP package comparisons. Of these 2,019 active respondents, approximately 1,100 (54%) were members of the original panel in 2008.

Figure 1　　　Panellist numbers

Sample set	Number
Total number of boxes dispatched	**3,650 (600 phased out)**
Total number of boxes connected	**2,218**
Excluded because of missing data, (i.e. measurements, packages, distance)	78
Excluded 'up to' 2Mbit/s	2
Other Exclusions to improve UK sample weighting (i.e. distance, market classification, region, ISP)	278
Total participants included in UK Analysis	**849**
Total participants included in ISP Package Analysis	**1,592**

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

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

because, for a small proportion of respondents, the occasional test result was far in excess of what was achievable on the line. The top 0.5% of results per respondents did not count towards the average.

The average number of measurements per respondent for the 24-hour multi-thread download speed tests in May 2013 was 228, from a theoretical maximum of 279 per respondent (i.e. if all panellists had their monitoring unit connected on 1st May and all scheduled tests were run - tests were not run when the monitoring unit detected concurrent use of the bandwidth).

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

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

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

- **National panel** (over 'up to' 2Mbit/s packages): 849 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**: 1,592 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):

  o **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

  o **Cable and fibre-to-the-cabinet (FTTC) packages** were not weighted, as speed of services is not directly related to distance from the exchange.

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

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

Figure 2   Variation of mean and variance, by distance band

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

Source: Ofcom

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

Assigning panellists to ISP and broadband package

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

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

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

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

  o 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:

  o 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.

  o 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.

  o 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.

  o 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 79%. The under-0.5s are primarily driven by the over representation (against current market shares) of both higher speed packages and shorter line lengths in the panel. The over-2s are driven by the interaction between market shortfall and distance from exchange.

Figure 3   National panel, range of weights

Range	Count	Column N%
Less than 0.5	370	17%
0.5 to 1	391	33%
1 to 1.5	208	32%
1.5 to 2	108	10%
2 to 3	20	7%

Source: Ofcom

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

Figure 4   ISP package panel, range of weights

Weights	Count	Column N %
0.5 to 1	349	21%
1 to 1.5	843	77%
1.5 to 2	36	3%

Source: Ofcom

**Figure 5   Weighting efficiency, by ISP package**

ISP package	Weighting efficiency
BT ADSL2+	89%
Karoo ADSL2+	81%
EE ADSL2+	96%
Plusnet ADSL2+	72%
Sky ADSL2+	88%
TalkTalk ADSL2+	89%
Virgin Media 'up to' 30Mbit/s	100%
BT 'up to' 38Mbit/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' 100Mbit/s	100%
Virgin Media 'up to' 120Mbit/s	100%

Source: Ofcom

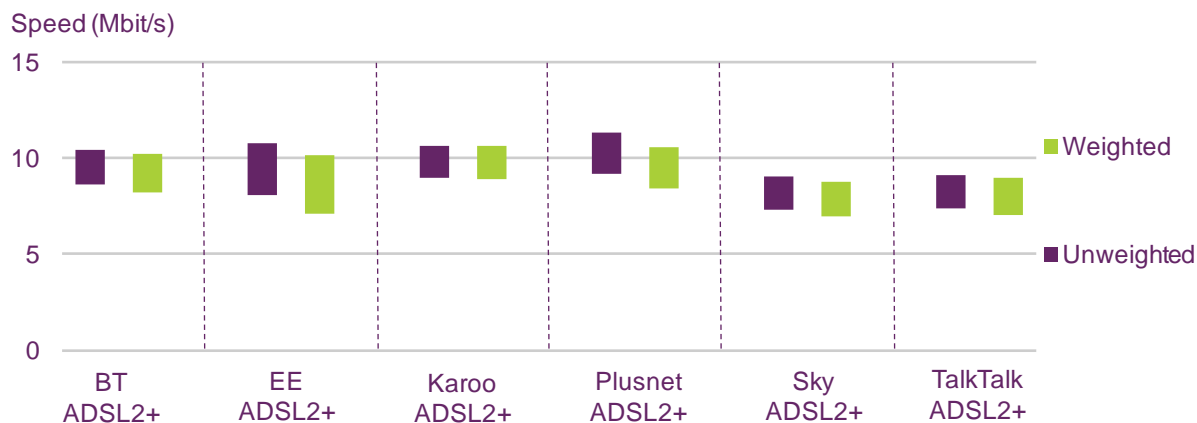**Weighted and unweighted measurement data for ADSL2+ ISP packages.**

The effect of the combined overall ISP panel weighting on ADSL2+ ISP package performance is shown in the following tables. This analysis is not relevant to FTTC and cable packages as these are not weighted.

