UK fixed-line broadband performance, May 2012

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

Research Report

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Contents

Section		Page
	Background	3
1	Overview of UK broadband speeds	6
2	Variations of speeds by internet service provider (ISP) package	12
3	Other metrics affecting performance	23
4	Additional analysis	40
2	Technical and research methodologies	53
3	Statistical methodology	60
4	Glossary	72

Background

Introduction

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 seventh 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. It is the final report in this research phase which covered the period from May 2010 to May 2012.[8] Given the importance of consumers having available reliable, accurate and up-to-date information on how different broadband services perform so that they can choose the broadband service that is most suitable for them, Ofcom has recently issued an invitation to tender to select a research partner in order to be able to continue the research later this year.

The present report sets out the findings from data collected during May 2012, during which 559 million test results were collected from a panel of 1,831 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 of UK fixed-line broadband speeds available.

Another measure which seeks to ensure that consumers have adequate information on broadband speeds is the Voluntary Code of Practice on Broadband Speeds (Code).[9] ISPs who have signed up to the Code have committed to provide prospective customers with certain information at point of sale, including an estimate of the maximum line speed (also called the 'access line speed') they are likely to obtain. ISPs have also agreed to explain that

[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] The reports are available on the Ofcom website at http://stakeholders.ofcom.org.uk/market-data-research/other/telecoms-research/broadband-speeds/?a=0.
[9] http://stakeholders.ofcom.org.uk/telecoms/codes-of-practice/?a=0.

customers' actual broadband speeds received in practice are likely to vary for a host of different reasons, and to provide information on how customers can improve their broadband performance.

With the cooperation and agreement of ISPs, an updated and strengthened Code came into force in July 2011. This requires ISPs to give more accurate estimates of a customer's expected speed in the form of a likely range, and ensures that, where possible, customers' speed-related problems will be resolved by their ISP. If this is not possible, customers whose speed is significantly below the estimated access line speed range will be able to leave their provider within three months of the start of their contract without penalty. All of the UK's largest ISPs are signatories to the Code.

Broadband performance is an issue for many consumers, and Ofcom research conducted in Q1 2012 suggests that 31% of internet users had suffered from problems regarding the speed of their broadband connection in the previous six months. Similarly, while the proportion of fixed broadband users who said that they were 'very' or 'fairly' satisfied with the speed of their service in Q1 2012 was relatively high at 80%, this was lower than the proportion who were 'very' or 'fairly' satisfied with their overall fixed broadband service (87%).

Using this report

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

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

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

- The '**headline speed**' or '**advertised speed**' is the speed at which broadband services are typically marketed, usually expressed as 'up to' xMbit/s (megabits per second).

- The '**average actual throughput**' speed, or '**average download**' speed represents the average speed that a consumer actually receives, which drives the speed at which web pages and files can be downloaded. Where in this report we refer to '**average actual speed**' or simply to '**average speed**', we mean the average actual throughput/download 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.

As regards advertising and headline speeds, we have observed that ISPs have changed the way they advertise their broadband services since new CAP and BCAP guidance on broadband speed claims in advertising came into force on 1 April 2012.[10] For example, Plusnet's ADSL2+ service is now advertised as being 'up to' 16Mbit/s (rather than 'up to' 20Mbit/s as it was previously) while BT's basic fibre-to-the-cabinet (FTTC) service is now

[10] Available at http://www.cap.org.uk/Media-Centre/2012/New-Telecoms-Help-Notes-get-up-to-speed.aspx.

advertised as being 'up to' 38Mbit/s (rather than 'up to' 40Mbit/s as it was previously). In fact, some ISPs no longer advertise their services on the basis of speed, instead focussing on price or added value features such as free security software. To reflect ISP's current behaviour we have therefore changed the way in which different ISP packages are identified and grouped in this report.

Since publication of the previous report in February 2012 (which was based on November 2011 data)[11], panellists included in the research have been migrating onto higher-speed packages, either by choosing to switch to a faster service or by being migrated onto one by their ISP as part of wider service upgrades. We have therefore not been able to include any ADSL1 ISP packages (previously advertised as 'up to' 8Mbit/s) in the ISP package comparisons in Sections 2 and 3 of this report (see structure of report below), i.e. we do not have a sufficient number of panellists on those packages to enable us to report robust results.

Anomalous test results recorded for some BT FTTC panellists

A number of BT FTTC panellists' measurement units recorded anomalous results during May 2012, and for 22 out of a total of 239 panellists on BT's 'up to' 38Mbit/s and 'up to' 76Mbit/s packages, download speeds fell to less than 1Mbit/s at certain times.

Having investigated the issue, BT explained that the low speeds recorded for the BT panellists affected were due to a software problem with some of its Home Hub routers, which constrained speeds over wired (but not wireless) connections, and which could be fixed by rebooting the unit, but which could subsequently reoccur. As the measurement units used for the research are connected to panellists' routers using an Ethernet cable, the speeds that we recorded were affected, and some panellists' units recorded low speeds for significant periods of time.

BT has now informed us that they have updated the Home Hub routers for those of its customers that may be affected. The main analysis in this report includes the test results from those BT panellists whose measurement units recorded anomalous results; however, we also provide figures excluding these panellists as footnotes, where relevant.

Structure of report

The report is structured as follows:

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

[11] http://stakeholders.ofcom.org.uk/binaries/research/broadband-research/Fixed_bb_speeds_Nov_2011.pdf.

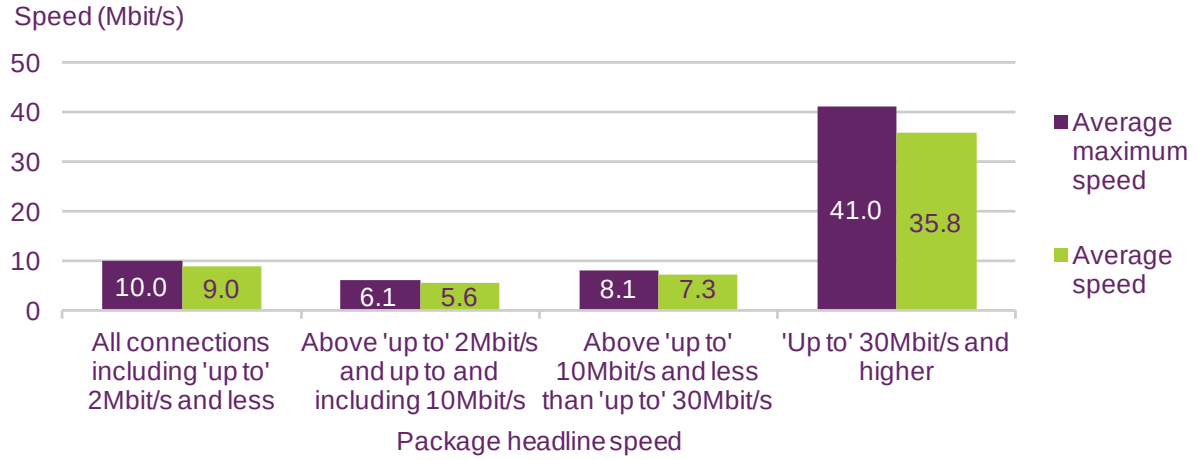
Section 1

Overview of UK broadband speeds

UK broadband speeds continue to increase as superfast take-up grows

1.1 Our research found that UK fixed-line residential broadband speeds continued to increase during the first half of 2012, and in May 2012 the average actual download speed was 9.0Mbit/s[12], a 1.4Mbit/s (19%) increase on the 7.6Mbit/s average recorded six months previously in November 2011, and 5.4Mbit/s (149%) faster than the 3.6Mbit/s average recorded in November 2008[13] (Figure 1.1).

Figure 1.1 Average UK broadband speeds: May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012
Panel Base: 1,105
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 2012; (3) Data collected from multi-thread download speed tests.

1.2 Average actual speeds recorded in May 2012 were higher than those in November 2011 for all of the connection categories shown below in Figure 1.2. For connections with a headline speed above 'up to' 2Mbit/s and up to and including 'up to' 10Mbit/s, average speeds increased from 5.3Mbit/s to 5.6Mbit/s in the six months to May 2012, while the average speed recorded for above 'up to' 10Mbit/s and less than 'up to' 30Mbit/s connections increased from 7.0Mbit/s to 7.3Mbit/s over the same period.

1.3 The average speeds recorded for superfast connections (i.e. those with an advertised speed of 'up to' 30Mbit/s or more) also increased in the six months to May

[12] The average UK residential actual broadband speed in May 2012 was 9.1Mbit/s when the data from those BT FTTC panellists whose measurement units reported anomalous results is excluded from the analysis.
[13] The average speed recorded in October/November 2008 was measured using single-thread rather than multi-thread speed tests (see the glossary of terms in Annex 4 for more details).

2012, up from 35.5Mbit/s to 35.8Mbit/s, despite the router issue encountered by a number of BT FTTC panellists, outlined on page 5 of this report.[14]

1.4 The main driver behind average actual speed increases continues to be consumers moving onto higher-speed packages, either by choosing to switch to a faster service or by being migrated onto one by their ISP as part of wider service upgrades. For example:

- BT is currently upgrading its ADSL network from ADSL1 to ADSL2+ (which is now frequently advertised as offering speeds of 'up to' 16Mbit/s) and is moving its customer base, and those connections which it provides to other ISPs on a wholesale basis, onto the faster service.

- In February 2012 Virgin Media started an 18-month programme to double the speeds of most of its broadband connections, thereby increasing the download speed of its fastest package to 'up to' 120Mbit/s.

1.5 The increase in the average speed of above 'up to' 2Mbit/s and up to and including 'up to' 10Mbit/s connections was partly because BT's upgrade from ADSL1 to ADSL2+ happened more quickly than Virgin Media's upgrade of its 'up to' 10Mbit/s customers onto its 'up to' 30Mbit/s service in the six months to May 2012. The meant that a higher proportion of these connections were Virgin Media 'up to' 10Mbit/s cable lines, which had an average speed more than twice as high as than that of an ADSL1 connection in May 2012 (at 9.6Mbit/s compared to 3.5Mbit/s), and the average speed for above 'up to' 2Mbit/s and up to and including 'up to' 10Mbit/s connections has increased accordingly.

1.6 There was a similar story among the above 'up to' 10Mbit/s and less than 'up to' 30Mbit/s category, where the rate at which consumers upgraded from ADSL2+ to higher-speed services was faster than the rate at which Virgin Media's 'up to' 20Mbit/s base was migrated onto its 'up to' 60Mbit/s service, again meaning that a higher proportion of these connections were cable. In May 2012 the average speed of an 'up to' 20Mbit/s cable connection was 18.8Mbit/s, compared to 6.7Mbit/s for an ADSL2+ connection without a headline speed or with one over 'up to' 10Mbit/s (an increase from 6.5Mbit/s in November 2011).

1.7 The average actual speed recorded for superfast connections increased by 0.3Mbit/s to 35.8Mbit/s in the six months to May 2012, despite the router issue affecting a number of BT FTTC panellists (which is outlined on page 5 of this report). This increase came after two periods during which average superfast speeds had fallen, and was a result of Virgin Media's migration of its customer base onto higher-speed packages, and the launch of 'up to' 76Mbit/s FTTC services.[15]

1.8 Prior to May 2012 the proportion of superfast services which had a headline speed of 'up to' 40Mbit/s or less had been increasing as take-up of both Virgin Media's 'up to' 30Mbit/s service and 'up to' 40Mbit/s FTTC services (now advertised as 'up to'

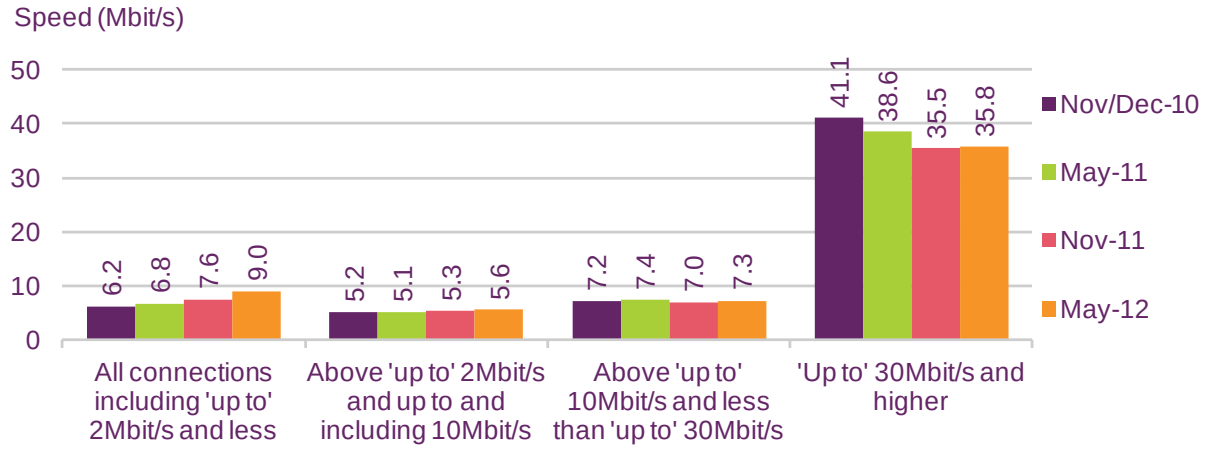
[14] The average actual speed of UK residential superfast broadband connections in May 2012 was 36.9Mbit/s when the data from those BT FTTC panellists whose measurement units reported anomalous results is excluded from the analysis.

[15] The average actual speed of residential UK superfast broadband connections in May 2012 was 36.9Mbit/s, a 1.5Mbit/s increase compared to November 2011, when the data from those BT FTTC panellists whose measurement units reported anomalous results was excluded from the analysis.

38Mbit/s) grew, and falling average superfast speeds were largely a result of this changing connection mix.

1.9 In the six months to May 2012 the proportion of superfast services with a headline speed over 40Mbit/s increased as 'up to' 76Mbit/s retail FTTC services launched and Virgin Media started to upgrade existing 'up to' 20Mbit/s and 'up to' 30Mbit/s customers onto its new 'up to' 60Mbit/s service; its 'up to' 50Mbit/s base onto 'up to' 100Mbit/s connections; and its existing 'up to' 100Mbit/s customers onto a new 'up to' 120Mbit/s service tier. It was this change in the mix of superfast services which was the key driver behind increasing average actual recorded download speeds for superfast connections over the period.

Figure 1.2 Average actual broadband speeds: November/December 2010 to May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012
Panel Base: 1,105
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 2012; (3) Data collected from multi-thread download speed tests.

Eight per cent of UK residential fixed-line broadband connections were classed as being 'superfast' in May 2012

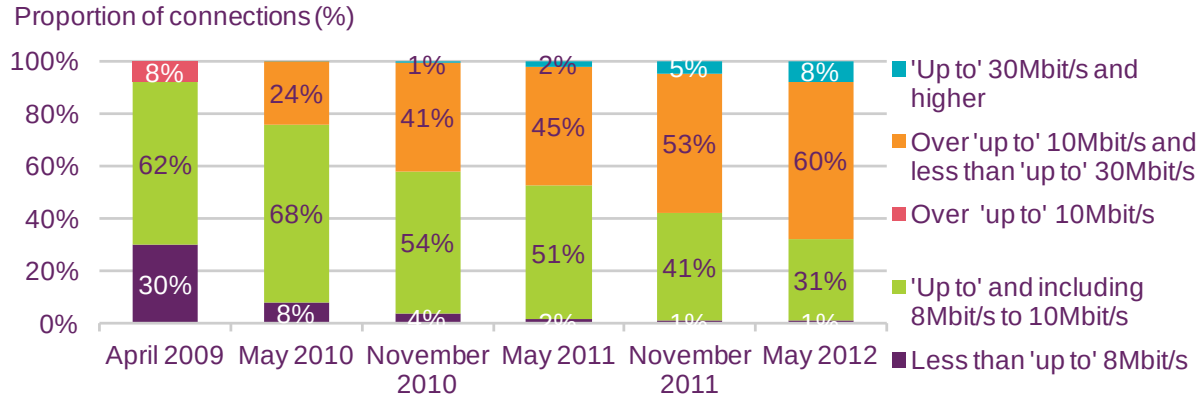
1.10 The continued migration of UK residential broadband customers onto higher-speed packages meant that over two-thirds of all UK residential connections (68%) had a headline speed above 'up to' 10Mbit/s in May 2012, a 20 percentage point increase on the 48% figure recorded a year previously (Figure 1.3).

1.11 This migration to higher-speed packages is a key driver behind increasing average actual UK broadband speeds, and in many cases these upgrades are made at little or no additional cost to the customer. While most local loop unbundling (LLU)-based ADSL services have already been upgraded to use ADSL2+, BT is in the process of upgrading its ADSL1 network, and in April 2012 raised the maximum speeds offered over its entire FTTC network to 'up to' 76Mbit/s. Additionally, Virgin Media is currently in the process of doubling the speed of most of its cable broadband connections.

1.12 The difference between the monthly rental fees for ISPs' lowest-cost 'superfast' services and their lowest-cost 'current generation' services (which have headline

speeds below 'up to' 30Mbit/s) is often relatively small, with the price differential ranging from £5 to £10 a month for most ISPs which offer both types of service. This, coupled with increasing demand for higher-speed connections as consumers use more bandwidth-hungry services and the number of connected devices per household increases, resulted in the proportion of residential fixed broadband connections that were superfast increasing from 5% to 8% in the six months to May 2012.

Figure 1.3 UK residential broadband connections, by headline speed



Source: Ofcom, based on data provided by the UK's largest ISPs by retail market share (representing over 90% of the total market)

Average cable broadband speeds increased by 26% in the six months to May 2012

1.13 In the six months to May 2012 the average speed of a UK residential cable broadband connection increased by 3.6Mbit/s (26%) to 17.9Mbit/s, largely as a result of Virgin Media's ongoing speed upgrade programme (Figure 1.4). Over the same six-month period the average speed of a residential ADSL connection also increased, up by 0.5Mbit/s (10%) to 5.9Mbit/s, partly as a result of ADSL1 customers being upgraded onto faster ADSL2+ services.

1.14 The average actual speeds recorded for FTTC panellists fell by 4.5Mbit/s (12%) to 31.6Mbit/s in the six months to May 2012,[16] although the majority of this fall (2.4Mbit/s) was due to the Home Hub router issue experienced by some of our BT FTTC panellists, which is outlined on page 5 of this report.[17]

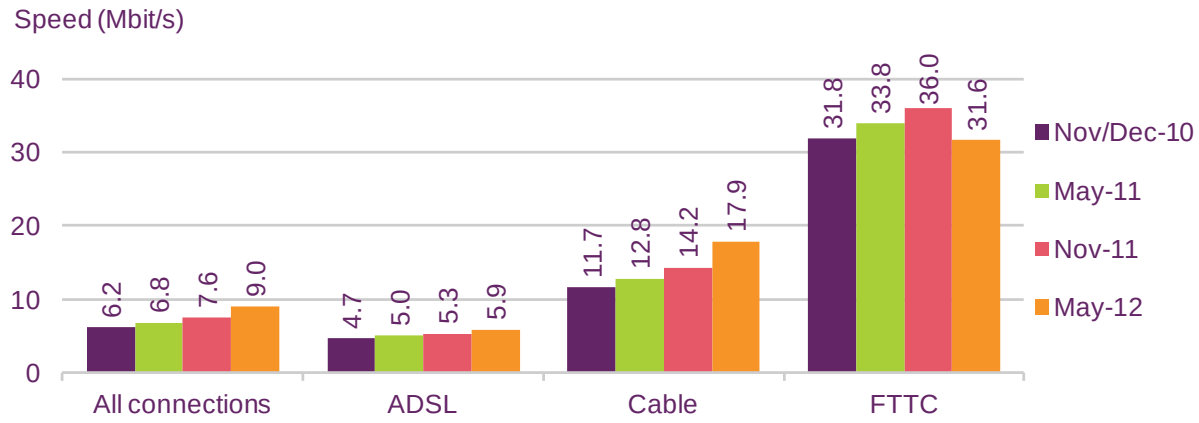
1.15 Other than the BT router issue, it is possible that one factor behind falling average FTTC speeds in the six months to May 2012 (which occurred despite the introduction of 'up to' 76Mbit/s retail services in April 2012) is the continuing rollout of FTTC services. As FTTC coverage increases it will extend to less densely-populated areas, where the average distance from the street cabinet to the exchange will tend to be greater. As is the case with ADSL services, the speed provided by the VDSL technology, which is used to transmit data from the street cabinet to the end user's

[16] This comparison should be treated with some caution as the May 2012 data is the first time that the average FTTC speed figure has included connections provided on a retail basis by ISPs other than BT.

[17] The average actual speed of residential FTTC connections in May 2012 was 34.0Mbit/s when the data from those BT panellists whose measurement units reported anomalous results is excluded from the analysis.

premises in an FTTC deployment, declines as the length of the copper cable increases, meaning that average FTTC speeds are likely to fall slightly as roll-out reaches more rural areas.

