



# UK fixed-line broadband performance, November 2011

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

Research Report

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# Background

## Using this report

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.<sup>1</sup> 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.<sup>2</sup> 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<sup>3</sup> and to the interests of consumers in respect to price, quality of service and value for money.<sup>4</sup>

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.<sup>5</sup> 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.<sup>6</sup>

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 sixth report into fixed-line residential broadband speeds that Ofcom has published using data collected by research partner SamKnows Limited (SamKnows).<sup>7</sup> It sets out the findings from data collected during November 2011, during which 572 million test results were collected from a panel of 1,703 UK residential broadband users. We believe that the integrity of our technical methodology (see Annex 2), combined with the scale of the project and the sophistication of the statistical analysis (see Annex 3), makes this research the most robust presentation of UK fixed-line broadband speeds available.

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.

In this report, we use four key terms to describe broadband speeds. (Also see 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 '**access line speed**' or '**modem synchronisation speed**' is the maximum download speed that a line is capable of supporting according to the way the line is configured by a customer's ISP.

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<sup>1</sup> Section 3(1) of the Act

<sup>2</sup> Section 3(2)(b)

<sup>3</sup> Section 3(4)(a) and (e)

<sup>4</sup> Section 3(5)

<sup>5</sup> Section 14

<sup>6</sup> Section 15

<sup>7</sup> <http://www.samknows.com/broadband>

- 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 maximum actual throughput speed that a customer receives in practice.

For ease of reference, the structure of this report is different to that used previously. Sections 1 and 2 provide commentary on some of the key findings of the research (Section 1 looks at the performance of UK residential broadband connections at a national level, while Section 2 sets out the performance of individual ISP packages). Annex 1 then contains an update of the full research dataset (previously included in the main body of the reports); Annex 2 sets out the technical and research methodologies used; Annex 3 contains the statistical methodology applied to the research; and Annex 4 contains the glossary of terms.

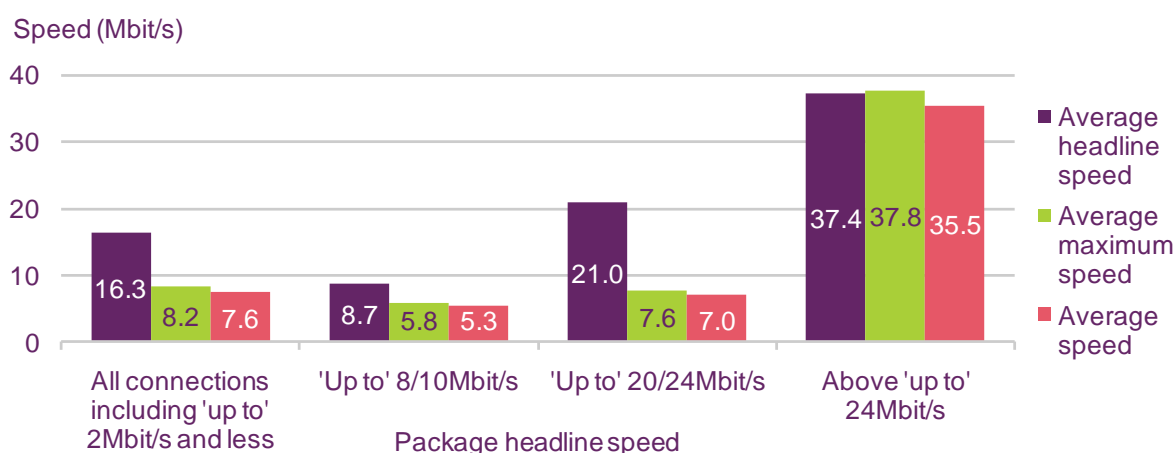
## Section 1

# Overview of UK broadband speeds

## UK broadband speeds increasing in 2011

1.1 Our research found that average actual UK fixed-line residential broadband speeds continued to increase during the second half of 2011, and in November 2011 the average actual speed was 7.6Mbit/s, a 0.8Mbit/s (11%) increase compared to the 6.8Mbit/s average recorded six months previously in May 2011 and 22% faster than the 6.2Mbit/s average recorded in November/December 2010 (Figure 1.1).

**Figure 1.1 Average UK broadband speeds, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011  
Panel Base: 1,226

Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in November 2011; (3) Data collected from multi-thread download speed tests.