Figure 6   Maximum download speeds for 'up ADSL2+ ISP packages, 24 hours, weighted and unweighted figures: May 2013
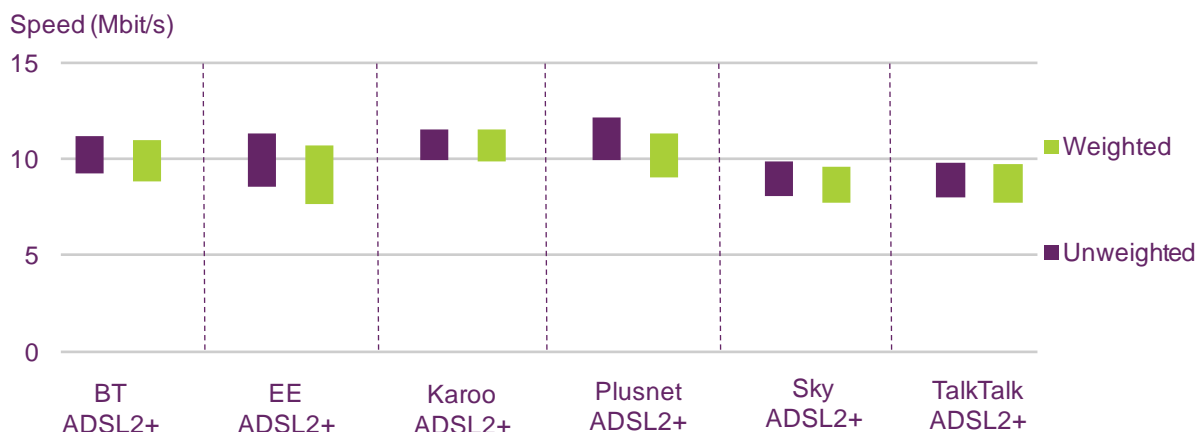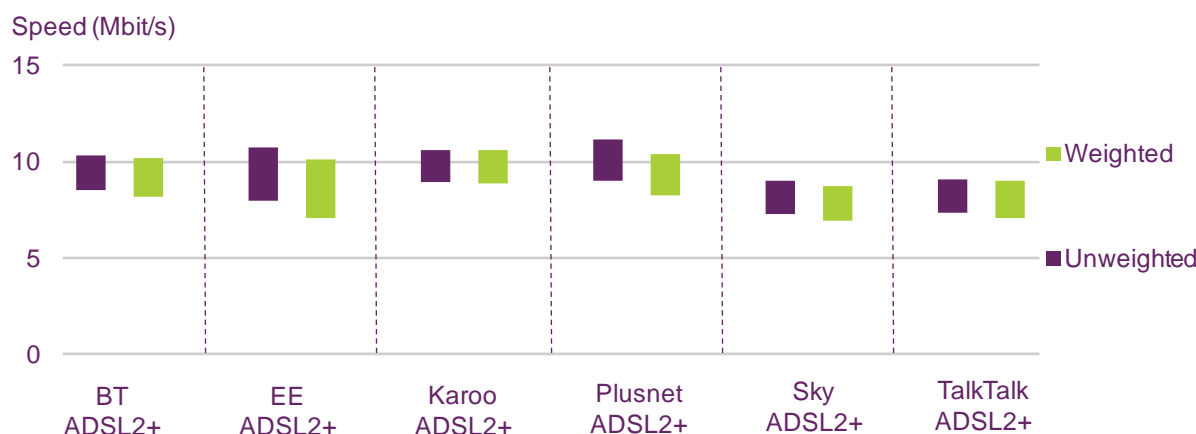

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been weighted to distance from exchange and data for Virgin Media's cable and BT fibre-to-the-cabinet is unweighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

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

Source: SamKnows measurement data for all panel members with a connection in May 2013
Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Includes only ADSL customers within 5km of the 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 weighted to distance from exchange and data for Virgin Media's cable and BT fibre-to-the-cabinet is unweighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 8   Peak-time download speeds for ADSL2+ ISP packages, weighted and unweighted figures: May 2013

Source: SamKnows measurement data for all panel members with a connection in May 2013.
Panel size: BT ADSL2+ 95, EE ADSL2+ 50, Karoo ADSL2+ 79, Plusnet ADSL2+ 89, Sky ADSL2+ 114 and TalkTalk ADSL2+ 102)
Notes: (1) Includes only ADSL customers within 5km of the 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 weighted 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 are within relates to a larger one or if it is the largest within ten miles. The seven groupings range from A (large cities such as London and Birmingham), to G (isolated rural areas such as the Western Isles and Dartmoor).

To simplify the analysis, the groupings have been banded together into three broad groups – Urban (cities and large to medium towns: population over 10k), suburban (small towns) and rural (population 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 – to avoid this biasing the data, the results from May 2012 and May 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 have 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.

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.

Headline speed The speed at which a broadband service is marketed, usually expressed as 'up to' (for example, in November 2012 all of BT's nationally available ADSL broadband services are advertised as "'up to' 16Mbit/s").

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

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

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

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

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

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

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

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

Multi-thread test: A test involving the download of two or more data files simultaneously - in the case of our research, three files (see Technical Methodology – Annex 2). Multi-thread tests typically record faster speeds than single-thread tests, in particular for higher-speed connections.

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

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

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

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

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

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