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



Source: SamKnows measurement data for all panel members with a connection in May 2012
Panel Base: 1,105
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

Average download speeds fell during peak times, but for some services more than for others

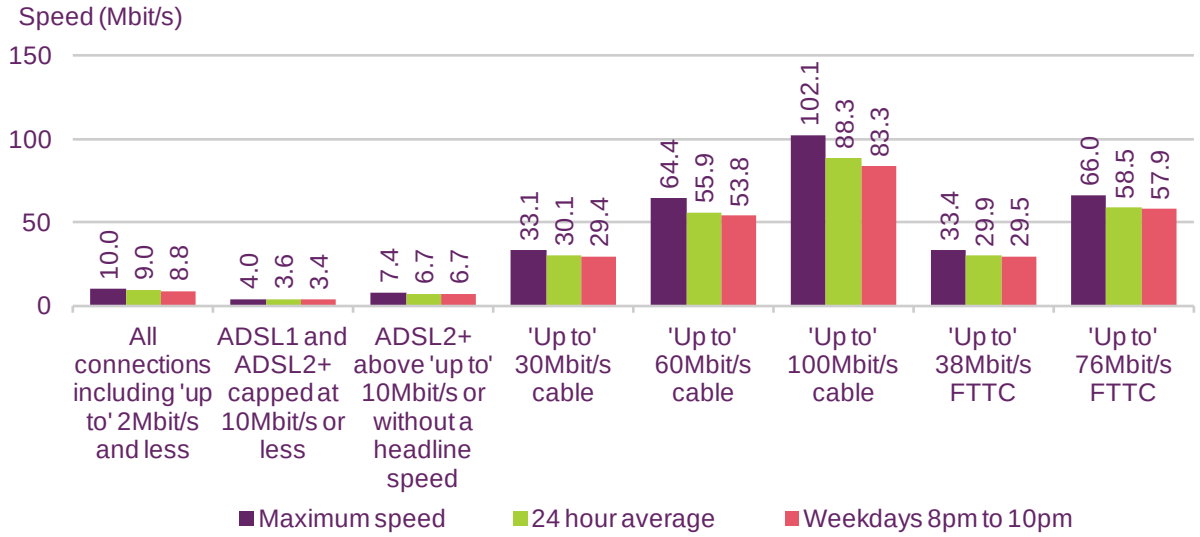
1.16 Average download speeds often fall during busy periods when a larger number of connections are being used, as a result of capacity constraints (contention) on ISPs' networks (Figure 1.5). While the average download speed recorded across a 24-hour period was 9.0Mbit/s in May 2012, it was 8.8Mbit/s during the peak weekday hours (8pm to 10pm, when speeds are usually slowest); 98% of the 24-hour average, and 87% of the 10.0Mbit/s average maximum speed delivered (typically recorded during the 'off-peak' hours of 12am to 6am).[18]

1.17 The relative performance of UK broadband connections varied by connection type during the weekday 8pm to 10pm peak period in May 2012: for 'up to' 100Mbit/s cable connections average speeds at peak times were 82% of the average maximum

[18] Excluding the results from those BT FTTC panellists whose measurement units reported anomalous results in May 2012, the average UK residential actual broadband speed recorded during the 8pm to 10pm weekday peak period was 8.9Mbit/s, 98% of the 9.1Mbit/s average over the 24-hour period and 88% of the 10.1Mbit/s average maximum speed. Similarly, excluding the results from those BT FTTC panellists whose measurement units reported anomalous results in May 2012, the respective average maximum, 24-hour and peak-time speeds for 'up to' 38Mbit/s FTTC connections were 34.2Mbit/s, 32.3Mbit/s and 32.1Mbit/s, while for 'up to' 76Mbit/s FTTC connections they were 65.4Mbit/s, 60.7Mbit/s and 60.2Mbit/s.

speeds, compared to 90% for ADSL2+ connections without a headline speed or with one above 'up to' 10Mbit/s.[19]

Figure 1.5 Variations in download speed by time of day: May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012. Panel Base: 1,105
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 2012; (3) Data collected from multi-thread download speed tests.

[19] Excluding the results from those BT FTTC panellists whose measurement units reported anomalous results in May 2012, 'up to' 38Mbit/s FTTC connections had the highest 8pm to 10pm weekday peak period average speed as a proportion of average maximum speed, at 94%.

Section 2

Variations of speeds by internet service provider (ISP) package

Background

2.1 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 2012 (listed in alphabetical order):

- BT Retail's ADSL2+ service and its 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC (*BT Infinity*) services;
- Karoo's ADSL2+ service;
- O2/Be's on-net ADSL2+ service (note that these were considered in aggregate as they are both owned by O2 and use the same network);
- Orange's ADSL2+ service;
- Plusnet's ADSL2+ service (note that although Plusnet is owned by BT, it was considered separately as parts of the network are different);
- Sky's on-net ADSL2+ service;
- TalkTalk's on-net ADSL2+ service; and
- Virgin Media's 'up to' 30Mbit/s, 'up to' 60Mbit/s and 'up to' 100Mbit/s cable services.

2.2 These ISP packages in total accounted for over half of UK residential broadband connections in May 2012; however, consumers should note that there are many other ISPs available, many of which may match or better the performance of some of the ISP packages included in the report.

2.3 Given that many panellists have been migrating onto higher-speed packages, we have not had sufficient panellists to be able to include any ADSL1 ISP packages (previously advertised as 'up to' 8Mbit/s) in the ISP package comparisons in this section.

2.4 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.

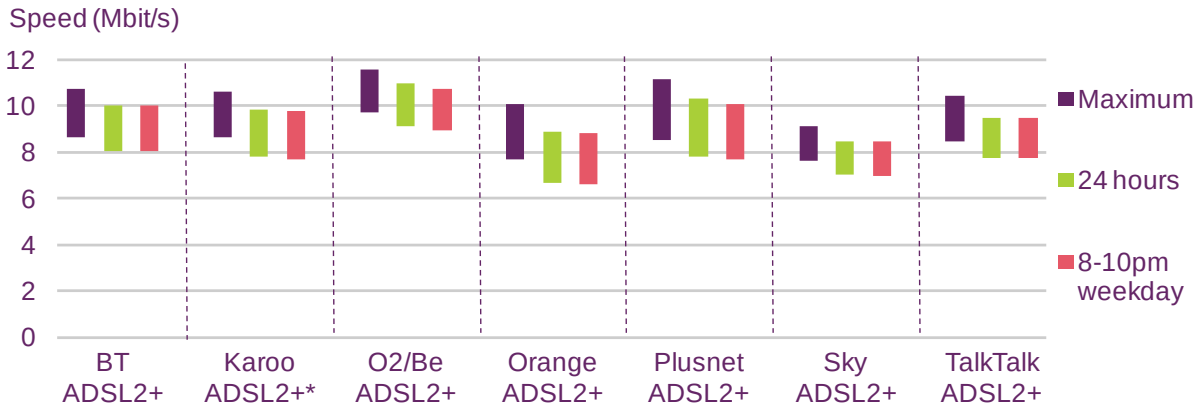
2.5 The sampling and statistical methodologies have been designed to enable us to report ISP package performance on a like-for-like basis. For example, data for ADSL panellists have been normalised for distance from the exchange, to ensure that there are no biases created by ISPs having customer bases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

ADSL2+ connections

2.6 The main variable affecting the speeds delivered by ADSL2+ services is the distance from the local exchange to the end user's premises (over which the ISP has little control), and as a result there were few differences between the average speeds delivered by the ADSL2+ ISP packages covered by our research in May 2012 (Figure 2.1). Over the 24-hour testing period, the average speeds recorded by O2/Be's ADSL2+ service (10.0Mbit/s) were faster than those of the ADSL2+ services provided by Orange (7.8Mbit/s) and Sky (7.7Mbit/s).

2.7 There was a similar pattern of results during the 8pm to 10pm weekday peak period (when speeds are, on average, slowest), when the average speed of O2/Be's ADSL2+ service (9.8Mbit/s) was faster than those provided by Orange and Sky (both (7.7Mbit/s). The average maximum speed of O2/Be's service (10.6Mbit/s) was also faster than those of Sky's ADSL2+ service (8.4Mbit/s). Among the ADSL2+ ISP packages, the proportion of 24-hour average speeds delivered during the weekday peak period ranged from 98% for O2/Be and Plusnet to 100% for BT, Sky and TalkTalk.

Figure 2.1 Maximum, average and peak-time download speeds for ADSL2+ ISP packages: May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012.
**Caution: Small sample size (<50)*
Notes: (1) Includes only customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data have been weighted to ISP regional coverage of LLU lines and distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

2.8 Figure 2.2 summarises the statistically significant differences in the download speed performance of the ADSL2+ ISP packages included in our research in May 2012.

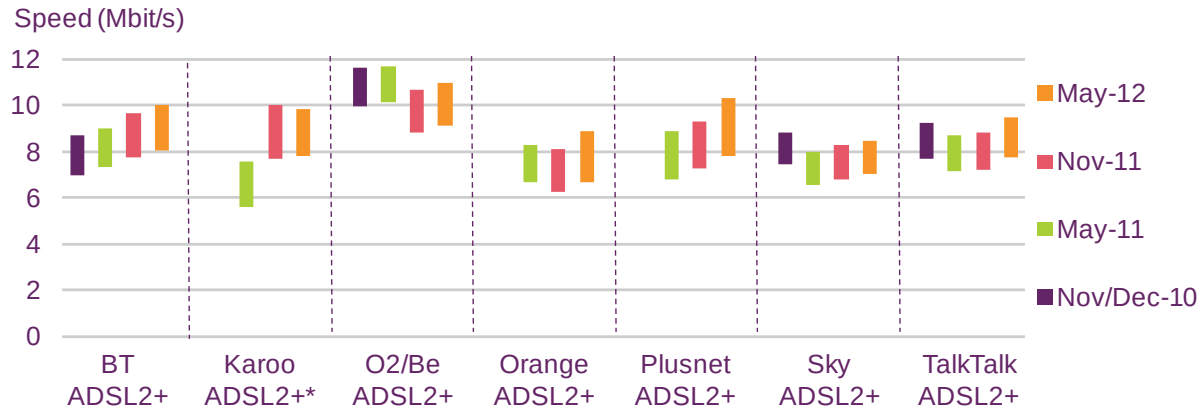
Figure 2.2 Significant differences to a 95% level of confidence between maximum, average and peak-time download speeds for ADSL2+ ISP packages: May 2012

	Maximum	24 hours	8-10pm weekday
ISP package	Is faster than...	Is faster than...	Is faster than...
O2/Be	Sky*	Orange* and Sky*	Orange* and Sky*

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

2.9 The average download speeds recorded in the previous four periods of testing for the ADSL2+ ISP packages included in this report are shown in Figure 2.3 below. This shows that there were no statistically significant changes in the performance of any of these packages between November 2011 and May 2012.

Figure 2.3 Average download speeds for ADSL2+ ISP packages: November / December 2010 to May 2012

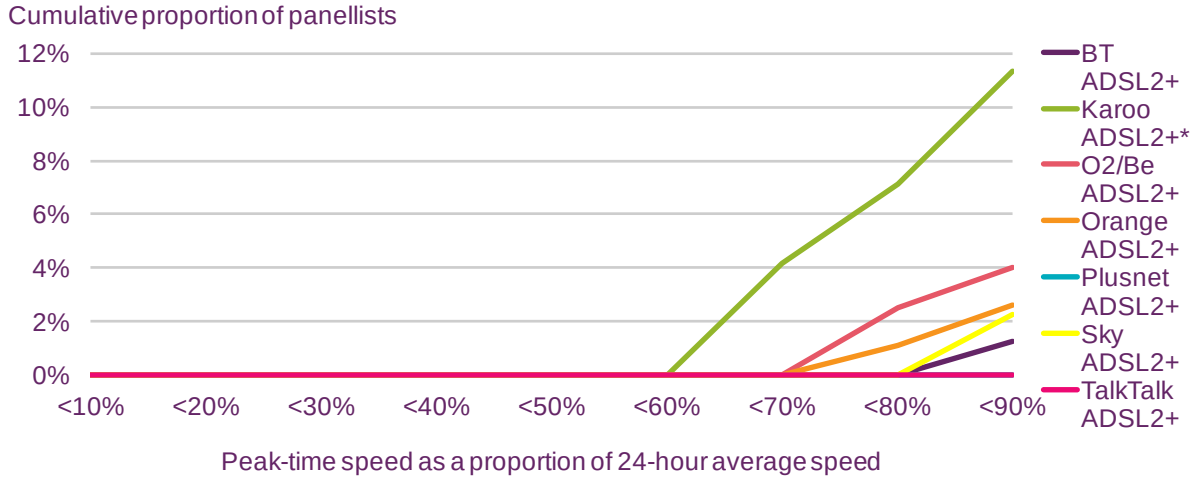


Source: SamKnows measurement data for all panel members.
**Caution: Small sample size (<50)*
Notes: (1) Only includes customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data have been weighted to ISP regional coverage of LLU lines and distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

2.10 Figure 2.4 shows analysis of our ADSL2+ panellists experiencing an average speed during the 8pm to 10pm weekday peak period as a proportion of average 24-hour speed. The intention of this analysis is to assess whether certain panellists are disproportionately affected by network contention. Higher levels of network contention are likely to limit the maximum achievable speeds more during the peak period than the off peak period. We would therefore expect to see more panellists experiencing greater drops in peak speed relative to average speed if contention was higher.

2.11 Among all of the ADSL2+ ISP packages covered by our research, fewer than 5% of panellists had average peak-time speeds which were less than 90% of their average 24-hour speed. The sole exception was Karoo's service, for which 11% of panellists received peak period speeds that were less than 90% of the 24-hour average speed. This suggests that Karoo had a higher level of contention than the other ADSL2+ ISPs included in the analysis during the testing period.

Figure 2.4 Distribution of average peak-time speed as a proportion of average 24-hour speed for ADSL2+ ISP packages: May 2012



Source: SamKnows measurement data for all panel members.
**Caution: Small sample size (<50)*
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

'Up to' 30Mbit/s and higher connections

2.12 Virgin Media's 'up to' 100Mbit/s service was faster than all of the other superfast ISP packages covered in our research, in terms of its maximum speed (102.1Mbit/s) and average download speeds recorded over the 24-hour (88.3Mbit/s) and 8pm to 10pm weekday peak periods (83.3Mbit/s) (Figure 2.5). There were no statistically significant differences between the performance of BT's 'up to' 76Mbit/s service (which had an average speed of 58.5Mbit/s over the 24-hour period) and Virgin Media's 'up to' 60Mbit/s service (which averaged 55.9Mbit/s over the 24-hour period), and both of these ISP packages were, on average, faster than BT's 'up to' 38Mbit/s service and Virgin Media's 'up to' 30Mbit/s service, in terms of maximum speeds, average 24-hour speeds and 8pm to 10pm weekday peak-time speeds.[20]

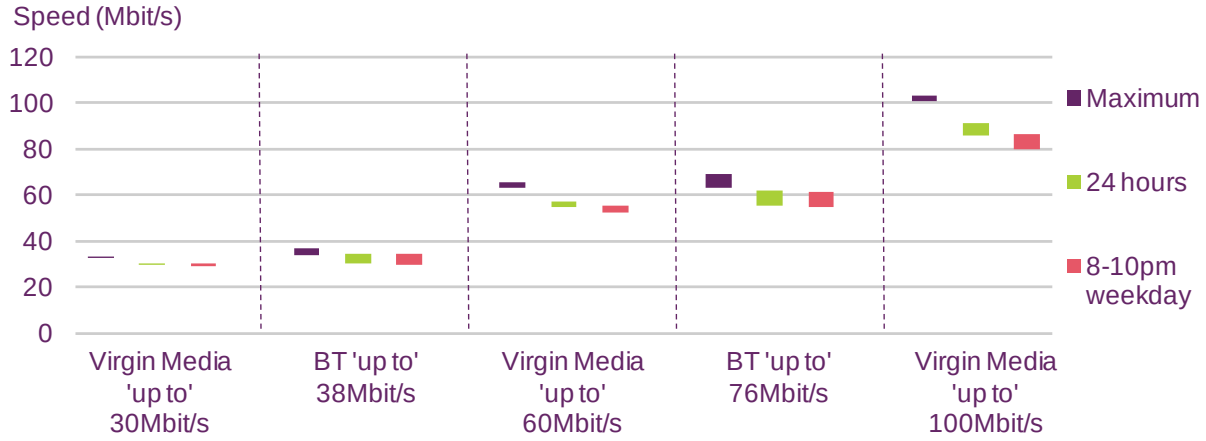
2.13 The only difference between the performance of BT's 'up to' 38Mbit/s FTTC service and Virgin Media's 'up to' 30Mbit/s service was that the former provided faster average maximum speeds, at 35.5Mbit/s compared to 33.1Mbit/s for the cable service.[21] Among the superfast packages covered, average peak-time speeds as a

[20] Excluding the results from those BT 'up to' 76Mbit/s FTTC panellists whose measurement units reported anomalous results in May 2012, over both the 24-hour and 8pm to 10pm weekday peak periods the average download speeds provided by the service (60.7Mbit/s and 60.2Mbit/s respectively) were higher than those provided by Virgin Media's 'up to' 60Mbit/s cable service (55.9Mbit/s and 53.8Mbit/s respectively).

[21] Excluding the results from those BT 'up to' 38Mbit/s FTTC panellists whose measurement units reported anomalous results in May 2012, the service provided higher average maximum, 24-hour and 8pm to 10pm weekday peak period speeds (35.9Mbit/s, 34.7Mbit/s and 34.7Mbit/s respectively) than those provided by Virgin Media's 'up to' 30Mbit/s cable service (33.1Mbit/s, 30.1Mbit/s and 29.4Mbit/s respectively).

proportion of those recorded across the 24-hour period ranged from 94% for Virgin Media's 'up to' 100Mbit/s service, to 100% for BT's 'up to' 38Mbit/s service.[22]

Figure 2.5 Maximum, average and peak-time download speeds for 'up to' 30Mbit/s and above ISP packages: May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Data for Virgin Media's cable service have been weighted to regional coverage only; (2) Data collected from multi-thread download speed tests; (3) The range shown represents a 95% confidence interval around the mean.

2.14 Figure 2.6 summarises the statistically significant differences in the download speed performance of the 'up to' 30Mbit/s and above ISP packages included in our research in May 2012.

Figure 2.6 Significant differences, to a 95% level of confidence, between maximum, average and peak-time download speeds for 'up to' 30Mbit/s and above ISP packages, May 2012

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

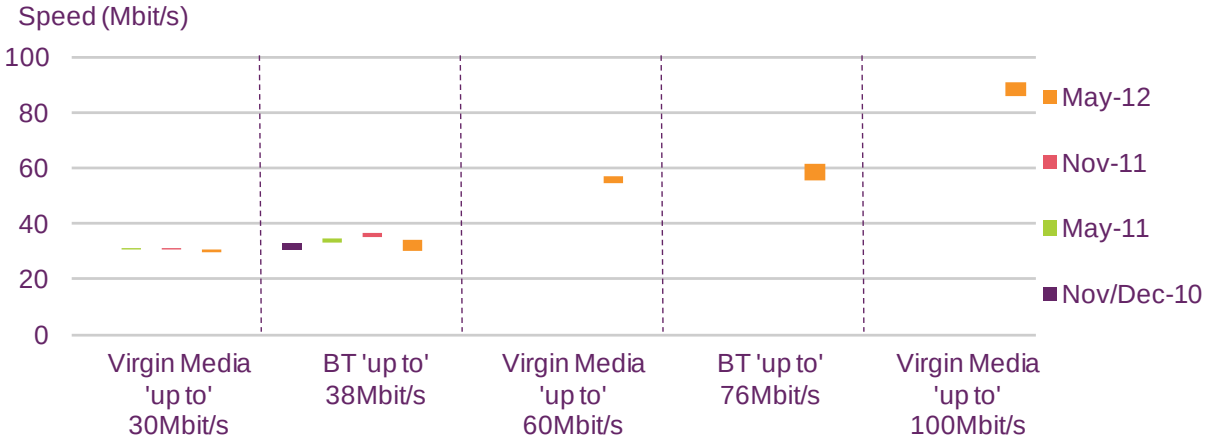
Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

2.15 Figure 2.7 shows the average download speeds recorded for the 'up to' 30Mbit/s and above ISP packages covered in this report for the four reporting periods between November/December 2010 and May 2012. This shows that the 24-hour average actual speeds recorded for BT's 'up to' 38Mbit/s FTTC service and Virgin Media's 'up

[22] Excluding the results from those BT FTTC panellists whose measurement units reported anomalous results in May 2012, average peak time speeds as a proportion of those recorded across the 24-hour period were highest for BT's 'up to' 38Mbit/s service among the superfast ISP packages included in our analysis, at 100%.

to' 30Mbit/s service both fell in the six months to May 2012, by 3.9Mbit/s to 32.2Mbit/s[23], and by 0.9Mbit/s to 30.1Mbit/s respectively.