- 1.2 While the average actual speeds recorded for 'up to' 8/10Mbit/s connections increased in the six months to November 2011 (up from 5.1Mbit/s to 5.3Mbit/s), the average speeds for 'up to' 20/24Mbit/s connections and above 'up to' 24Mbit/s connections fell, from 7.4Mbit/s to 7.0Mbit/s and from 38.2Mbit/s to 35.5Mbit/s respectively.
- 1.3 These changes in speed (the increase as well as the falls) can be largely attributed to the migration of BT and Virgin Media customers onto higher-speed services.
- 1.4 BT is currently upgrading its ADSL network from ADSL1 (which offers speeds of 'up to' 8Mbit/s) to ADSL2+ (which offers speeds of 'up to' 20Mbit/s) and is moving its customer base (and those connections which it provides to other ISPs on a wholesale basis) onto the faster services. As a result, a higher proportion of 'up to' 8/10Mbit/s connections are cable connections, which on average provide higher average download speeds than those provided using ADSL (see Figure 2.1), and the average speed for these connections has therefore increased.

- 1.5 There are two main factors which have contributed to the decrease in the average actual speed of 'up to' 20/24Mbit/s connections.
- Firstly, BT has continued the upgrade of its network to offer ADSL2+. As BT's roll-out of higher-speed ADSL services covers more of the UK, it encompasses more rural areas, where the average length of the copper wire from the local exchange to the customer's home is longer. Because the speeds offered by DSL technologies decrease as the length of this line (the 'local loop') increases, the average speed offered by 'up to' 20/24Mbit/s ADSL services will fall, resulting in a decline in the average speed of all 'up to' 20/24Mbit/s services.
  - Secondly, Virgin Media launched an 'up to' 30Mbit/s cable broadband service in February 2011; in doing so, it withdrew its 'up to' 20Mbit/s cable service for new customers and allowed its existing 'up to' 20Mbit/s customer base to upgrade to the higher-speed service for a one-off payment of £30. As customers take advantage of this offer, the proportion of 'up to' 20/24Mbit/s connections provided using cable has fallen, and (for the reason outlined previously) so has the average speed of these connections.
- 1.6 The increasing take-up of Virgin Media's 'up to' 30Mbit/s service is the main driver behind the decline in average speeds for connections with a headline speed above 'up to' 24Mbit/s. As the proportion of *above* 'up to' 24Mbit/s connections that are 'up to' 30Mbit/s increases, there will be a fall in the average speeds provided by these connections, as they provide lower average speeds than the previously available connections in this category, which had either a headline speed of 'up to' 40Mbit/s for FTTC or 50Mbit/s for cable. (Virgin Media is also rolling out an 'up to' 100Mbit/s cable service, but this was not included in the research.)
- 1.7 Therefore the falling average speeds recorded for both 'up to' 20/24Mbit/s connections and above 'up to' 24Mbit/s connections are not a result of individual customers receiving lower speeds – in fact the opposite is likely to be true as consumers are migrating to higher speed packages. Rather, it comes as a result of changes in the mix of connections within these two connection categories as new broadband products are launched.

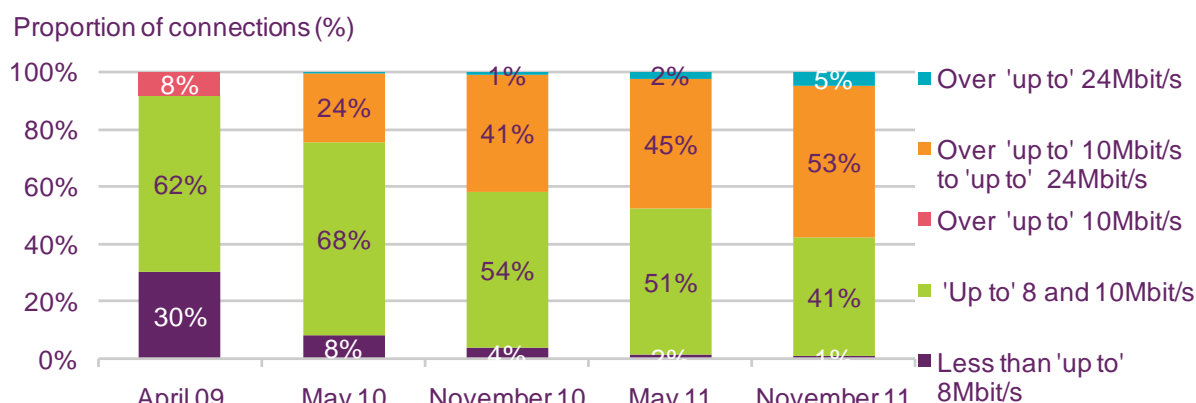
### **More than half of UK residential broadband connections have a headline speed above 10Mbit/s**