Figure 2.7 Average download speeds for 'up to' 30Mbit/s and above ISP packages: November/December 2010 to May 2012



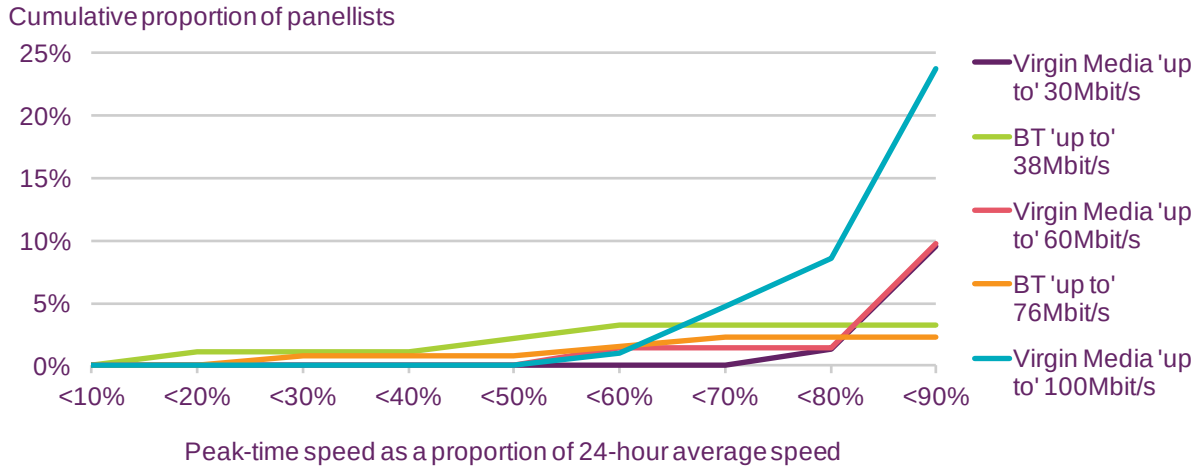
Source: SamKnows measurement data for all panel members with a connection in May 2012. Notes: (1) Data for Virgin Media's cable service have been weighted to regional coverage only; (2) Data collected from multi-thread download speed tests; (3) The range shown represents a 95% confidence interval around the mean.

2.16 The analysis of the distribution of our superfast panellists in terms of average speeds during the 8pm to 10pm weekday peak period as a proportion of average 24-hour speeds, shows that the proportion of panellists who received peak speeds of less than 90% of their average 24-hour speed was higher among the superfast cable packages than among BT's FTTC packages (Figure 2.8).

2.17 The proportion of BT FTTC panellists receiving less than 90% of their 24-hour average speed at peak times was 2% for its 'up to' 76Mbit/s service and 3% for its 'up to' 38Mbit/s service, while among the three superfast Virgin Media cable services included in the analysis it was 10% for Virgin Media's 'up to' 30Mbit/s and 'up to' 60Mbit/s services, and 24% for its 'up to' 100Mbit/s service. This suggests that while there is relatively little contention in BT's FTTC network, levels of contention are higher in Virgin Media's cable network.[24]

[23] The average actual speed of BT's 'up to' 38Mbit/s FTTC service was 34.7Mbit/s in May 2012 when the data from those panellists whose measurement units reported anomalous results is excluded from the analysis. This was statistically significantly lower than the 36.0Mbit/s recorded in November 2011.
[24] Excluding the results from those BT FTTC panellists whose measurement units reported anomalous results in May 2012, the proportion of panellists receiving less than 90% of their 24-hour average speed at peak times was lowest for BT's 'up to' 38Mbit/s and 'up to' 76Mbit/s FTTC services, at 0% for both.

Figure 2.8 Distribution of average peak-time speed as a proportion of average 24-hour speed for 'up to' 30Mbit/s and above ISP packages: May 2012



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

Summary of average download speeds of all ISP packages

2.18 Figure 2.9 summarises the average maximum, 24-hour and weekday peak period download speeds achieved by all of the ISP packages included in our research in May 2012. 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 to a 95% level of confidence that that the average speed of these packages falls somewhere in the stated range.

Figure 2.9 Summary of average download speed by ISP package: May 2012[25]

	Average download speed during period		
	Maximum	24 hours	8-10pm weekdays
BT ADSL2+	8.6Mbit/s to 10.7Mbit/s	8.1Mbit/s to 10.0Mbit/s	8.0Mbit/s to 10.0Mbit/s
Karoo ADSL2+*	8.6Mbit/s to 10.6Mbit/s	7.8Mbit/s to 9.9Mbit/s	7.7Mbit/s to 9.8Mbit/s
O2/Be ADSL2+	9.7Mbit/s to 11.6Mbit/s	9.1Mbit/s to 10.9Mbit/s	8.9Mbit/s to 10.7Mbit/s
Orange ADSL2+	7.7Mbit/s to 10.1Mbit/s	6.7Mbit/s to 8.9Mbit/s	6.6Mbit/s to 8.8Mbit/s
Plusnet ADSL2+	8.5Mbit/s to 11.2Mbit/s	7.8Mbit/s to 10.3Mbit/s	7.7Mbit/s to 10.1Mbit/s
Sky ADSL2+	7.6Mbit/s to 9.1Mbit/s	7.0Mbit/s to 8.5Mbit/s	7.0Mbit/s to 8.5Mbit/s
TalkTalk ADSL2+	8.5Mbit/s to 10.4Mbit/s	7.7Mbit/s to 9.5Mbit/s	7.7Mbit/s to 9.4Mbit/s
Virgin Media 'up to' 30Mbit/s	32.7Mbit/s to 33.4Mbit/s	29.7Mbit/s to 30.5Mbit/s	28.8Mbit/s to 30.0Mbit/s
BT 'up to' 38Mbit/s	34.0Mbit/s to 37.0Mbit/s	30.0Mbit/s to 34.3Mbit/s	29.8Mbit/s to 34.3Mbit/s
Virgin Media 'up to' 60Mbit/s	63.2Mbit/s to 65.5Mbit/s	54.7Mbit/s to 57.0Mbit/s	52.3Mbit/s to 55.2Mbit/s
BT 'up to' 76Mbit/s	63.1Mbit/s to 68.8Mbit/s	55.3Mbit/s to 61.7Mbit/s	54.7Mbit/s to 61.1Mbit/s
Virgin Media 'up to' 100Mbit/s	101.0Mbit/s to 103.2Mbit/s	85.7Mbit/s to 90.9Mbit/s	80.1Mbit/s to 86.6Mbit/s

Source: SamKnows measurement data for all panel members with a connection in May 2012.
**Caution: Small sample size (<50)*
Panel Base:1,357
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Upload speeds

2.19 Broadband connections work both ways, and have an upstream as well as a downstream direction. While broadband advertising tends to focus on download speeds (which are important for most consumer applications), upload speeds matter to those looking to share large files, use real-time two-way video communications and for some online gaming. We therefore also consider upload speeds in our research.

ADSL2+ connections

2.20 Among the ADSL2+ ISP packages included in the research, O2/Be's 'up to' 20/24Mbit/s services delivered significantly faster upload speeds than the other ADSL2+ ISP packages included in this research, with an average maximum speed of

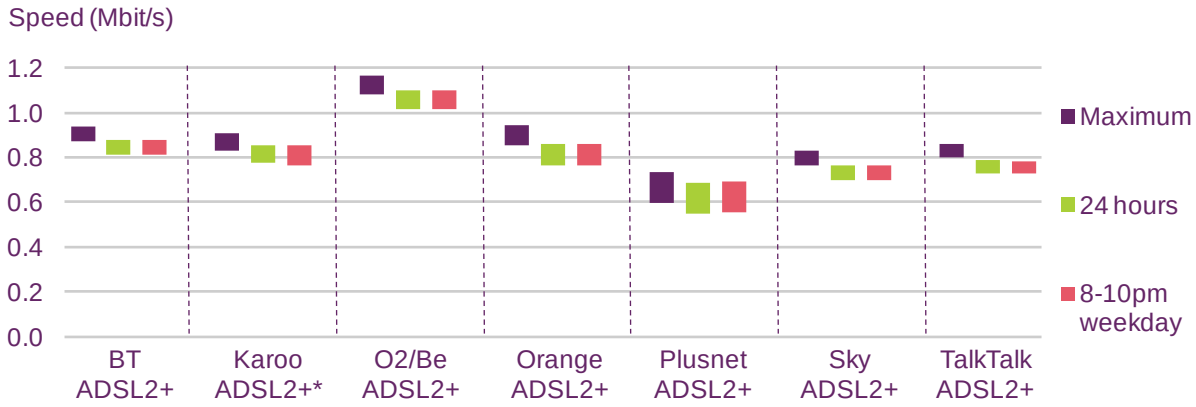
[25] Excluding the results from those BT FTTC panellists whose measurement units reported anomalous results in May 2012, the average maximum, 24-hour and weekday peak period download speeds achieved by these packages were as follows:

	Maximum	24 hours	8-10pm weekdays
BT 'up to' 38Mbit/s	34.4Mbit/s to 37.3Mbit/s	33.2Mbit/s to 36.2Mbit/s	33.2Mbit/s to 36.2Mbit/s
BT 'up to' 76Mbit/s	62.3Mbit/s to 68.5Mbit/s	57.7Mbit/s to 63.7Mbit/s	57.3Mbit/s to 63.2Mbit/s

1.1Mbit/s, the same as was recorded during the 24-hour and weekday 8pm to 10pm peak periods (Figure 2.10).

2.21 BT and Orange's ADSL2+ services (which both had average maximum upload speeds of 0.9Mbit/s and average upload speeds of 0.8Mbit/s over the 24-hour period and during the 8pm to 10pm weekday peak periods) were both faster than Plusnet, Sky and TalkTalk's ADSL2+ services, on average, across the whole day. The average upload speeds delivered by Plusnet's ADSL2+ service were lower than those of all the other ADSL2+ services over the 24-hour period, at 0.6Mbit/s.

Figure 2.10 Maximum, average and peak-time upload speeds for ADSL2+ ISP packages: May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012.
**Caution: Small sample size (<50)*
Notes: (1) Includes only customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data have been weighted to ISP regional coverage of LLU lines and distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 2.11 Significant differences to a 95% level of confidence between maximum, average and peak-time upload speeds for ADSL2+ ISP packages: May 2012

	Maximum	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**	**Is faster than...**
O2/Be	BT, Karoo*, Orange, Plusnet, Sky & TalkTalk	BT, Karoo*, Orange, Plusnet, Sky & TalkTalk	BT, Karoo*, Orange, Plusnet, Sky & TalkTalk
BT	Plusnet, Sky & TalkTalk**	Plusnet, Sky** & TalkTalk**	Plusnet, Sky & TalkTalk
Orange	Plusnet, Sky** & TalkTalk**	Plusnet, Sky** & TalkTalk**	Plusnet
Karoo*	Plusnet & Sky**	Plusnet	No differences
TalkTalk	Plusnet	Plusnet	Plusnet
Sky	Plusnet**	Plusnet**	Plusnet**

Source: Ofcom
*Notes: No other differences were statistically significant; *caution: small sample size (<50); **difference not significant to a 99% level of confidence*

'Up to' 30Mbit/s and higher connections

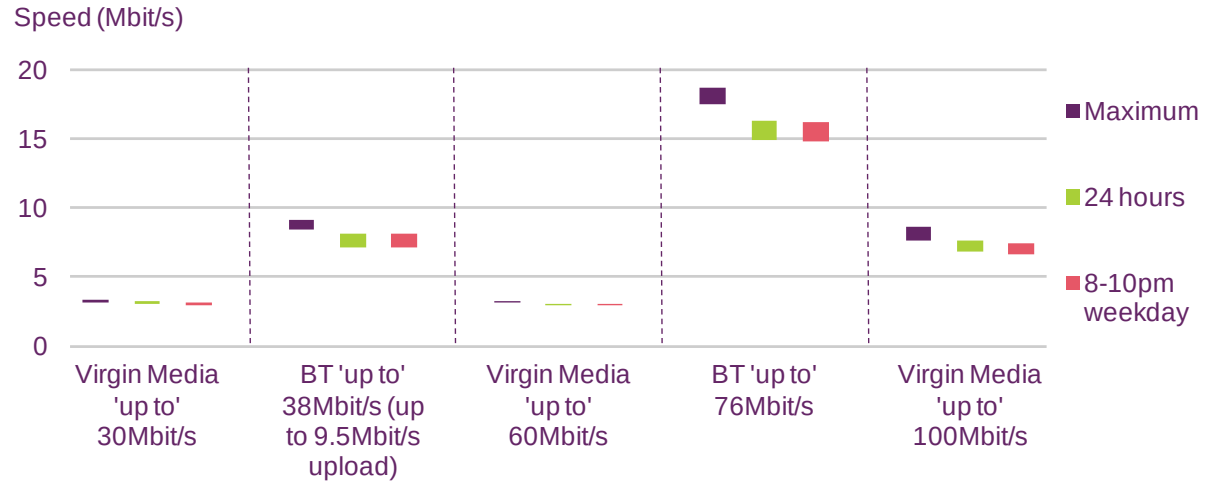
2.22 Virgin Media is currently upgrading the upstream and downstream speeds offered by its cable broadband connections, with the upload speed increase for a particular customer typically taking place a few months after the downstream speed upgrade. In our research we classify panellists' connections according to their download speed; this means that some panellists who have recently been upgraded to a higher downstream speed will not yet have had their upload speeds upgraded. As a result, although the Virgin Media upload speeds figures shown in Figure 2.12 below are representative of performance in May 2012, they do not necessarily reflect future upstream connection performance.

2.23 BT's 'up to' 76Mbit/s FTTC package, which has an advertised upload speed of 'up to' 19Mbit/s, delivered higher maximum upload speeds and average upload speeds over the 24-hour and peak periods than any other ISP package in our research, averaging 15.6Mbit/s over the 24-hour period. Virgin Media's 'up to' 100Mbit/s service and BT's 'up to' 38Mbit/s ISP packages both had higher average maximum, average 24-hour and average peak-time speeds than both Virgin Media's 'up to' 60Mbit/s and 'up to' 30Mbit/s services.

2.24 Counter-intuitively, Virgin Media's 'up to' 30Mbit/s service had higher upload speeds than its 'up to' 60Mbit/s service. As indicated above, we believe this is due to its 'up to' 30Mbit/s being an established service, whereas its 'up to' 60Mbit/s service is new, meaning that a higher proportion of 'up to' 60Mbit/s panellists will have been recently upgraded from lower-speed ('up to' 20Mbit/s and 'up to' 30Mbit/s) services, and many of these will not yet have benefited from the accompanying upstream speed upgrade.

2.25 There were no significant differences between average maximum and 8-10pm weekday peak average upload speeds among any of the 'superfast' ISP packages included in the research, indicating that contention in the network is not typically a significant constraint on upload speeds.

Figure 2.12 Maximum, average and peak-time upload speeds for 'up to' 30Mbit/s and above ISP packages; May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012).
Notes: (1) Data for Virgin Media's cable service have been weighted to regional coverage only; (2) Data collected from multi-thread download speed tests; (3) The range shown represents a 95% confidence interval around the mean.

Figure 2.13 Significant differences to a 95% level of confidence between maximum, average and peak-time upload speeds for 'up to' 30Mbit/s and above ISP packages: May 2012

	Maximum	24 hours	8-10pm weekday
ISP package	Is faster than...	Is faster than...	Is faster than...
BT 78	BT 38, Virgin Media 100, Virgin Media 60 & Virgin Media 30	BT 38, Virgin Media 100, Virgin Media 60 & Virgin Media 30	BT 38, Virgin Media 100, Virgin Media 60 & Virgin Media 30
Virgin Media 100	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
Virgin Media 30	Virgin Media 60	Virgin Media 60*	Virgin Media 60*

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

Section 3

Other metrics affecting performance

3.1 A number of other metrics influence the overall experience of using a broadband connection, and the most important of these are outlined below in Figure 3.1. As the technologies and providers which deliver the highest download speeds do not always deliver the best performance on other metrics, it is important that consumers understand the impact these have on overall performance, and choose the service that best meets their needs.

Figure 3.1 Summary of additional metrics covered in the research

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

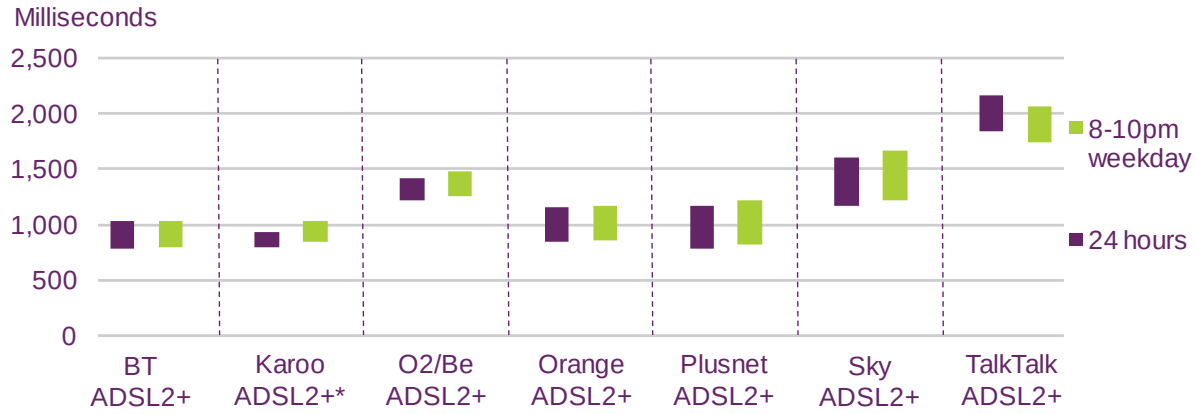
Source: Ofcom

3.2 The performance of the ISP packages included in this report against these metrics can be found in Figure 3.2 onwards).

Web browsing

3.3 In order to assess the basic web browsing performance of packages with different headline speeds, we measured the time in milliseconds to fetch the main HTML and assets (i.e. text, basic code and content files) from three test pages. Note that in Figures 3.2 and 3.4 better performance is faster loading times, which are indicated by lower bars.

Figure 3.2 Average and peak time loading of web pages for ADSL2+ ISP packages: May 2012
(Lower bars indicate better performance).



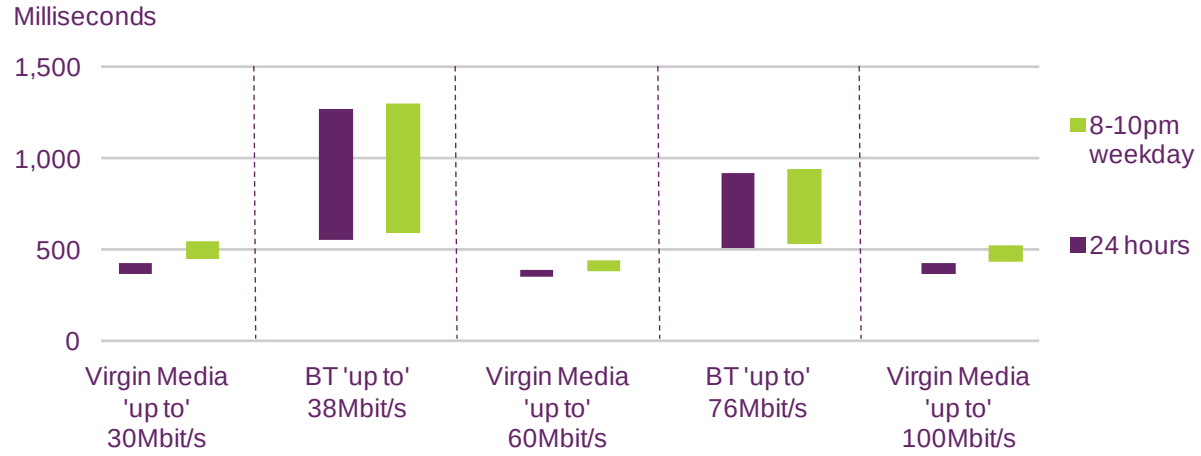
Source: SamKnows measurement data for all panel members with a connection in May 2012.
**Caution: small sample size (<50)*
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data for AOL Broadband, Orange, Plusnet and TalkTalk were excluded as the measurement values had a large variance, and their sample was insufficient (5) Data collected from multi-thread download speed tests; (6) The range shown represents a 95% confidence interval around the mean; (7) Better performance is indicated by a faster loading time, i.e. lower values.