- 1.8 The migration of UK residential broadband customers onto higher-speed packages means that more than half of all UK residential connections now have a headline speed of above 'up to' 10Mbit/s. Data provided to Ofcom by ISPs making up around 95% of the residential broadband market show that in November 2011, 58% of connections had a headline speed greater than 10Mbit/s, compared to 48% in May 2011 (Figure 1.2).
- 1.9 This migration to higher-speed packages is the main driver behind the increase in overall average UK broadband speeds – and it is notable that these upgrades are often made at little or no additional cost to the customer. While most LLU-based services have already been upgraded to 'up to' 20/24Mbit/s ADSL2+-based services, BT is in the process of upgrading its ADSL network, and Virgin Media has increased the headline speed of its mid-tier offering from 20Mbit/s to 30Mbit/s; it also

announced in January 2012 that it intends to double the headline speed for the majority of its connections by mid-2013.<sup>8</sup>

- 1.10 The difference between the monthly rental fees for 'superfast' services (those with an 'up to' headline speed of 30Mbit/s or more) and 'current generation' services (which have a lower headline speed) is often relatively small. In January 2012 BT's 'up to 20Mbit/s ADSL *More Broadband and Evening & Weekend Calls* service had the same monthly line fee (£18 a month plus fixed phone line rental) as its *More Broadband and Evening & Weekend Calls with superfast BT Infinity* service which offered exactly the same bundled calls, download allowance and WiFi hot-spot use, but a faster 'up to' 40Mbit/s FTTC-based broadband connection.
- 1.11 As another example, based on tariffs available in January 2012, Virgin Media's 'up to 30Mbit/s service typically cost £5 a month more than its basic 'up to' 10Mbit/s cable service, while TalkTalk charged £10 a month for the *Fibre Optic Boost* required to have an 'up to' 40Mbit/s FTTC connection rather than its ADSL2+ service (which is marketed as the fastest speed that the customer's line can handle). Plusnet's line rental and evening and weekend calls service cost £5 a month more with 'up to' 40Mbit/s rather than an ADSL2+ connection, although the latter had a higher download cap of 60GB (rather than 40GB) per month, and no annual contract (the price difference was over £13 if the ADSL service was taken with a lower 10GB a month usage allowance).

**Figure 1.2 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)

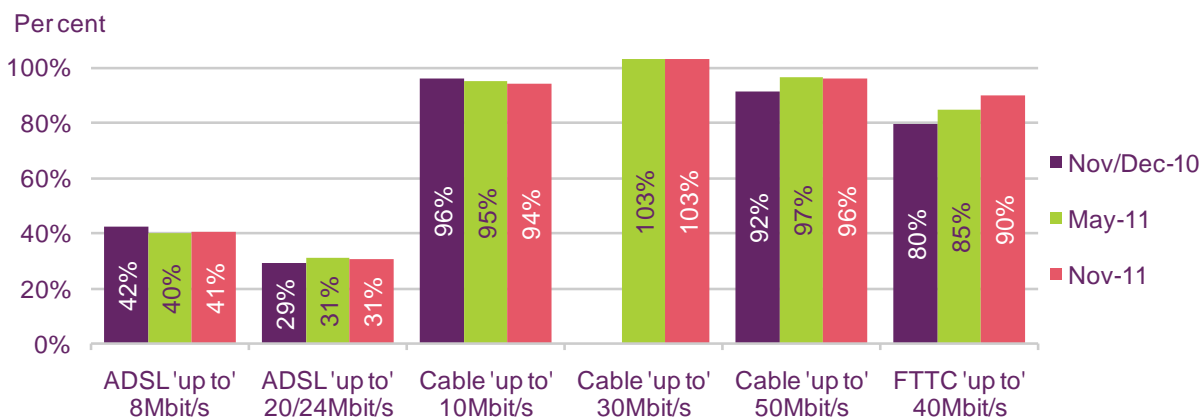
**Fibre-to-the-cabinet connections are getting faster**

- 1.12 Analysis of the average download speed performance of UK broadband connections, by headline speed and technology, shows little change between May 2011 and November 2011 (Figure 1.3). The main difference was for 'up to' 40Mbit/s FTTC connections, where average speeds were 90% of the advertised speed in November 2011, up from 85% in May 2011 and 80% in November/December 2010.
- 1.13 In November 2011, ADSL-based connections continued to deliver average download speeds that were much lower than the headline 'up to' speeds which are frequently

<sup>8</sup> <http://mediacentre.virginmedia.com/Stories/Virgin-Media-boosts-Britain-s-broadband-speeds-2322.aspx>

used to advertise broadband services. 'Up to' 8Mbit/s and 'up to' 20/24Mbit/s ADSL connections delivered just 41% and 31% of headline speeds during the period, in line with results from previous research, while cable and FTTC-based services on average delivered between 90% and 103% of headline speeds.

**Figure 1.3 Average download speeds (24 hours) as a proportion of headline speeds by connection headline speed and technology**

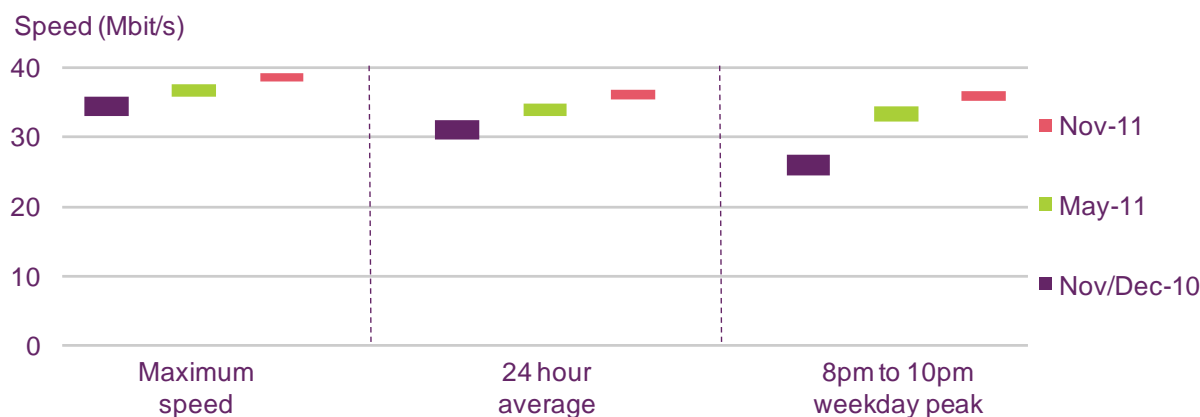


Source: SamKnows measurement data for all panel members with a connection in November 2011  
 Panel Base: 1,226

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

1.14 Analysis of the speeds recorded for 'up to' 40Mbit/s FTTC connections shows that while the 24 hour average increased by 5.0Mbit/s to 36.1Mbit/s between November/December 2010 and November 2011, the increase in maximum speeds (up 4.2Mbit/s) was less than that recorded at peak times (up 9.9Mbit/s) over the same period (Figure 1.4). This suggests that increasing FTTC speeds come as a result of BT having increased backhaul capacity in its core network to deal with the extra demand associated with superfast connections.

**Figure 1.4 Maximum, average and peak download speeds for 'up to' 40Mbit/s FTTC connections, November/December 2010 to November 2011**