Figure 3.3 Significant differences to a 95% level of confidence between average and peak time loading of web pages for ADSL2+ ISP packages: May 2012

	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**
Karoo*	O2/Be, Sky & TalkTalk	O2/Be, Sky & TalkTalk
BT	O2/Be, Sky** & TalkTalk	O2/Be, Sky** & TalkTalk
Orange	O2/Be & TalkTalk	O2/Be & TalkTalk
Plusnet	O2/Be & TalkTalk	O2/Be** & TalkTalk
Sky	TalkTalk	No differences

Source: Ofcom
*Notes: No other differences were statistically significant; *caution: small sample size (<50); **difference not significant to a 99% level of confidence*

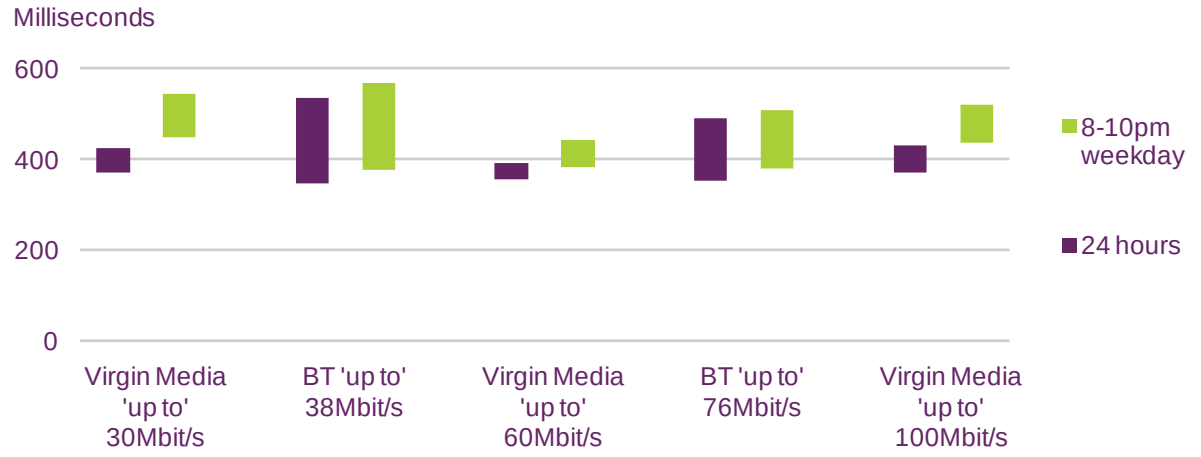
Figure 3.4 Average and peak time loading of web pages for 'up to' 30Mbit/s and above ISP packages: May 2012[26]
(Lower bars indicate better performance).



Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

[26] Average and peak time loading of web pages for 'up to' 30Mbit/s and above ISP packages were as follows in May 2012 when the data from those BT FTTC panellists whose measurement units reported anomalous results was excluded from the analysis:

Average and peak time loading of web pages for 'up to' 30Mbit/s and above ISP packages: May 2012
(Lower bars indicate better performance).



Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 3.5 Significant differences to a 95% level of confidence between average and peak time loading of web pages for 'up to' 30Mbit/s and above ISP packages: May 2012[27]

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

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

[27] 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 are as follows in May 2012 when the data from those BT FTTC panellists whose measurement units reported anomalous results was excluded from the analysis:

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 2012

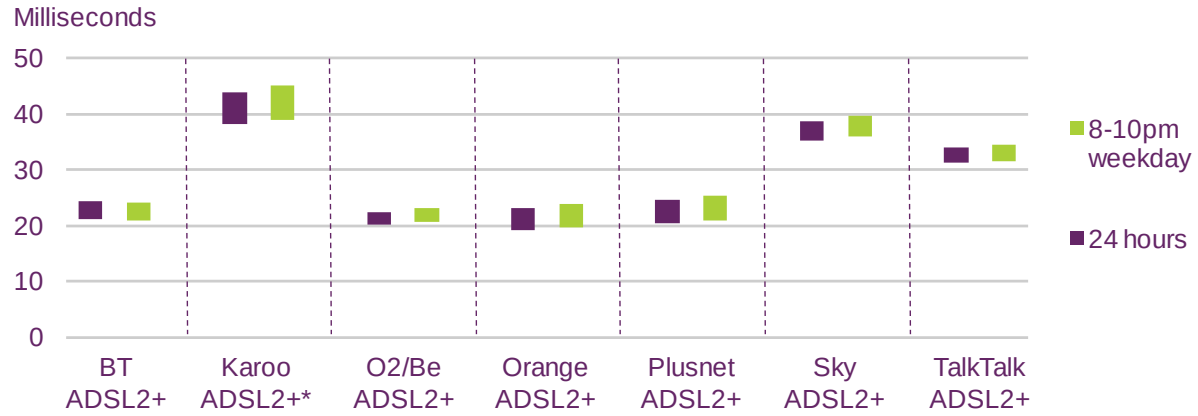
	24 hours	8-10pm weekday
ISP package	Is faster than...	Is faster than...
Virgin Media 60	No differences	Virgin Media 30

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

Latency

3.4 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 3.6 and 3.8 better performance is lower latency, which is indicated by lower bars.

Figure 3.6 Average and peak time latency for ADSL2+ ISP packages: May 2012 (Lower bars indicate better performance).



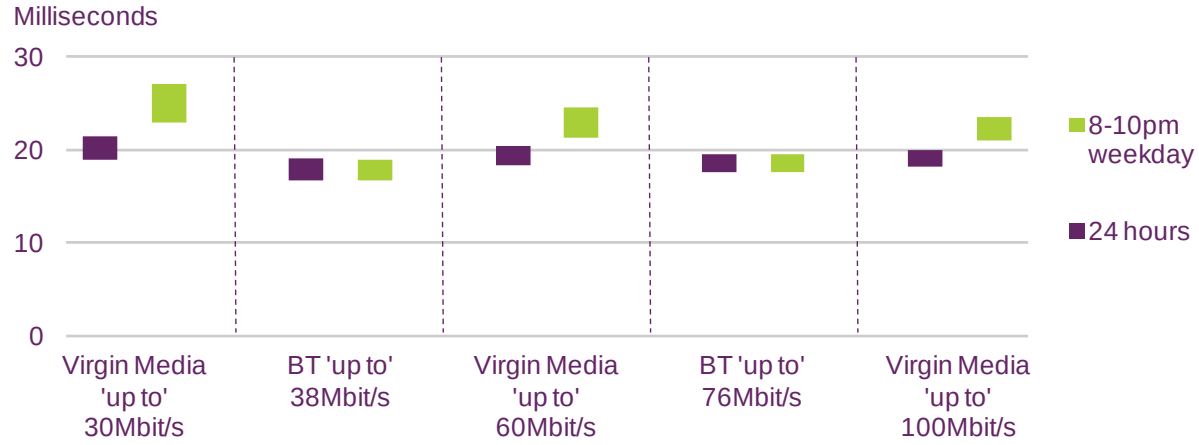
Source: SamKnows measurement data for all panel members with a connection in May 2012.
**Caution: small sample size (<50)*
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Better performance is indicated by a low speed (i.e. lower values).

Figure 3.7 Significant differences to a 95% level of confidence between average and peak time latency for ADSL2+ ISP packages: May 2012

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
BT	Karoo*, Sky & TalkTalk	Karoo, Sky & TalkTalk
O2/Be	Karoo*, Sky & TalkTalk	Karoo, Sky & TalkTalk
Orange	Karoo*, Sky & TalkTalk	Karoo, Sky & TalkTalk
Plusnet	Karoo*, Sky & TalkTalk	Karoo, Sky & TalkTalk
Karoo*	Sky** & TalkTalk	Sky** & TalkTalk

Source: Ofcom
*Notes: No other differences were statistically significant; *caution: small sample size (<50); **difference not significant to a 99% level of confidence*

Figure 3.8 Average and peak time latency for 'up to' 30Mbit/s and above ISP packages: May 2012
(Lower bars indicate better performance).



Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 3.9 Significant differences to a 95% level of confidence between average and peak time latency for 'up to' 30Mbit/s and above ISP packages: May 2012

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

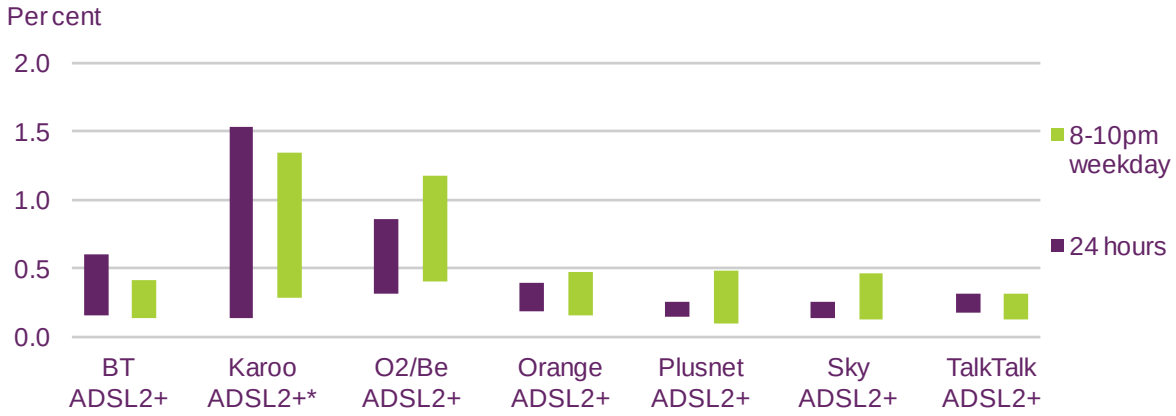
Packet loss

3.5 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 on the end-user, there may still be a temporary slow-down.

3.6 This can be a major concern for online gamers, and can also have a severe impact on voice over IP (VoIP) telephony or streaming audio or video (the odd dropped packet is generally acceptable as each packet in the test only accounts for 0.2 seconds, but extended periods of loss lead to choppy and broken-up video and audio). Note that in Figures 3.10 and 3.12 better performance is lower packet loss, which is indicated by lower bars.

Figure 3.10 Average and peak time packet loss for ADSL2+ ISP packages: May 2012

(Lower bars indicate better performance).



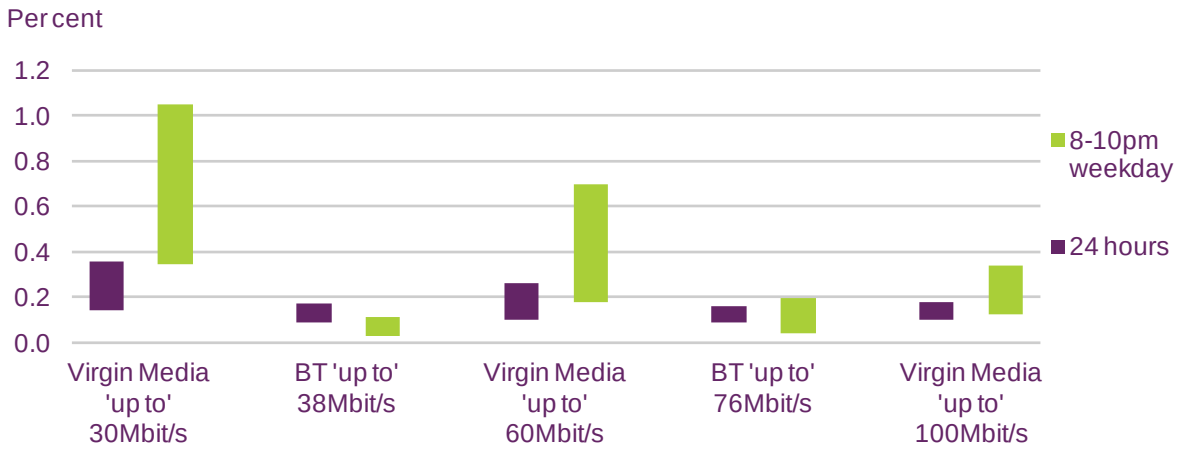
Source: SamKnows measurement data for all panel members with a connection in May 2012
**Caution: small sample size (<50).*
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Note that better performance is indicated by lower packet loss (i.e. lower values).

Figure 3.11 Significant differences to a 95% level of confidence between average and peak time packet loss for ADSL2+ ISP packages: May 2012

	24 hours	8-10pm weekday
ISP package	Is better than...	Is better than...
TalkTalk	Karoo*** & O2/Be**	Karoo*** & O2/Be**
Plusnet	Karoo*** & O2/Be**	Karoo***
Sky	Karoo*** & O2/Be**	No differences
BT	No differences	Karoo***

Source: Ofcom
*Notes: No other differences were statistically significant; *caution: small sample size (<50); **difference not significant to a 99% level of confidence*

Figure 3.12 Average and peak time packet loss for 'up to' 30Mbit/s and above ISP packages: May 2012
(Lower bars indicate better performance).



Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 3.13 Significant differences to a 95% level of confidence between average and peak time packet loss for 'up to' 30Mbit/s and above ISP packages: May 2012

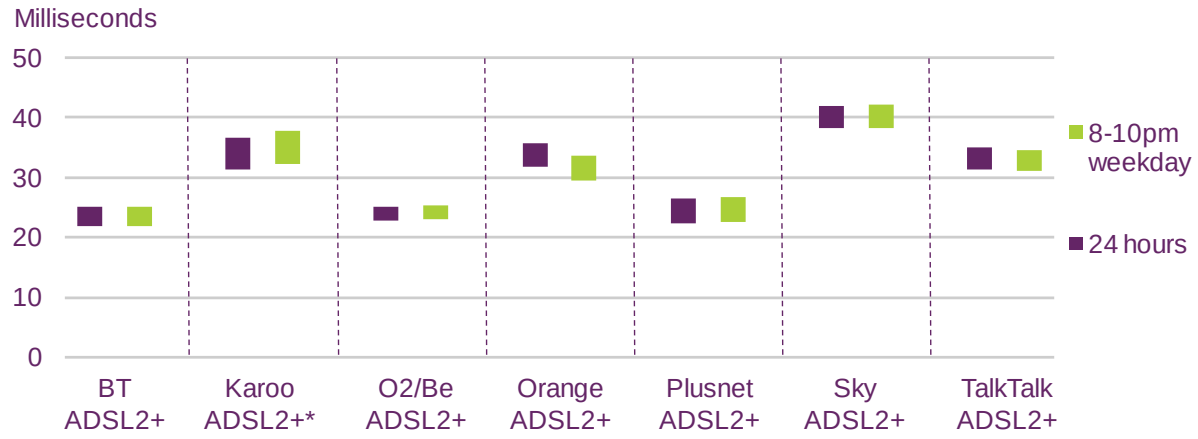
	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
BT 38	No differences	Virgin Media 100*, Virgin Media 60* & Virgin Media 30
BT 76	No differences	Virgin Media 30*

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

DNS resolution

3.7 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 3.14 and 3.16 better performance is faster resolution times, which are indicated by lower bars.

Figure 3.14 Average and peak time DNS resolution time for ADSL2+ ISP packages: May 2012
(Lower bars indicate better performance).



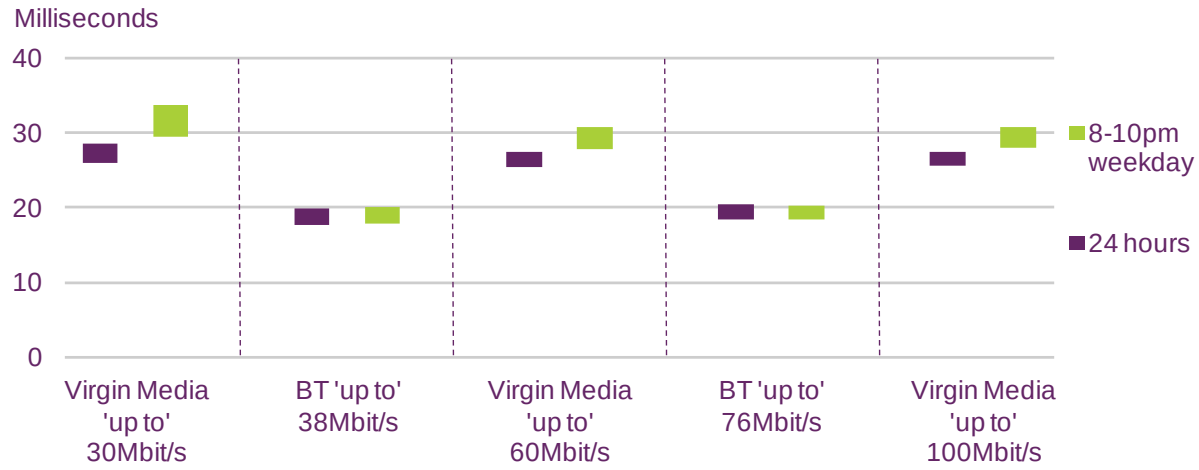
Source: SamKnows measurement data for all panel members with a connection in May 2012.
**Caution: small sample size (<50)*
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Note that better performance is indicated by faster resolution times (i.e. lower values).

Figure 3.15 Significant differences to a 95% level of confidence between average and peak time DNS resolution time for ADSL2+ ISP packages: May 2012

	24 hours	8-10pm weekday
ISP package	**Is faster than...**	**Is faster than...**
BT	Karoo*, Orange, Sky & TalkTalk	Karoo*, Orange, Sky & TalkTalk
O2/Be	Karoo*, Orange, Sky & TalkTalk	Karoo*, Orange, Sky & TalkTalk
Plusnet	Karoo*, Orange, Sky & TalkTalk	Karoo*, Orange, Sky & TalkTalk
Orange	Sky	Sky
TalkTalk	Sky	Sky
Karoo*	Sky	Sky**

Source: Ofcom
*Notes: No other differences were statistically significant; *caution: small sample size (<50); **difference not significant to a 99% level of confidence*

Figure 3.16 Average and peak-time DNS resolution time for 'up to' 30Mbit/s and above ISP packages: May 2012
(Lower bars indicate better performance).



Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 3.17 Significant differences to a 95% level of confidence between average and peak-time DNS resolution time for 'up to' 30Mbit/s and above ISP packages: May 2012

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

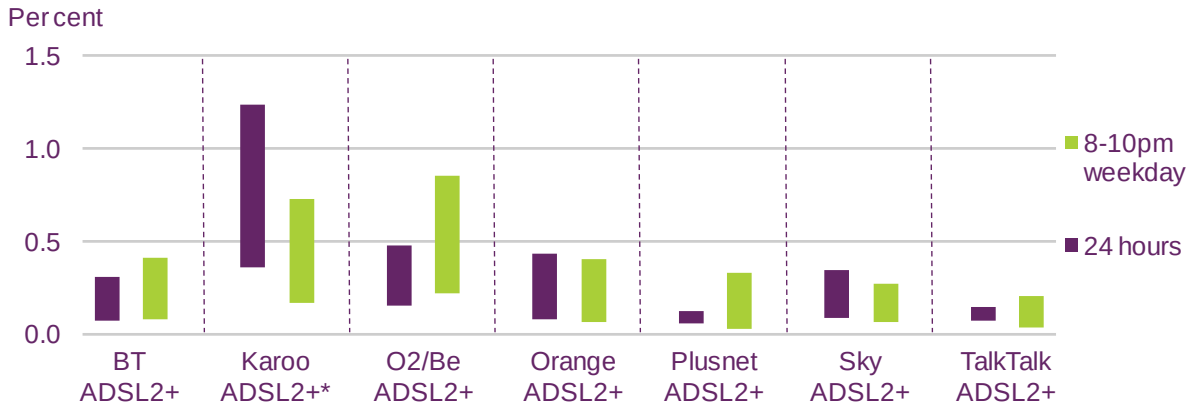
Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

DNS failure

3.8 DNS failure occurs when an ISP's DNS server is unable to translate a domain name to an IP address in a TCP/IP network. When a DNS failure occurs the user is presented with an error message such as "*This server is unavailable*" or "*Host could not be found*", and is unable to access the requested page on that occasion. Note that in Figures 3.18 and 3.20 better performance is indicated by shorter times, which are indicated by lower bars.

Figure 3.18 Average and peak-time DNS failure rates for ADSL2+ ISP packages: May 2012

(Lower bars indicate better performance).



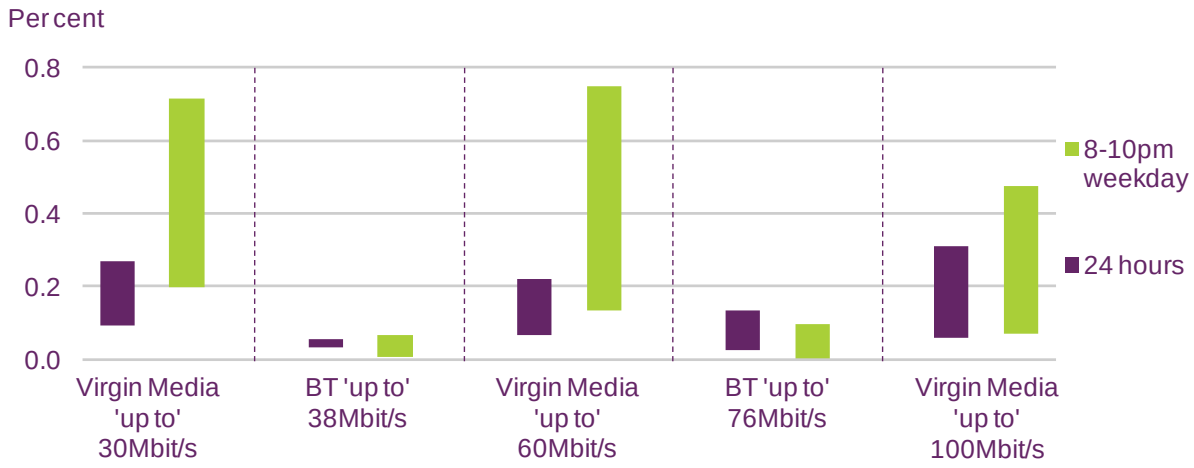
Source: SamKnows measurement data for all panel members with a connection in May 2012.
**Caution: small sample size (<50)*
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Note that better performance is indicated by faster resolution times (i.e. lower values).

Figure 3.19 Significant differences to a 95% level of confidence between average and peak-time DNS failure rates for ADSL2+ ISP packages: May 2012

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
TalkTalk	Karoo* & O2/Be**	Karoo* ** & O2/Be**
Plusnet	Karoo* & O2/Be**	No differences
BT	Karoo*	No differences
O2/Be	Karoo* **	No differences
Orange	Karoo* **	No differences
Sky	Karoo* **	No differences

Source: Ofcom
*Notes: No other differences were statistically significant; *caution: small sample size (<50); **difference not significant to a 99% level of confidence*

Figure 3.20 Average and peak-time DNS failure rates for 'up to' 30Mbit/s and above ISP packages: May 2012
(Lower bars indicate better performance).



Source: SamKnows measurement data for all panel members with a connection in May 2012
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 3.21 Significant differences to a 95% level of confidence between average and peak-time DNS failure rates for 'up to' 30Mbit/s and above ISP packages: May 2012

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

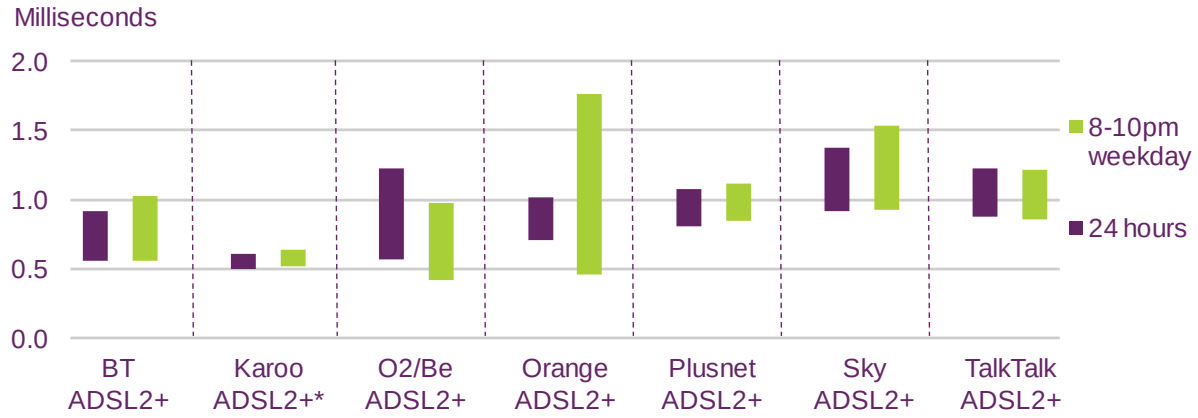
Source: Ofcom
*Notes: No other differences were statistically significant; *difference not significant to a 99% level of confidence*

Jitter

3.9 '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 20 millisecond jitter with no noticeable effect for the end user. Note that in Figures 3.22, 3.24, 3.26 and 3.28 better performance is indicated by shorter times, which are indicated by lower bars

Figure 3.22 Average and peak-time upstream jitter for ADSL2+ ISP packages: May 2012

(Lower bars indicate better performance).



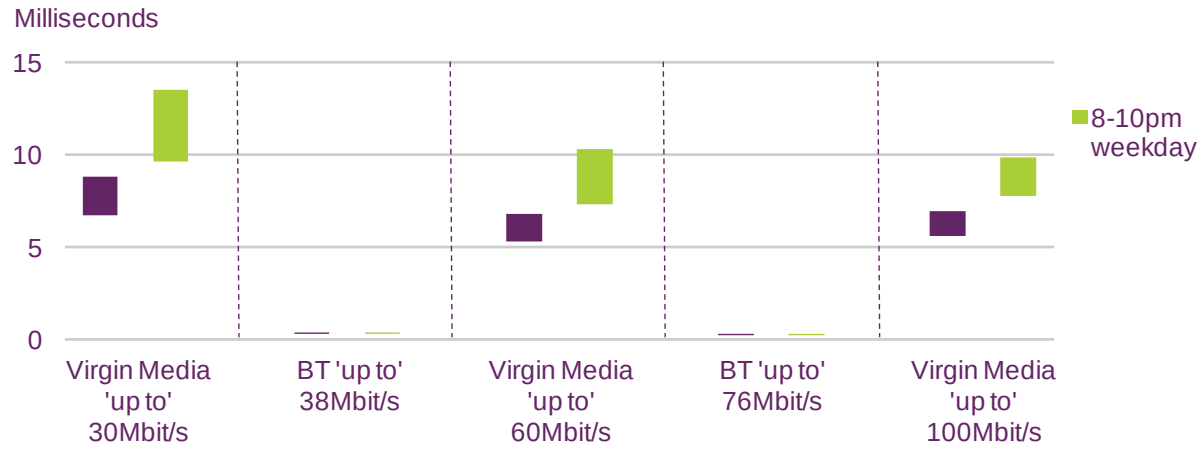
Source: SamKnows measurement data for all panel members with a connection in May 2012.
**Caution: small sample size (<50)*
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Note that better performance is indicated by shorter times (i.e. lower values).

Figure 3.23 Significant differences to a 95% level of confidence between average and peak-time upstream jitter for ADSL2+ ISP packages: May 2012

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

Source: Ofcom
*Notes: No other differences were statistically significant; *caution: small sample size (<50); **difference not significant to a 99% level of confidence*

Figure 3.24 Average and peak-time upstream jitter for 'up to' 30Mbit/s and above ISP packages: May 2012
(Lower bars indicate better performance).



Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

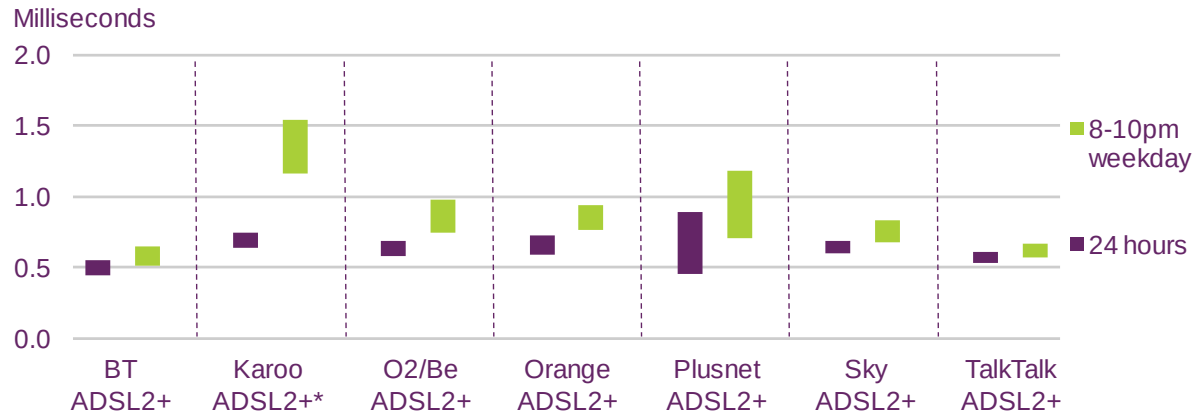
Figure 3.25 Significant differences to a 95% level of confidence between average and peak-time upstream jitter for 'up to' 30Mbit/s and above ISP packages: May 2012

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

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

Figure 3.26 Average and peak-time downstream jitter for ADSL2+ ISP packages: May 2012

(Lower bars indicate better performance).



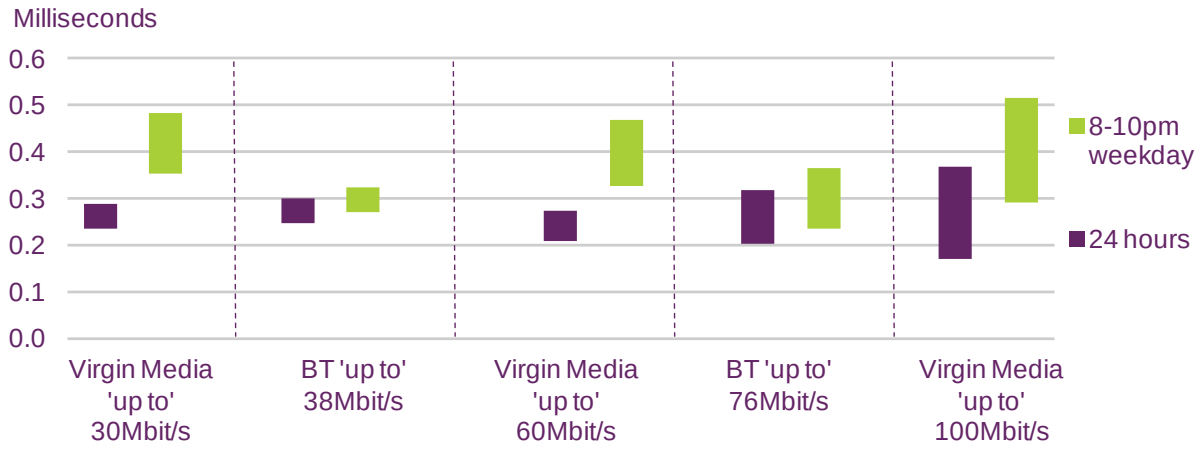
Source: SamKnows measurement data for all panel members with a connection in May 2012.
**Caution: small sample size (<50)*
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Note that better performance is indicated by shorter times (i.e. lower values).

Figure 3.27 Significant differences to a 95% level of confidence between average and peak-time downstream jitter for ADSL2+ ISP packages: May 2012

	24 hours	8-10pm weekday
ISP package	**Is better than...**	**Is better than...**
BT	*Karoo, O2/Be**, Orange & Sky**	Karoo*, O2/Be, Orange, Plusnet & Sky **
TalkTalk	Karoo*	Karoo*, O2/Be, Orange & Plusnet**
O2/Be	No differences	Karoo*
Orange	No differences	Karoo*
Plusnet	No differences	Karoo*
Sky	No differences	Karoo*

Source: Ofcom
*Notes: No other differences were statistically significant; *caution: small sample size (<50); **difference not significant to a 99% level of confidence*

Figure 3.28 Average and peak-time downstream jitter for 'up to' 30Mbit/s and above ISP packages: May 2012
(Lower bars indicate better performance).



Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 3.29 Significant differences to a 95% level of confidence between average and peak-time downstream jitter for 'up to' 30Mbit/s and above ISP packages: May 2012

	24 hours	8-10pm weekday
ISP package	Is better than...	Is better than...
BT 38	No differences	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

3.10 This report presents 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 2012. The broadband market is changing rapidly as operators invest in their networks in order to make faster broadband available (as has been seen in the last six months), and the results set out in this report will therefore not necessarily reflect the future performance of networks and providers.

3.11 Despite these anticipated changes, 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 online gaming.

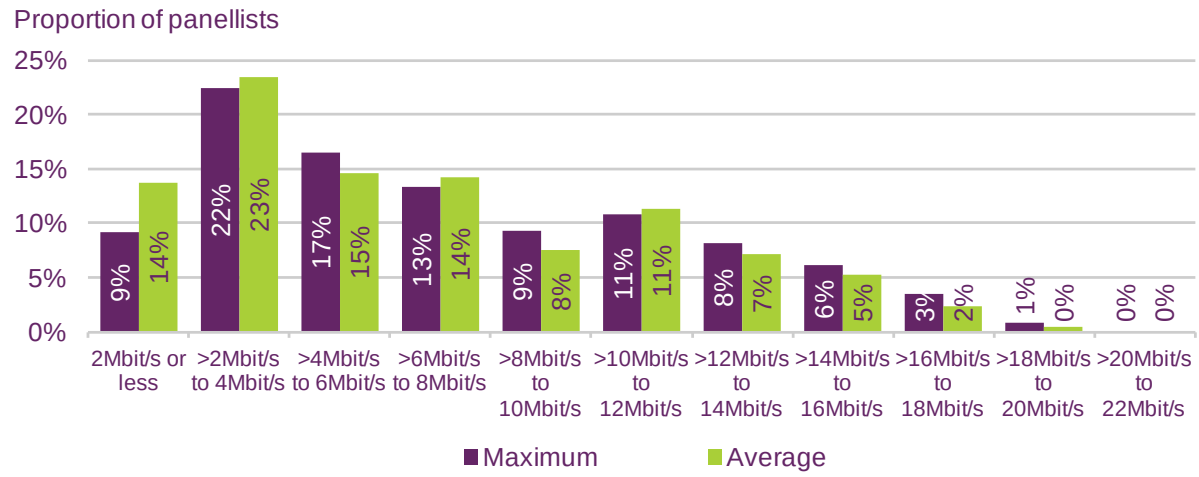
3.12 Following a tender process to be completed in the autumn, we will select a research partner to collect UK fixed-line broadband performance data for the next research phase, which will cover the period from around November 2012 to November 2014. We plan to publish the next UK fixed-line broadband performance report in early 2013, using data collected from tests run in or around November 2012.

Annex 1

Additional analysis

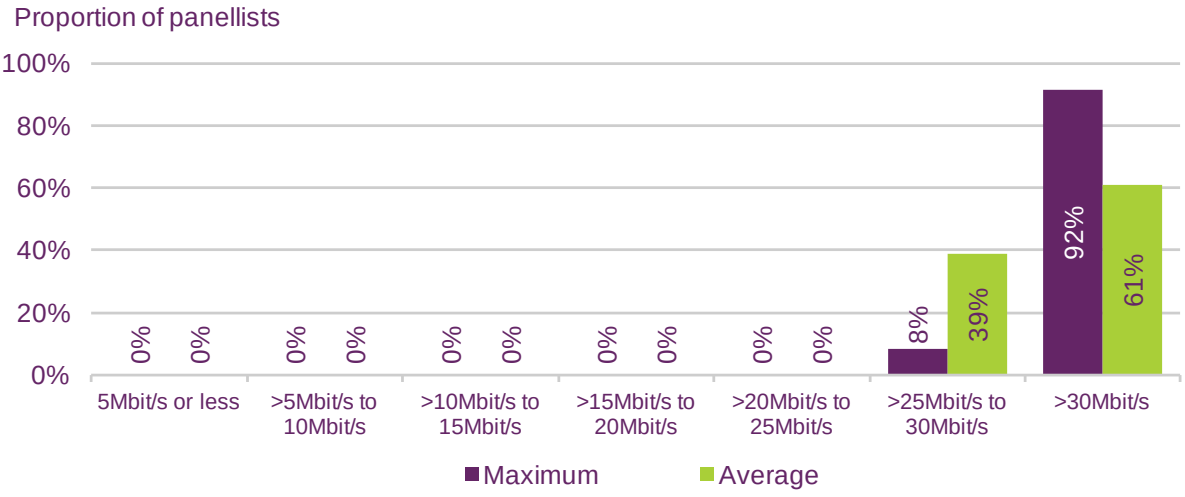
The distribution of actual broadband speeds

Figure 1 Distribution of maximum and average download speeds for consumers on ADSL2+ packages: May 2012



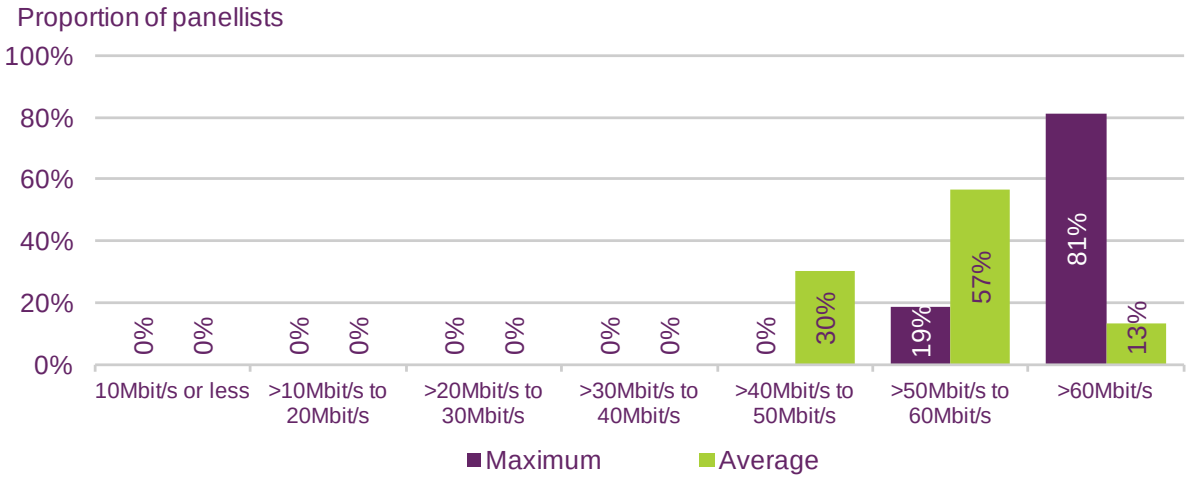
Source: SamKnows measurement data for panel members with a connection in May 2012.
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK ADSL2+ residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 2 Distribution of maximum and average download speeds for consumers on 'up to' 30Mbit/s cable packages: May 2012



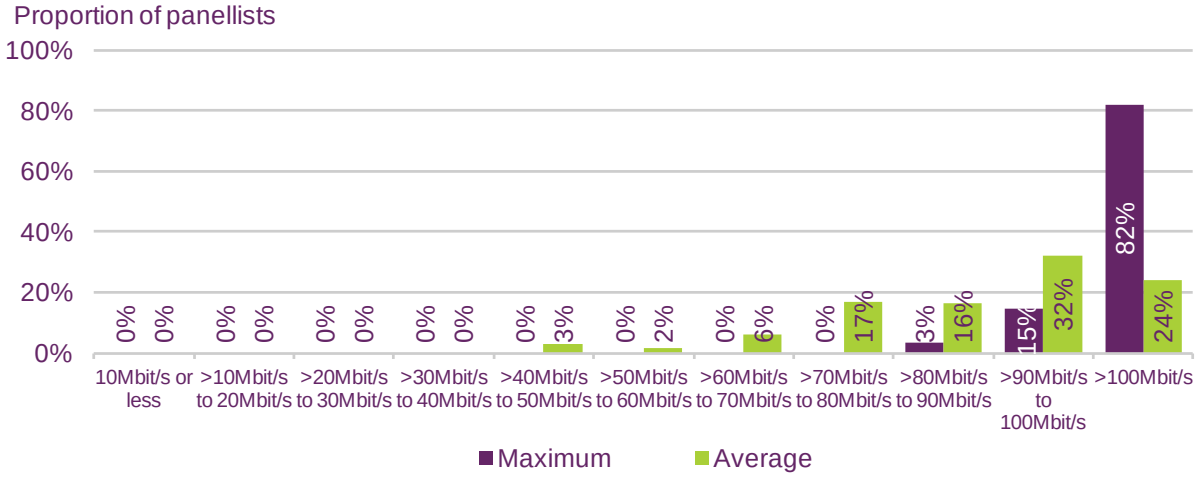
Source: SamKnows measurement data for panel members with a connection in May 2012.
Notes: (1) Data have been weighted to regional coverage to ensure that they are representative of UK cable 'up to' 30Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 3 Distribution of maximum and average download speeds for consumers on 'up to' 60Mbit/s cable packages: May 2012