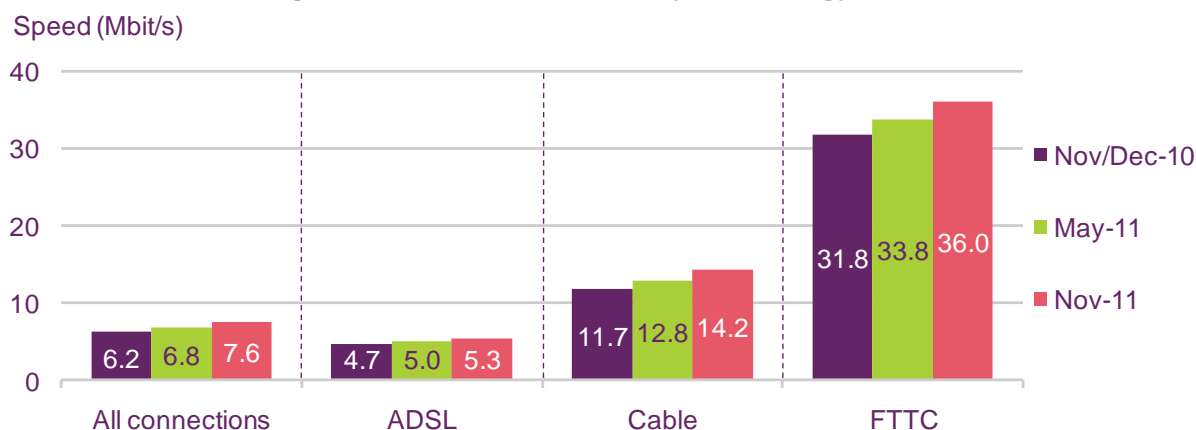
Source: SamKnows measurement data for all panel members with a connection in each period

1.15 The increase in average FTTC connection speeds is also apparent in Figure 1.5, which shows that between November/December 2010 and November 2011 average download speeds increased by 4.2Mbit/s (13%) while at the same time advertised

speeds were unchanged at 'up to' 40Mbit/s. BT announced in May 2011 that it would "roughly double" the speed of its FTTC service in 2012.<sup>9</sup>

- 1.16 The average speed of connections provided using ADSL and cable technologies also increased over the period, although the main driver behind these increases was the shift of consumers onto higher-speed packages rather than improvements in the performance of existing services.

**Figure 1.5 Average download speeds for fixed broadband connections, all connections including 'up to' 2Mbit/s and less, by technology**



Source: SamKnows measurement data for all panel members with a connection in November 2011  
Panel Base: 1,226

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

- 1.17 The significant differences between the advertised and actual download speeds of ADSL-based services led the Advertising Standards Authority to ask CAP and BCAP (the Advertising Code writing bodies) to conduct a review of the use of 'up to' speed claims in broadband advertising, in order to ensure that the advertisements do not mislead consumers.<sup>10</sup>
- 1.18 Following this review, CAP and BCAP published guidance on the use of speed claims in broadband advertising in September 2011.<sup>11</sup> This will come into force in April 2012 and requires that speed claims should be achievable by at least 10% of an ISP's customers and, where a significant proportion of customers do not receive a speed sufficiently close to the advertised speed, further qualifying information (for example, a statement that a proportion of customers achieve speeds within a certain range) should be included in the advertisement.<sup>12</sup> Ofcom's response to the CAP/BCAP consultation had recommended that a 'Typical Speed Range' (TSR) should be used when advertising broadband on the basis of speeds, and that the

<sup>9</sup> <http://www.btplc.com/News/ResultsPDF/q411release.pdf>

<sup>10</sup> <http://www.asa.org.uk/Resource-Centre/Hot-Topics/Broadband-advertising.aspx>

<sup>11</sup> [http://www.cap.org.uk/CAP-and-BCAP-Consultations/Closed-consultations/~media/Files/CAP/CAP/Speeds\\_Regulatory\\_Statement.ashx](http://www.cap.org.uk/CAP-and-BCAP-Consultations/Closed-consultations/~media/Files/CAP/CAP/Speeds_Regulatory_Statement.ashx) and <http://www.cap.org.uk/Media-Centre/2011/Changes-in-advertising-of-'unlimited'-and-broadband-speed-claims.aspx>

<sup>12</sup> In addition, any claim should be based on robust and reasonably representative data.

TSR should have at least equal prominence to the maximum 'up to' speed (which should be achievable by a material number of customers).<sup>13</sup>

- 1.19 Figure 1.6 below shows the average speed that at least 10% of the connections in our research received in November 2011, split by technology and headline speed, as well as the average speed that at least half of connections obtained, and an example of the 25% to 75% 'typical speed range'. For all of these different metrics, the figures for connections provided using cable and FTTC were much closer to the headline speeds than they were for ADSL connections.