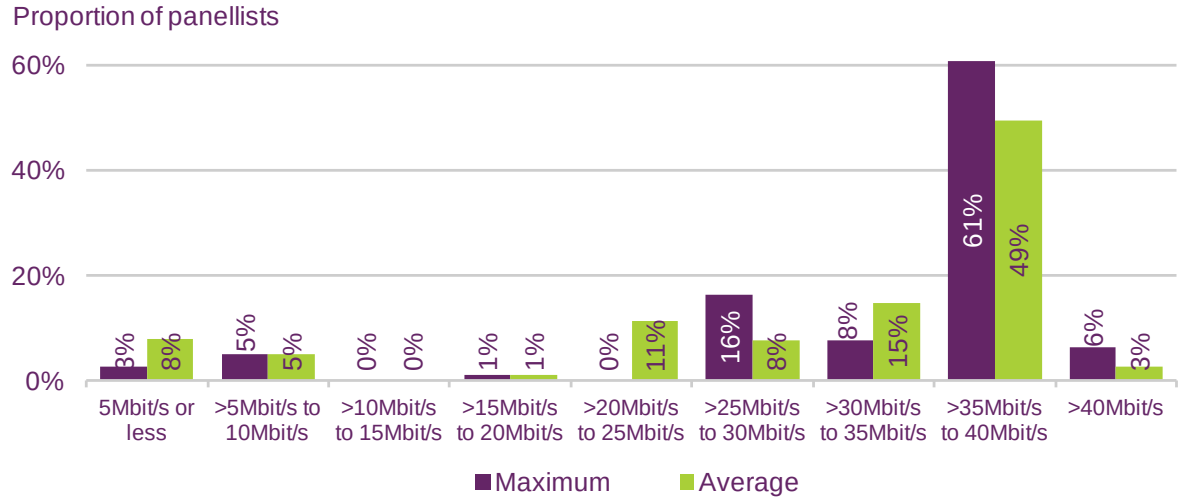
Source: SamKnows measurement data for panel members with a connection in May 2012.
Notes: (1) Data have been weighted to regional coverage to ensure that they are representative of UK cable 'up to' 60Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 4 Distribution of maximum and average download speeds for consumers on 'up to' 100Mbit/s cable packages: May 2012



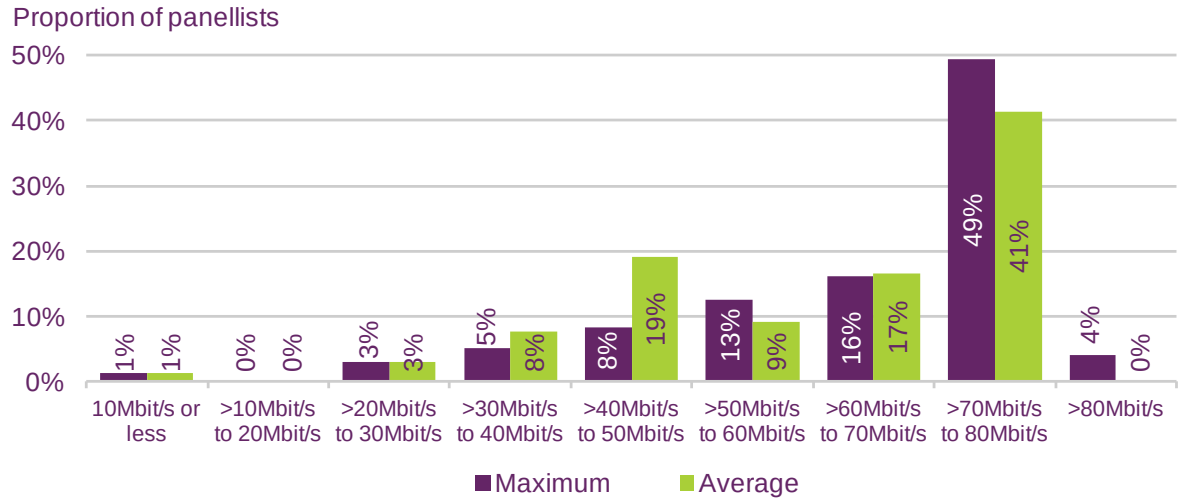
Source: SamKnows measurement data for panel members with a connection in May 2012.
Notes: (1) Data have been weighted to regional coverage to ensure that they are representative of UK cable 'up to' 100Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 5 Distribution of maximum and average download speeds for consumers on 'up to' 38Mbit/s FTTC packages: May 2012



Source: SamKnows measurement data for panel members with a connection in May 2012.
Notes: (1) Data collected from multi-thread download speed tests.

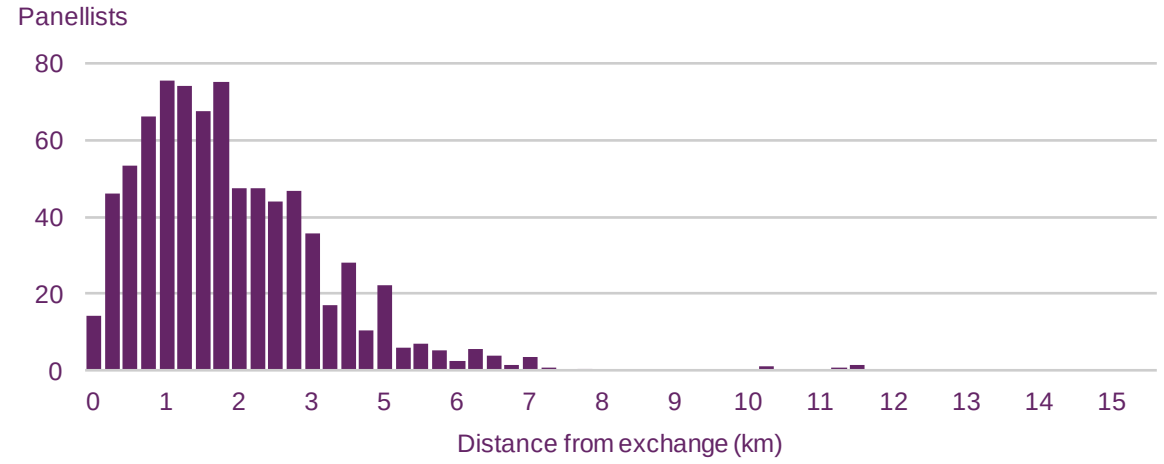
Figure 6 Distribution of maximum and average download speeds for consumers on 'up to' 76Mbit/s FTTC packages: May 2012



Source: SamKnows measurement data for panel members with a connection in May 2012.
Notes: (1) Data collected from multi-thread download speed tests.

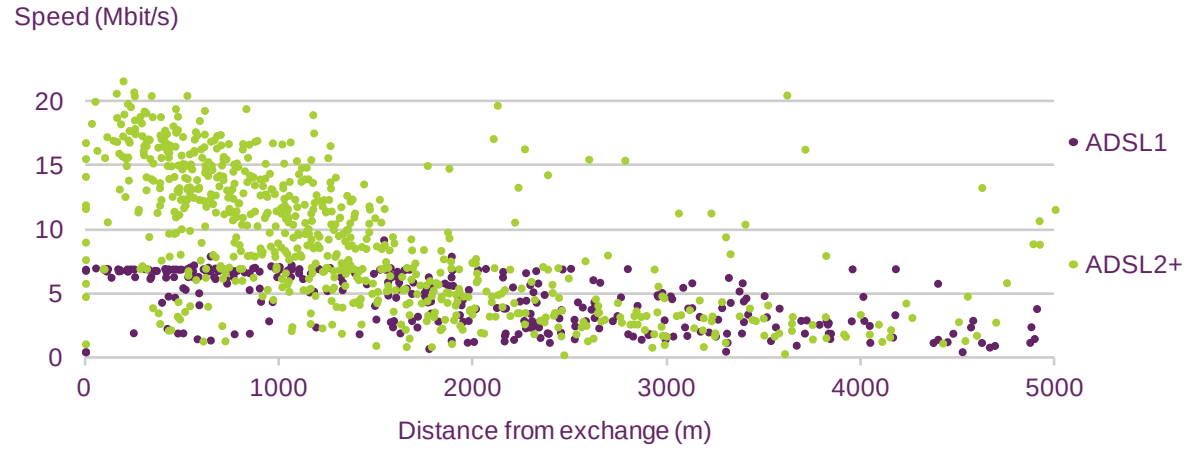
Variation of speeds by geographic location

Figure 7 Distribution of panellists, by distance from exchange



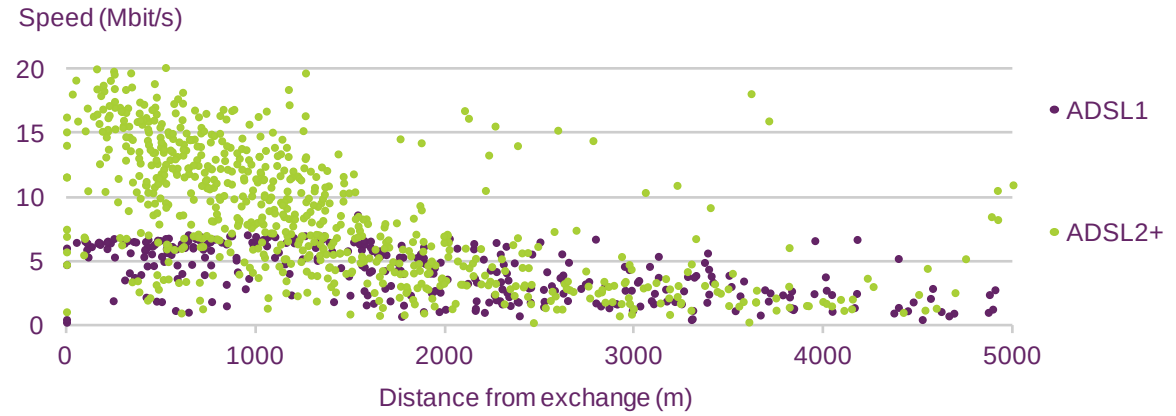
Source: Ofcom, using data supplied by SamKnows

Figure 8 Distance from exchange and maximum download speeds achieved by panellists on ADSL ISP packages: May 2012



Source: SamKnows measurement data for all panellists with an ADSL connection in May 2012.
Note: Data are unadjusted so are not directly comparable with data elsewhere in this report, which have been weighted for line length.

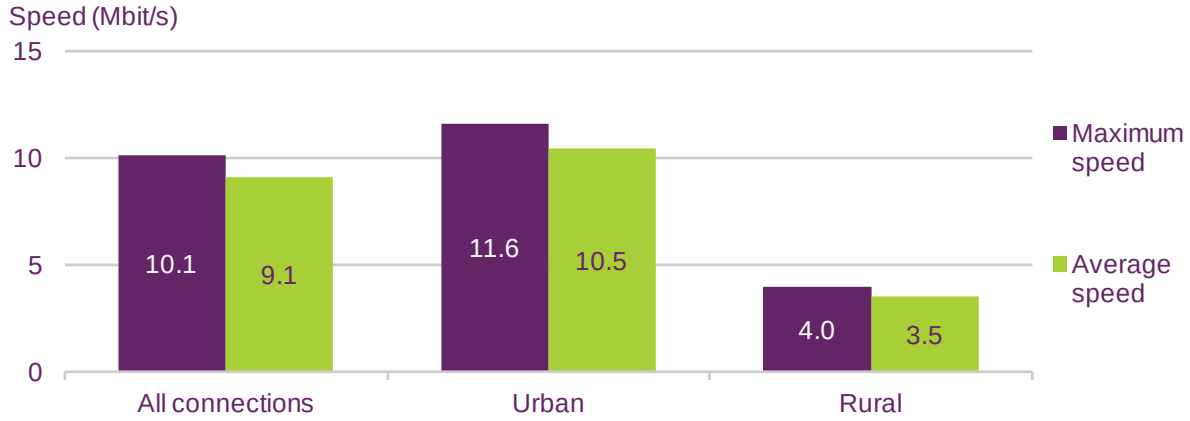
Figure 9 Distance from exchange and average download speeds achieved by panellists on ADSL ISP packages: May 2012



Source: SamKnows measurement data for all panellists with an ADSL connection in May 2012.
Note: Data are unadjusted so are not directly comparable with data elsewhere in this report, which have been weighted for line length.

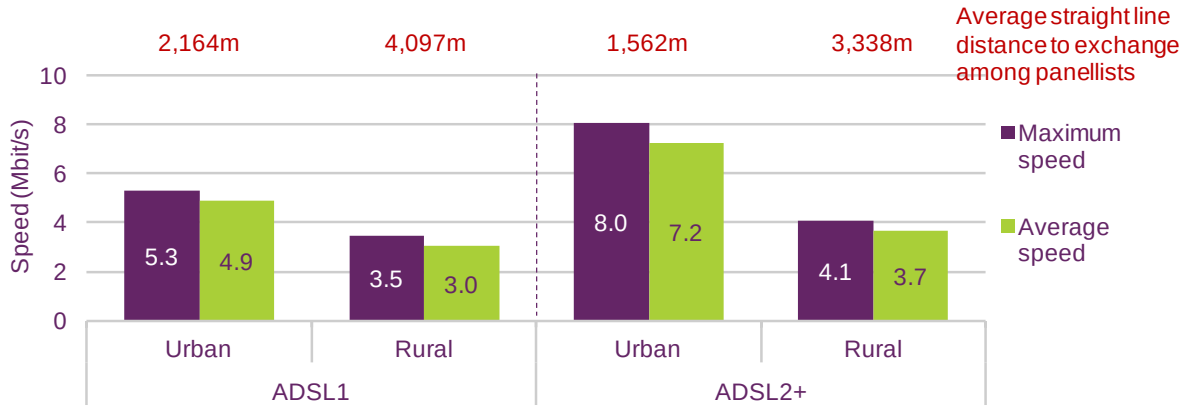
Rural versus urban location

Figure 10 Estimated average and maximum download speeds for broadband connections in rural and urban areas: May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012.
Panel Base: 1,105
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 2012 and an estimated split between rural and urban areas; (3) Data collected from multi-thread download speed tests.

Figure 11 Average and maximum download speeds for ADSL broadband connections in rural and urban areas: May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012,
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

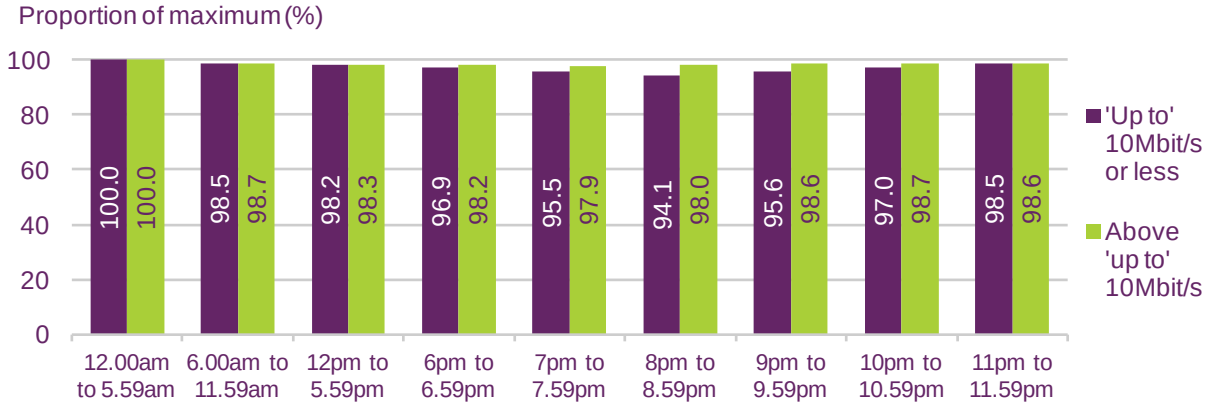
Geographic market situation

Figure 12 Average and maximum download speeds, by geographic market: May 2012

Source: SamKnows measurement data for all panel members with a connection in May 2012.
Panel Base: 1,105
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 2012 and an estimated split between rural and urban areas; (3) Data collected from multi-thread download speed tests.

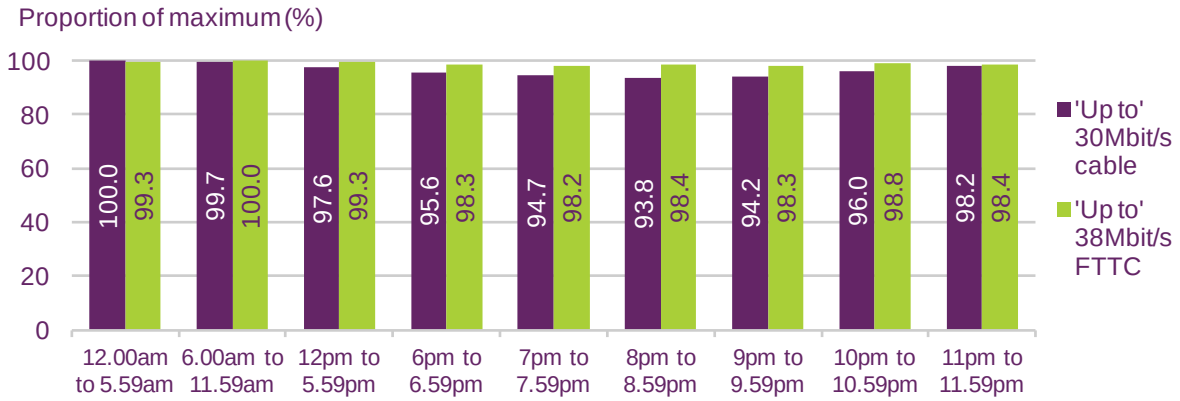
Variation of speeds by time of day

Figure 13 Average download speed as a proportion of maximum speed, by time of day, for ADSL ISP packages: May 2012



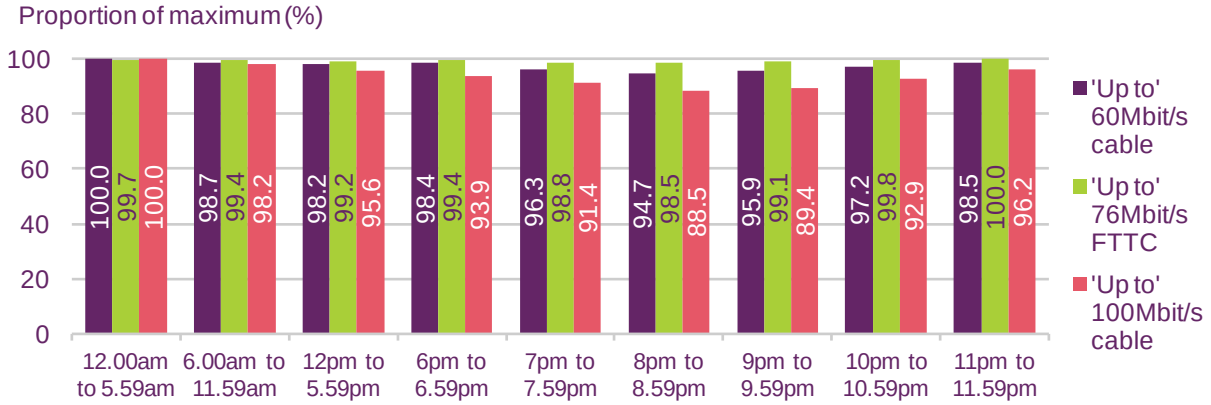
Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK ADSL2+ residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Figure 14 Average download speed as a proportion of maximum speed, by time of day, for above 'up to' to 30Mbit/s and 'up to' 38Mbit/s ISP packages: May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK 'up to' 30Mbit/s cable and 'up to' 38Mbit/s FTTC residential customers as a whole; (2) Data collected from multi-thread download speed tests.

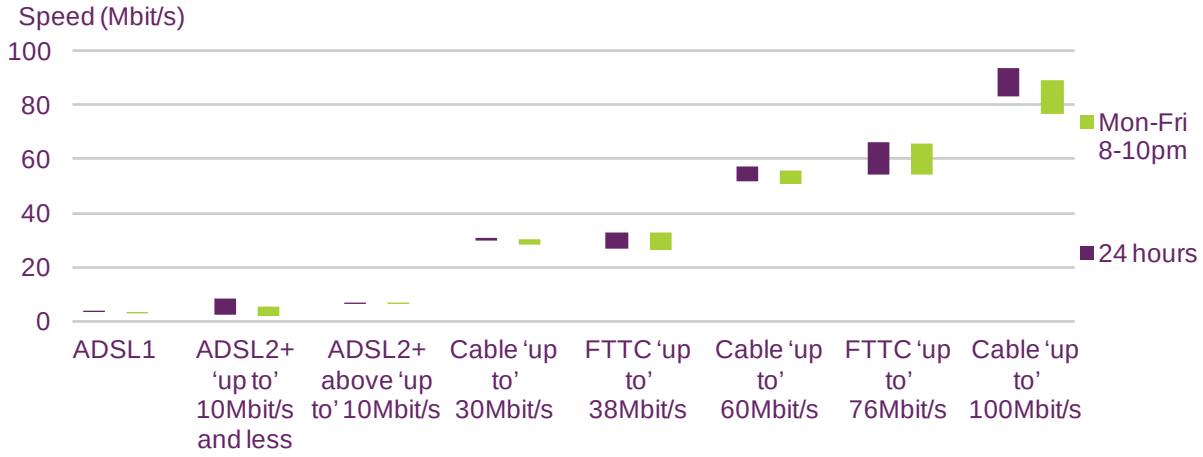
Figure 15 Average download speeds as a proportion of maximum speed, by time of day, for panellists above 'up to' 40Mbit/s ISP packages: May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Data have been weighted by ISP package, rural/urban and geographic Market classification to ensure that they are representative of UK 'up to' 60Mbit/s cable, 'up to' 76Mbit/s FTTC and 'up to' 100Mbit/s cable residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Variation in speeds, by access technology

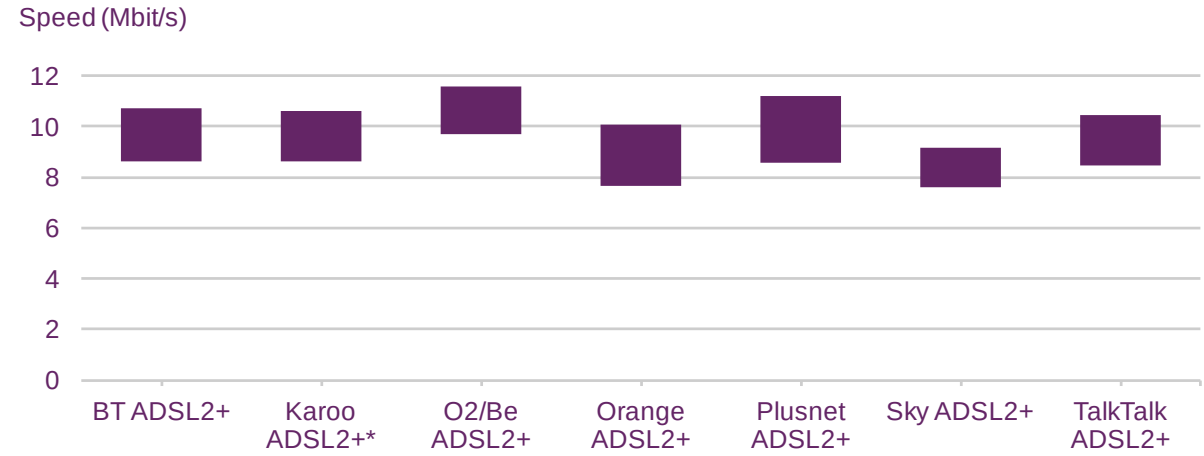
Figure 16 Average download speeds, by technology and headline speed: May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012.
Panel Base: 1,105
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 2012; (3) Data collected from multi-thread download speed tests; (4) The range shown represents a 95% confidence interval around the mean.