**Figure 1.6 Average speeds obtained by at least 10% and 50% of panellists and estimated typical speed ranges (25th to 75th percentile), by technology and connection headline speed**

Current packages	10% receive more than (the 90 <sup>th</sup> percentile)	50% receive more than (the median speed)	25th to 75th percentile 'typical speed range'
ADSL 'up to' 8Mbit/s	6Mbit/s	3Mbit/s	1 Mbit/s to 5Mbit/s
ADSL 'up to' 20/24Mbit/s	14Mbit/s	5Mbit/s	3Mbit/s to 10Mbit/s
Cable 'up to' 10Mbit/s	10Mbit/s	10Mbit/s	9Mbit/s to 10Mbit/s
Cable 'up to' 30Mbit/s	32Mbit/s	32Mbit/s	31Mbit/s to 32Mbit/s
Cable 'up to' 50Mbit/s	51Mbit/s	49Mbit/s	47Mbit/s to 50Mbit/s
FTTC 'up to' 40Mbit/s	38Mbit/s	38Mbit/s	35Mbit/s to 38Mbit/s

Source: Ofcom based on SamKnows measurement data for all panel members with a connection in November 2011

Note: Figures are rounded down to the nearest Mbit/s

- 1.20 In 2008 Ofcom and a number of ISPs agreed a Voluntary Code of Practice on Broadband Speeds. ISPs signing up to the Code committed to providing consumers with certain information at the point of sale, including an estimate of the maximum line speed (access line speed) they are likely to obtain. ISPs also committed to explain to customers that their actual broadband speeds are likely to vary for a host of different reasons, and provide information and advice on how consumers can improve their broadband performance.
- 1.21 With the co-operation and agreement of ISPs, an updated and strengthened Code came into force on 27 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 customers' speed-related problems will be resolved by their ISP if possible, and if this is not possible, then customers whose speed is significantly less than expected have the ability to leave their provider within three months of the start of their contract without penalty. Most of the UK's largest ISPs are signatories to the Code.<sup>14</sup>

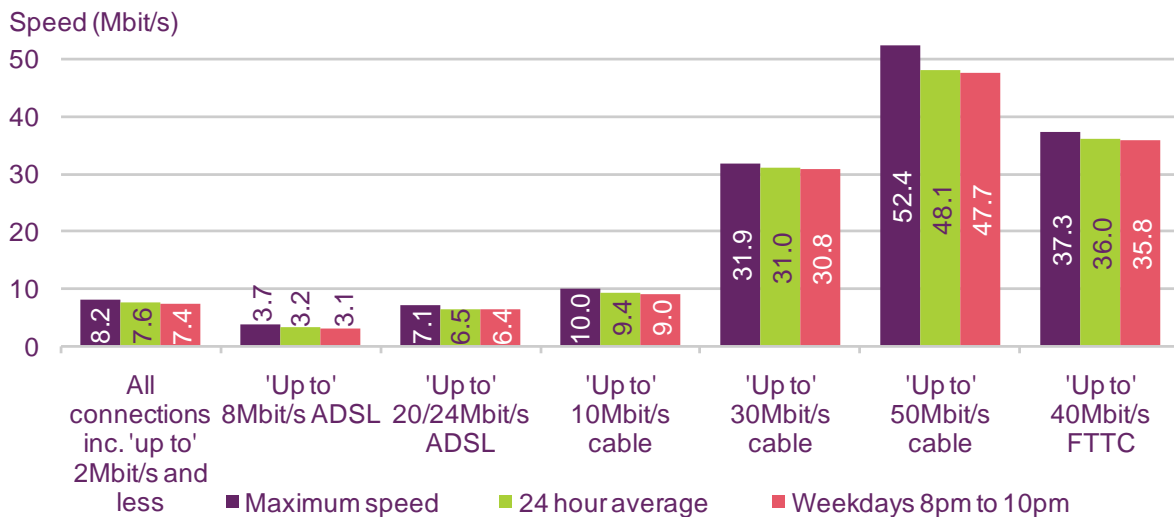
<sup>13</sup> <http://stakeholders.ofcom.org.uk/binaries/research/telecoms-research/bbspeeds2011/response-to-asa.pdf>

<sup>14</sup> <http://stakeholders.ofcom.org.uk/telecoms/codes-of-practice/broadband-speeds-cop-2010/>. Ofcom has recently commissioned mystery shopping research to look at whether ISPs are adhering to the spirit of the Code and is planning to publish the findings in the spring.

**Download speeds fell during peak times, but for some services more than others**

- 1.22 Capacity constraints on ISPs' networks (contention) means that average download speeds frequently fall during peak periods when, typically, a larger number of connections are sharing the same bandwidth (Figure 1.7). While the average download speed recorded in November 2011 was 7.6Mbit/s, during the peak weekday hours of 8pm to 10pm (on average, the hours in the week when speeds were slowest) the average recorded speed was 7.4Mbit/s, 98% of the 24-hour average and 90% of the 8.2Mbit/s average maximum speed delivered (typically recorded during the 'off-peak' hours of 12am to 6am). Both of these proportions were unchanged since May 2011.
- 1.23 The relative performance of UK broadband connections varied by technology during the weekday 8pm to 10pm peak period in November 2011: 'up to' 8Mbit/s ADSL connections delivered just 84% of the 24-hour average at peak times, compared to 96% for 'up to' 40Mbit/s FTTC and 'up to' 30Mbit/s cable connections.

**Figure 1.7 Variations in download speed by time of day, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011. Panel Base: 1,226

Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in November 2011; (3) Data collected from multi-thread download speed tests.

## 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 November 2011 (listed in alphabetical order):

- BT Retail's 'up to' 8Mbit/s and 'up to' 20Mbit/s ADSL services and its 'up to' 40Mbit/s FTTC service (*BT Infinity*);
- Karoo's 'up to' 24Mbit/s ADSL service;
- O2/Be's on-net 'up to' 20/24Mbit/s ADSL service (note that these were considered in aggregate as they are both owned by O2 and use the same network);
- Orange's 'up to' 20Mbit/s ADSL service;
- Plusnet's 'up to' 8Mbit/s and 'up to' 20Mbit/s ADSL services (note that although Plusnet is owned by BT, it was considered separately as parts of the network are different);
- Sky's on-net 'up to' 20Mbit/s ADSL service;
- TalkTalk's on-net 'up to' 24Mbit/s ADSL service; and
- Virgin Media's 'up to' 10Mbit/s, 'up to' 30Mbit/s and 'up to' 50Mbit/s cable services.

2.2 These ISP packages in total accounted for 78% of UK residential broadband connections in November 2011; 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.

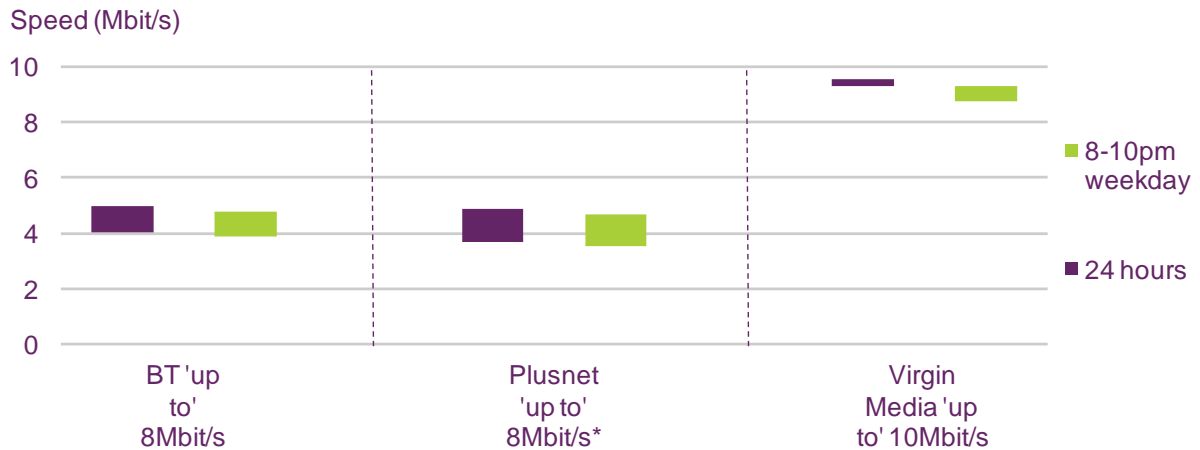
2.3 Results are presented in terms of bars showing the 95% confidence interval: this means that there is a 95% probability that the actual average speed for all consumers (i.e. not just the consumer panellists within our sample) falls within the range shown. The sample size for each group and the variation 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.

2.4 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 has 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.