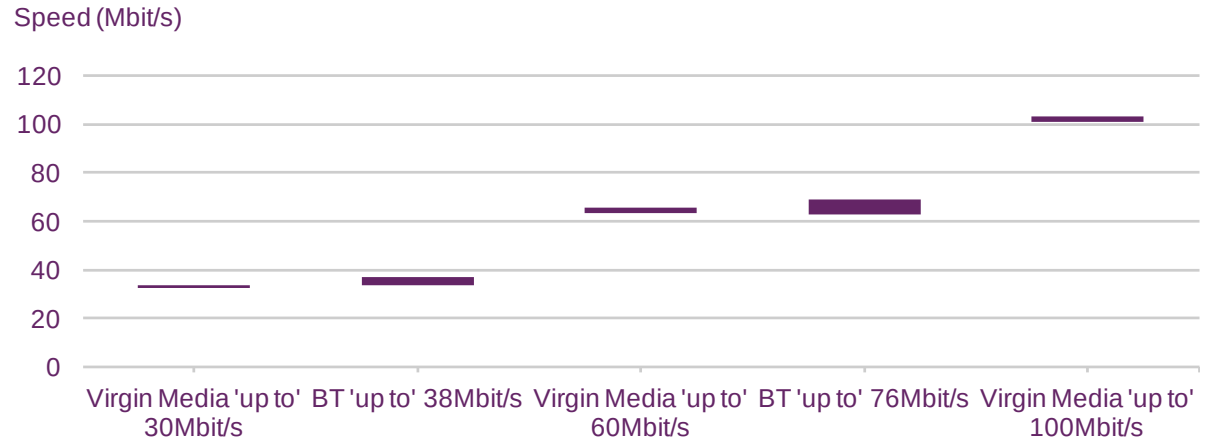
Variation of speeds, by internet service provider (ISP) package

Figure 17 Maximum download speeds for ADSL2+ ISP packages: May 2012



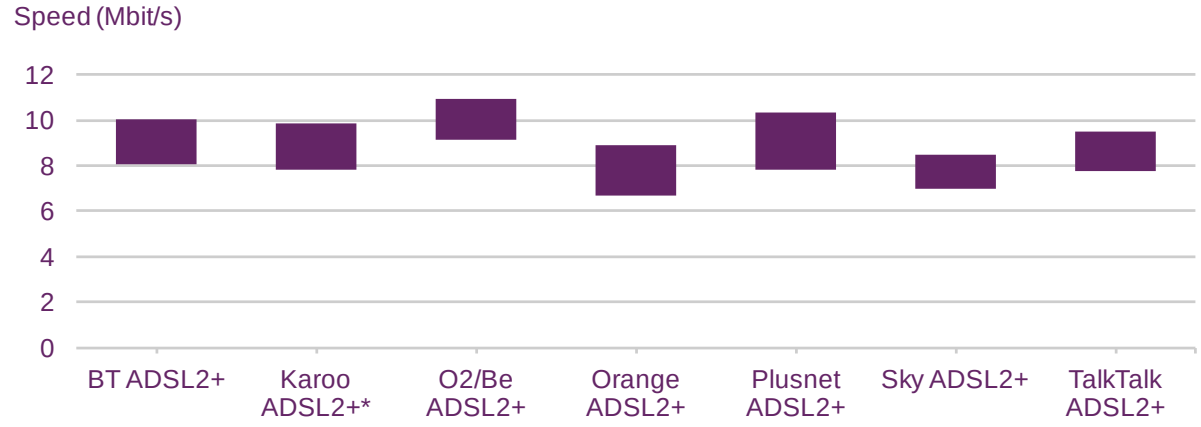
Source: SamKnows measurement data for all panel members with a connection in May 2012.
**Caution: Small sample size (<50)*
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 18 Maximum download speeds for 'up to' 30Mbit/s and above ISP packages: May 2012



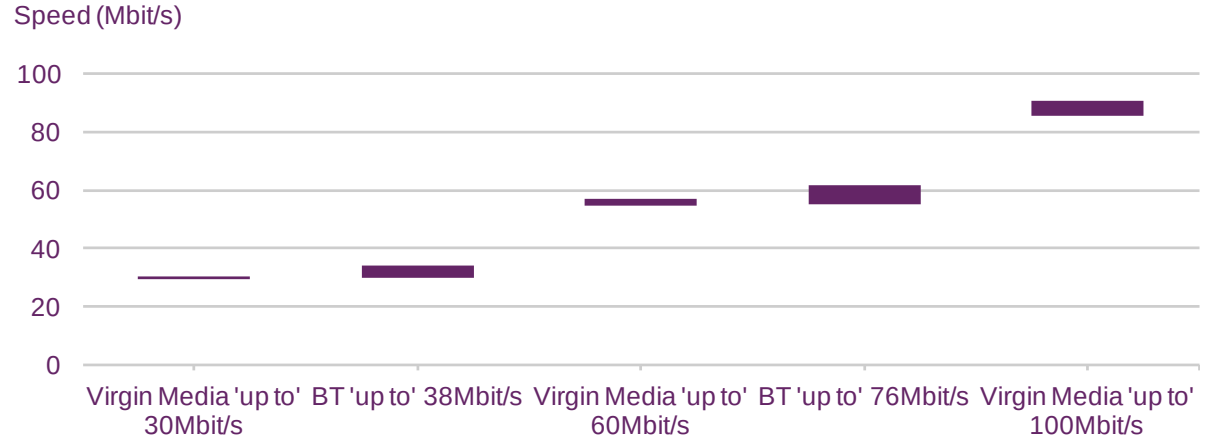
Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 19 Average download speeds for ADSL2+ ISP packages, 24 hours: May 2012



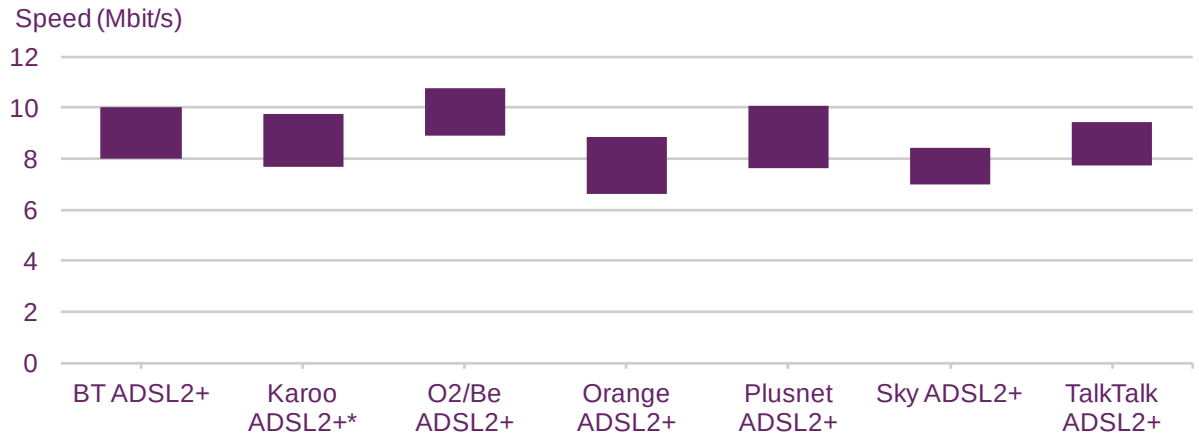
Source: SamKnows measurement data for all panel members with a connection in May 2012
**Caution: Small sample size (<50)*
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

Figure 20 Average download speeds for 'up to' 30Mbit/s and above ISP packages, 24 hours: May 2012



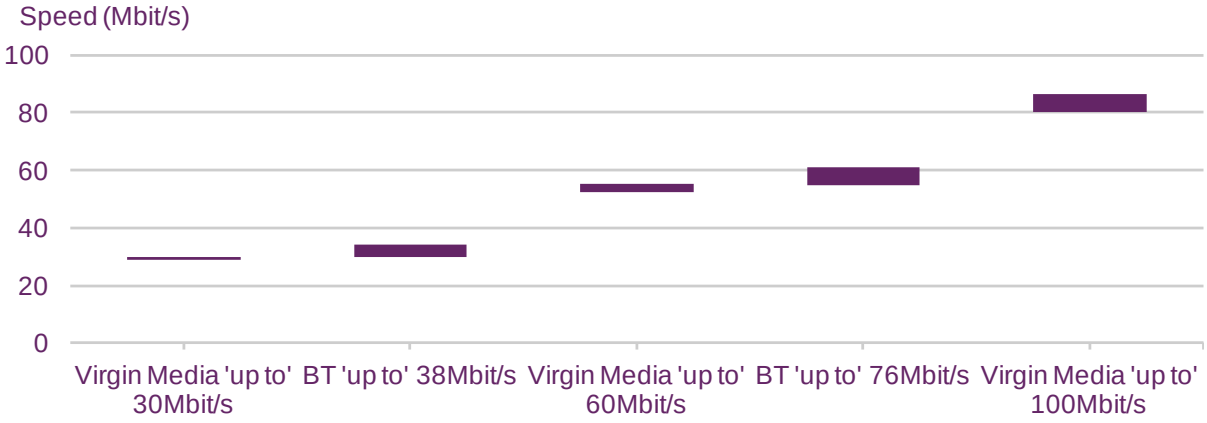
Source: SamKnows measurement data for all panel members with a connection in May 2012
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 21 Average download speeds for ADSL2+ ISP packages, 8pm to 10pm weekdays: May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012.
**Caution: Small sample size (<50)*
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

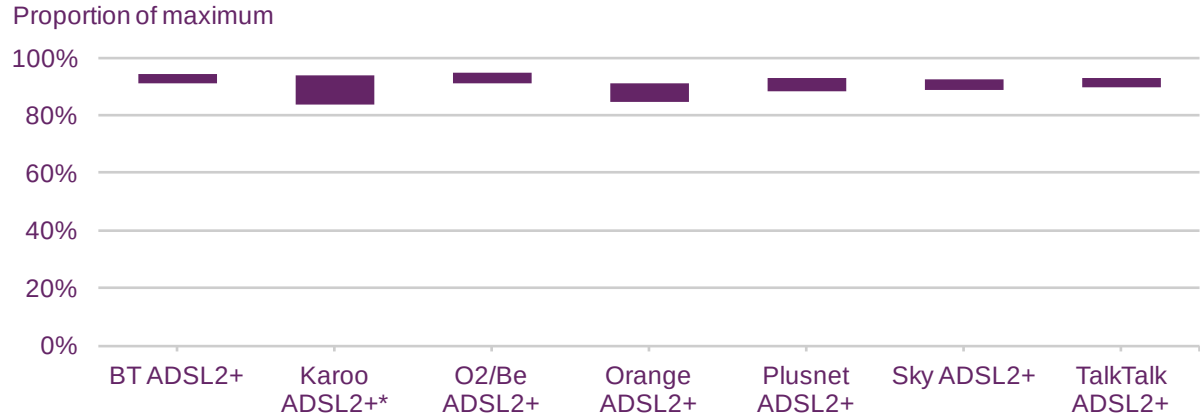
Figure 22 Average download speeds 'up to' 30Mbit/s and above ISP packages, 8pm to 10pm weekdays: May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5)The range shown represents a 95% confidence interval around the mean.

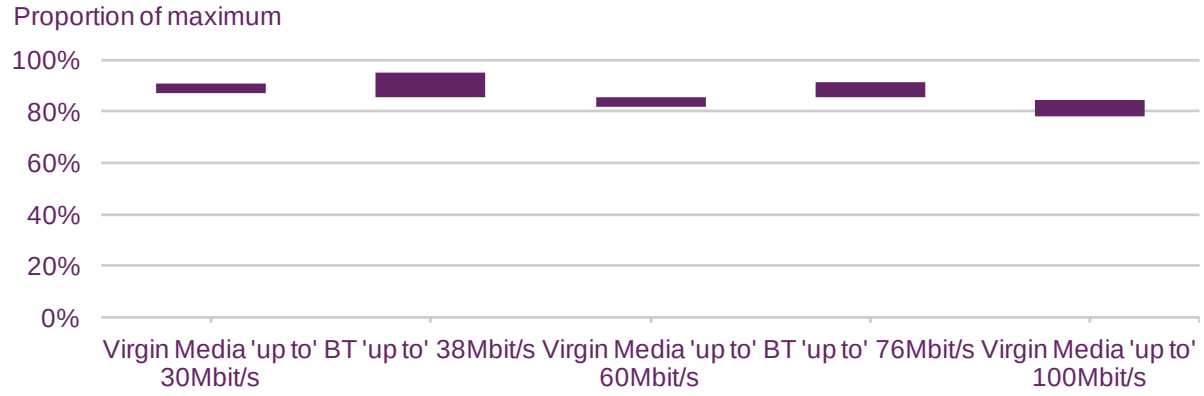
Peak download speeds as a proportion of maximum line speeds

Figure 23 Peak (8 to 10pm weekday) speeds as a proportion of maximum speeds for ADSL2+ ISP packages: May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012.
**Caution: Small sample size (<50)*
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 24 Peak (8 to 10pm weekday) speeds as a proportion of maximum speeds for 'up to' 30Mbit/s and above ISP packages: May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Annex 2

Technical and research methodologies

1. Technical methodology

This report is Ofcom's seventh fixed-line residential broadband speeds report and the sixth 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, thus 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).

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). Connections faster than 55Mbit/s will transfer an increased amount during the downstream throughput test. This amount is up to 20MB 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.

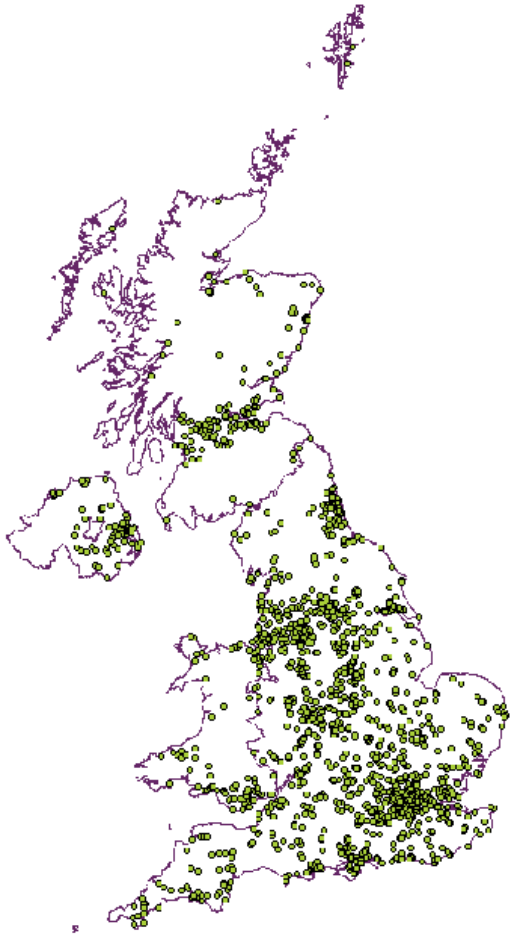
Connections with usage caps

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.

2. Research methodology

The performance data in this report are taken from a base of 1,831 panellists who had a broadband monitoring unit connected to their routers in May 2012. Figure 1 details the geographical spread of the panellists, which is broadly in line with the geographic distribution of UK residential broadband subscribers.

Figure 1 Geographic distribution of panellists



Source: Ofcom, based on distribution of SamKnows-sourced broadband speeds panel

Figure 2 sets out Ofcom's definitions of geographic broadband markets (based on the definitions for the wholesale broadband access (WBA) market[28]). 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).

[28] 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 only used 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 LLU operator). This avoids any potential distortions of the data by ISPs using BT Wholesale services (BT Retail, Orange 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.

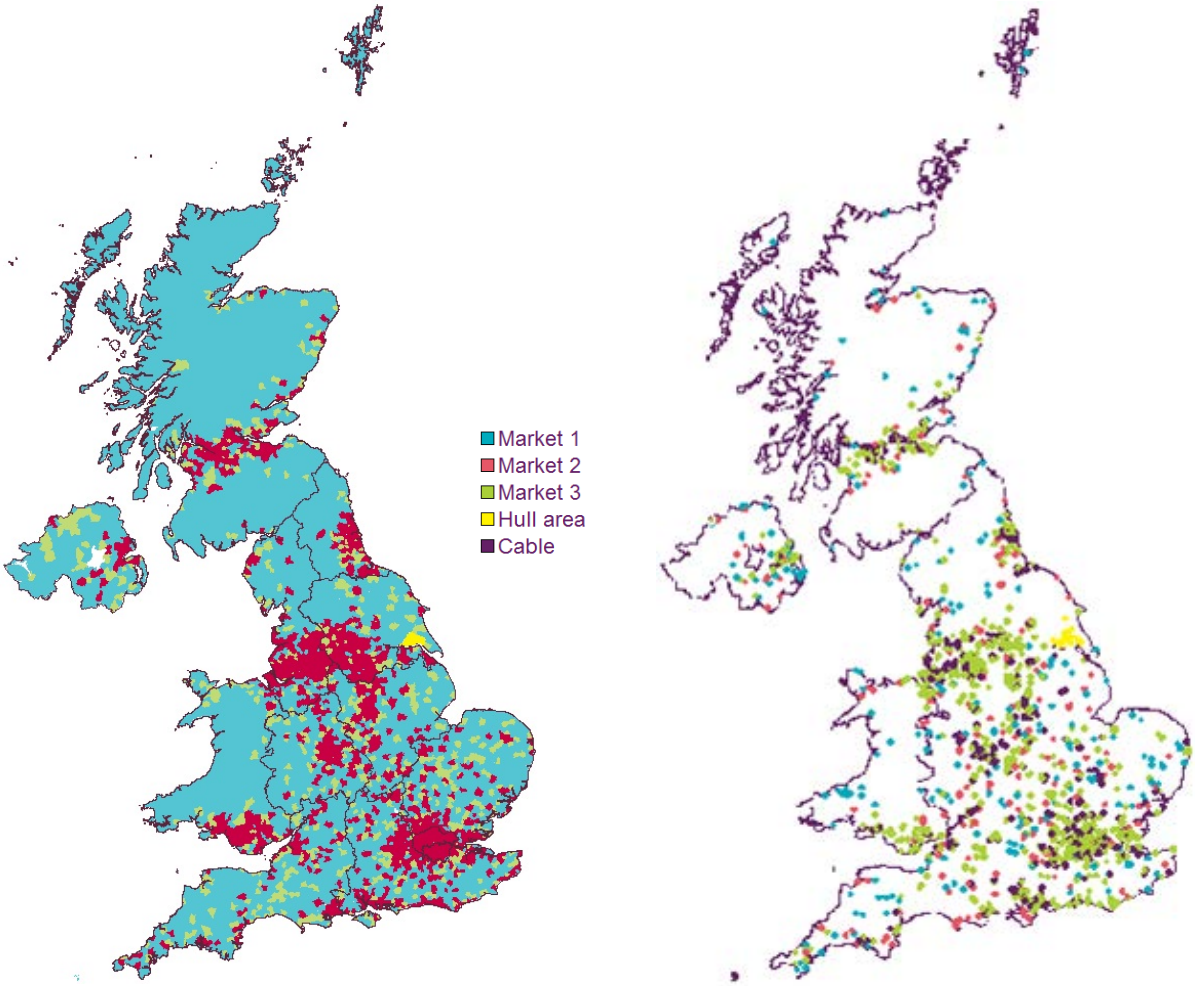
Figure 2 Ofcom definitions of geographic broadband markets

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, Orange, Sky, TalkTalk and, in local exchange areas where cable coverage exceeded 65 per cent of premises, Virgin Media

Figure 3 shows a map of the UK, colour-coded by geographic broadband market designation, and the location of our panellists.

Figure 3 Distribution of exchange areas and panellists, by geographic market definition



Source: Ofcom, based on distribution of SamKnows-sourced broadband speeds panel

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[29] 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

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

had expert review and endorsement by econometrician Professor Andrew Chesher of University College London[30].

[30] 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 559 million[31] 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

[31] 525 million of these were to test connection latency/packet loss.

quality of the particular consumer's telephone line. Therefore, providers which have a higher proportion of customers in rural areas, where line lengths are typically longer, may be expected to deliver lower speeds on average than those which focus on towns and cities, simply because they have a different customer profile. To address this issue we have taken the following steps:

- For ADSL comparisons we have included only consumers who live in an area where the exchange has been 'unbundled' by at least one LLU operator[32]. This means that ISPs using wholesale services (such as BT Wholesale's *IPstream or Wholesale Broadband Connect* products) can be compared on a like-for-like basis with LLU operators.

- We have excluded all ADSL customers where the straight-line distance from their home to the local telephone exchange is more than 5km, in order to limit the impact of outliers when weighting and normalising data to straight-line distance distributions.

- Distance weighting was applied only to ADSL operators 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, Orange '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 November 2011 and May 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.

Quotas were set by geographic market classification, LLU, ISP market and package shares, rural/urban, region (for ten regions in England, and for [the whole of] Scotland, Wales and Northern Ireland) 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.

[32] 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 34% of the sample contributing less than 0.5 a response towards the UK average; this is an increase of 2% since November 2011, due to the inclusion of fibre-to-the-cabinet and cable superfast packages. 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 May 2012, and a reduction from 1.1% since November 2011). In our first round of research conducted between October 2008 and April 2009[33], 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 are only six remaining panellists that use this 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. 1,831 of these were connected by panellists between 1st and 31st May 2012. Of these, 1,105 supplied data to the UK average, and 1,357 to the named ISP package comparisons. Of these 1,831 active respondents, approximately 1,100 (60%) were members of the original panel in 2008.

Figure 1 Panellist numbers

Sample set		Number
Total number of boxes dispatched		**3,000 (600 phased out)**
Total number of boxes connected		**1,831**
	Excluded because of missing data, (i.e. measurements, packages, distance)	57
	Excluded 'up to' 2Mbit/s	6
	Other Exclusions to improve UK sample weighting (i.e. distance, market classification, region, ISP)	233
Total participants included in UK Analysis		**1,105**
Total participants included in ISP Package Analysis		**1,357**

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

[33] And 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/.

each time interval were included in the monthly analysis. A trimmed mean was used because, for a small proportion of respondents, the occasional test result was far in excess of what was achievable on the line. The top 0.5% of results per respondents did not count towards the average.

The average number of measurements per respondent for the 24-hour multi-thread download speed tests in May 2012 was 207, from a theoretical maximum of 275 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.

Karoo's ADSL2+ service achieved the minimum threshold of 40 against the specified criteria (with 43 panellists) and is included in these findings with a warning regarding small sample size.

The results and analysis of the 1,831 panellists' measurement results were divided into two separate datasets, each weighted to targets.

- **National panel** (over 'up to' 2Mbit/s packages): 1,105 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.

- **ISP package panel**: 1,357 panellists. A subset of the national panel, consisting of panellists from Geographic Markets 2 & 3 only, panellists from LLU operators O2/Be, Sky and TalkTalk and cable provider Virgin Media were on-net only. There was a target of 100 valid panellists for each ISP package, but the criterion for inclusion in the reporting was an effective sample minimum of 50 valid panellists (those with a base of fewer than 75 should be treated with caution).

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

Sample weighting

There were two weighting classifications applied to the data:

- **National panel**. Weighting by ISP market and package shares by LLU/non-LLU connections supplied by ISPs as at October 2011, urban/rural, Geographic Market classification and distance to exchange (fitted to April 2009 UK straight-line distance to exchange line distribution); and
- **ISP package panel.** Weighting to distance from exchange (those panellists with an unrecorded or straight-line distance to the exchange of more than 5km were excluded):
    - **ADSL2+ packages** were normalised by distance from exchange, to the aggregated distribution of straight-line distance between premises and exchanges of all panellists on those headline packages, Gamma a=2.170 b=619
    - **Cable and fibre-to-the-cabinet (FTTC) packages** were not weighted, as speed of services is not directly related to distance from the exchange.
- As mentioned previously, our measurement approach does not take into account respondent-specific issues, such as wiring, which may influence the speed of connection. Such variations have most impact on high-speed services where a respondent has a short line length. We assessed several methods of accommodating this issue and asked Saville Rossiter-Base for guidance.
- The conclusion was that allowing for variance across the sample based on line length would not necessarily lead to the widening of confidence intervals to build in this element of respondent variability. This is because the calculation of confidence intervals requires a constant mean and standard error across the sample or sub-sample, under review. If we allow variance to differ by band, we would also need to allow the mean to differ by distance band. Leaving aside the increased complexity of the calculation, allowing the mean to differ by distance band to reflect respondent difference would reduce the variance in each band and reduce the confidence intervals for pooled estimate of the mean across the whole sample. The following calculation, based on all non-cable 'up to' 20Mbit/s packages in November 2011, 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. Therefore, the current methodology over-estimates the variance in the sample and hence the confidence intervals.

Assigning panellists to ISP and broadband package

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

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

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

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

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

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

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

    - The initial assumption was that the package assignment, recorded in the panel data file, was correct. However, the ISPs provided the IP ranges associated with their packages and, where possible, these were used to reassign respondents to the correct package. This was necessary due to the large scale-migration of customers from ‘up to’ 8Mbit/s to ‘up to’ 20/24Mbit/s packages by some ISPs before the research commenced.

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

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

- Panellists with an ADSL connection who lived closer than 1km to the local exchange and received maximum speeds of between 7Mbit/s and 8Mbit/s were assumed to be on headline packages of 'up to' 8Mbit/s or 10Mbit/s for analysis purposes.

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 ADSL 2+ 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

Intra-ISP package weights

O2 and Be are reported combined as a single ISP package entity, but the product offerings are considerably different. The O2/Be ADSL2+ packages were therefore weighted in addition to operator split by LLU, to maintain representative samples.

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	34%
0.5 to 1	391	36%
1 to 1.5	208	19%
1.5 to 2	108	10%
2 to 3	20	2%

Source: Ofcom

Overall, against the entire weight frame, the ISP package panel achieved a weighting efficiency of 67%. The under-0.5s are primarily driven by shorter line lengths on the high-

speed packages and over-representation of BT FTTC and higher speed Virgin Media cable services.

Figure 4 ISP package panel range of weights

Weights	Count	Column N %
Less than 0.5	8	1%
0.5 to 1	349	26%
1 to 1.5	843	62%
1.5 to 2	36	6%
2+	121	10%

Source: Ofcom

Figure 5 Weighting efficiency, by ISP package

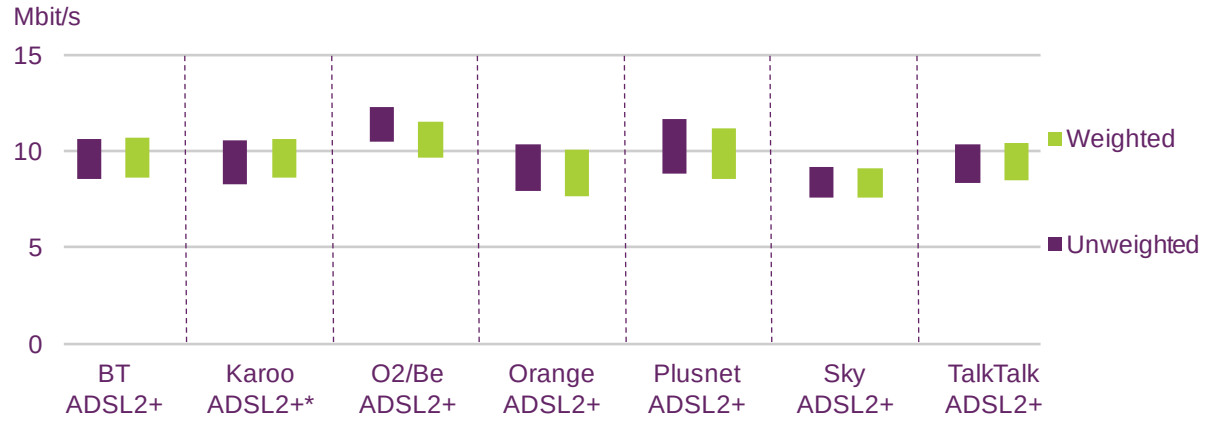
ISP package	Weighting efficiency
BT ADSL2+	88%
Karoo ADSL2+*	85%
O2/Be ADSL2+	79%
Orange ADSL2+	93%
Plusnet ADSL2+	94%
Sky ADSL2+	95%
TalkTalk ADSL2+	91%
Virgin Media 'up to' 30Mbit/s	100%
BT 'up to' 38Mbit/s	100%
Virgin Media 'up to' 60Mbit/s	100%
BT 'up to' 76Mbit/s	100%
Virgin Media 'up to' 100Mbit/s	100%

Source: Ofcom

Weighted and unweighted measurement data

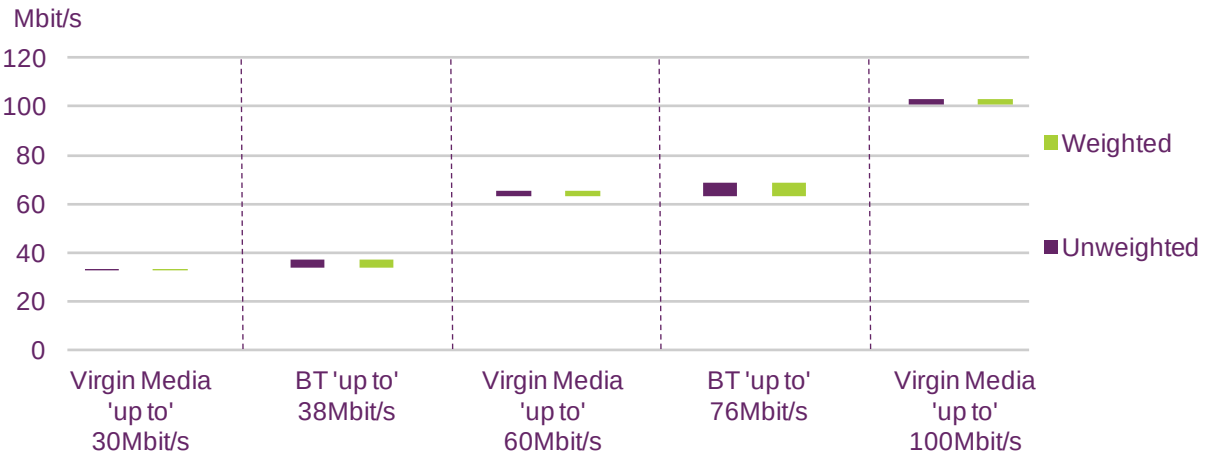
The effect of the combined overall ISP panel weighting on the comparative relative ISP package performance is shown in the following tables

Figure 6 Maximum download speeds for 'up ADSL2+ ISP packages, 24 hours, weighted and unweighted figures: May 2012



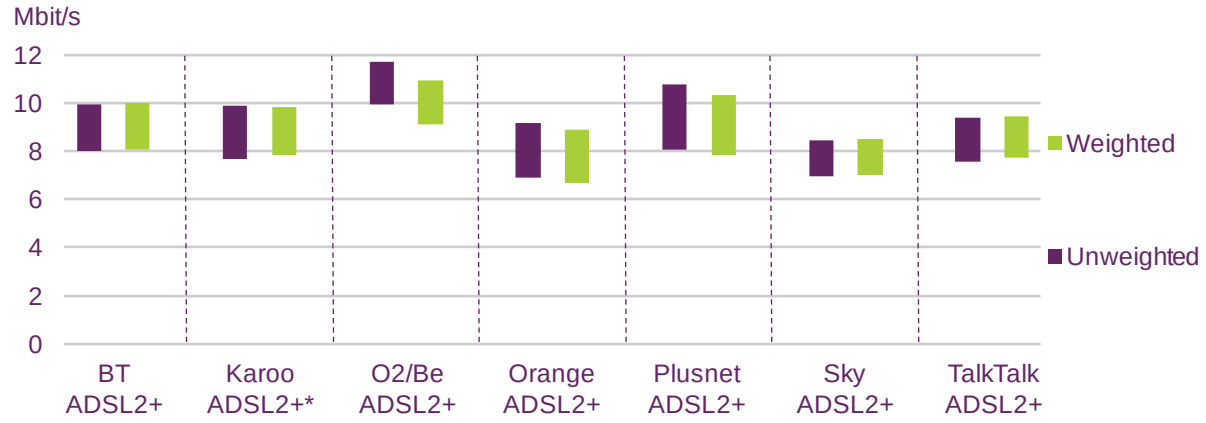
Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been unweighted to distance from exchange and data for Virgin Media's cable and BT fibre-to-the-cabinet is unweighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 7 Maximum download speeds for 'up to' 30Mbit/s and above ISP packages, 24 hours, weighted and unweighted figures: May 2012



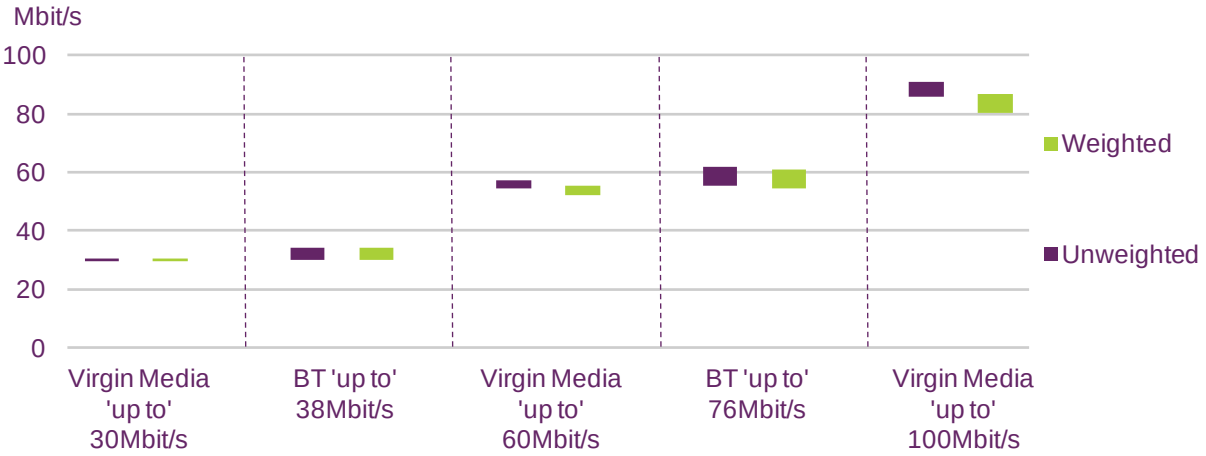
Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been unweighted to distance from exchange and data for Virgin Media's cable and BT fibre-to-the-cabinet is unweighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 8 Average download speeds for ADSL2+ ISP packages, weighted and unweighted figures: May 2012



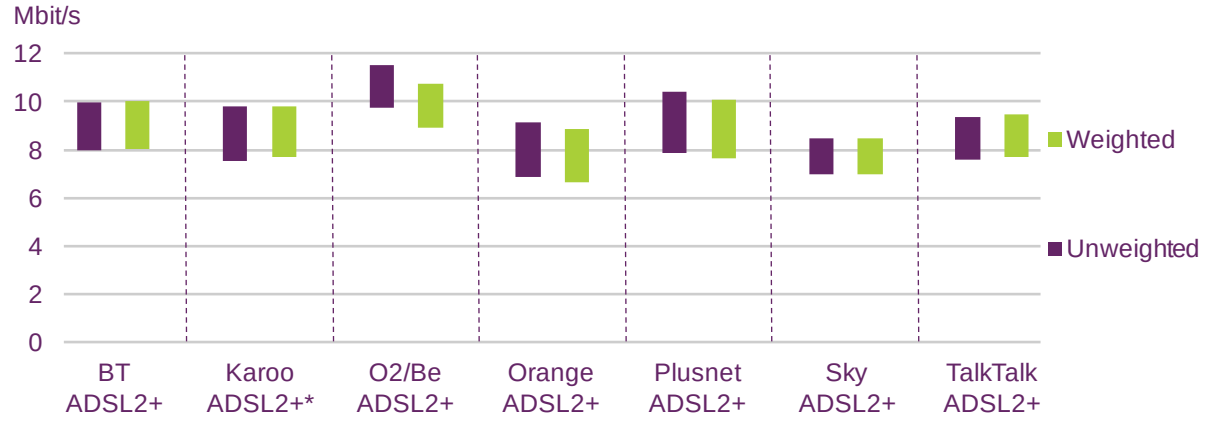
Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been unweighted to distance from exchange and data for Virgin Media's cable and BT fibre-to-the-cabinet is unweighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 9 Average download speeds for 'up to' 30Mbit/s and above ISP packages: May 2012



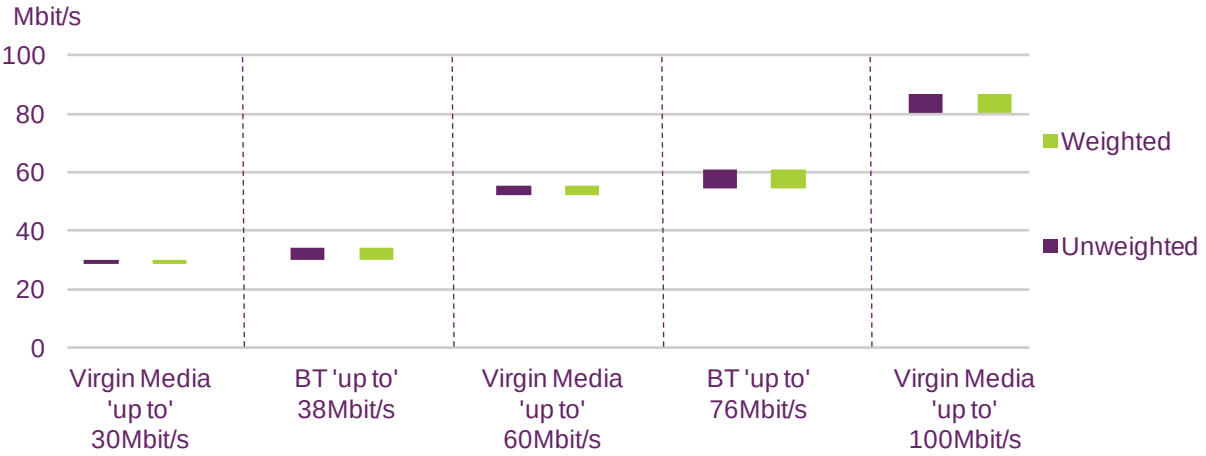
Source: SamKnows measurement data for all panel members with a connection in May 2012.
Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been unweighted to distance from exchange and data for Virgin Media's cable and BT fibre-to-the-cabinet is unweighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 10 Peak-time download speeds for ADSL2+ ISP packages, weighted and unweighted figures: May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012. Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been unweighted to distance from exchange and data for Virgin Media's cable and BT fibre-to-the-cabinet is unweighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 11 Peak-time download speeds for 'up to' 30Mbit/s and above ISP packages: May 2012



Source: SamKnows measurement data for all panel members with a connection in May 2012. Notes: (1) Includes only ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been unweighted to distance from exchange and data for Virgin Media's cable and BT fibre-to-the-cabinet is unweighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Annex 4

Glossary

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

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

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

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

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

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

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

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

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

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

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

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

DSL Digital subscriber line. A family of technologies generally referred to as DSL, or xDSL, capable of transforming ordinary phone lines (also known as 'twisted copper pairs') into high-speed digital lines, capable of supporting advanced services such as fast internet access and video-on-demand. ADSL, HDSL (high data rate digital subscriber line) and VDSL (very high data rate digital subscriber line) are all variants of xDSL).

Exchange The local telephone exchange is the building where all consumers' copper telephone lines are connected to enable telephone calls to be switched, and where network

equipment is installed which enables consumers' data traffic to be routed via an operator's core network to its destination.

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

Headline speed The speed at which a broadband service is marketed, usually expressed as 'up to' (for example, in May 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.