**‘Up to’ 8Mbit/s and ‘up to’ 10Mbit/s connections**

- 2.5 Among the three ‘up to’ 8Mbit/s and ‘up to’ 10Mbit/s ISP packages covered by our research in November 2011, Virgin Media’s cable service delivered higher average download speeds than BT and Plusnet’s ‘up to’ ADSL broadband services over both the 24-hour period and during the weekday 8pm to 10pm peak period (Figure 2.1). On average, Virgin’s ‘up to’ 10Mbit/s service provided speeds of 9.4Mbit/s over the 24-hour period, more than twice that of BT and Plusnet’s ‘up to’ 8Mbit/s services, which delivered speeds of 4.5Mbit/s and 4.3Mbit/s respectively.
- 2.6 The same was true during the 8pm to 10pm weekday peak period, when Virgin Media’s ‘up to’ 10Mbit/s service delivered average speeds of 9.0Mbit/s compared to 4.3Mbit/s and 4.1Mbit/s respectively for BT and Plusnet’s ADSL services. Average speeds during the peak period were 96% of the 24-hour averages for all three of the ‘up to’ 8Mbit/s and 10Mbit/s services covered by the research during November 2011.

**Figure 2.1 Average download speeds for ‘up to’ 8Mbit/s and ‘up to’ 10Mbit/s connections by package, overall and in the peak period, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011.

\*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.

- 2.7 Figure 2.2 summarises the statistically significant differences in the download speed performance of the ‘up to’ 8Mbit/s and 10Mbit/s ISP packages included in our research.

**Figure 2.2 Significant differences to a 95% level of confidence between average download speeds for ‘up to’ 8Mbit/s and ‘up to’ 10Mbit/s connections by package, overall and in the peak period, November 2011**

	24 hours	8-10pm weekday
<b>ISP package</b>	<b>Is faster than...</b>	<b>Is faster than...</b>
Virgin Media	BT and Plusnet*	BT and Plusnet*

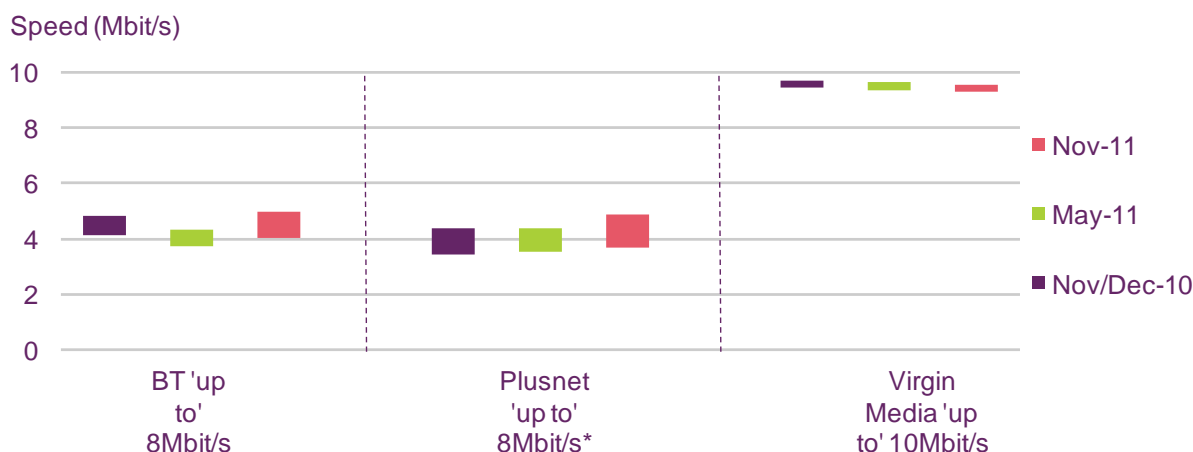
Source: Ofcom

\*Caution: Small sample size (<50)

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

2.8 Figure 2.3 shows the average download speeds recorded for the ‘up to’ 8Mbit/s and ‘up to’ 10Mbit/s ISP packages covered in this report between November/December 2010 and November 2011, and shows that there were no statistically significant changes in the performance of any of these three packages during the three periods in which comparable testing took place.

**Figure 2.3 Average download speeds for ‘up to’ 8Mbit/s and ‘up to’ 10Mbit/s connections by ISP package, November/December 2010 to November 2011**



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; data for Virgin Media’s cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

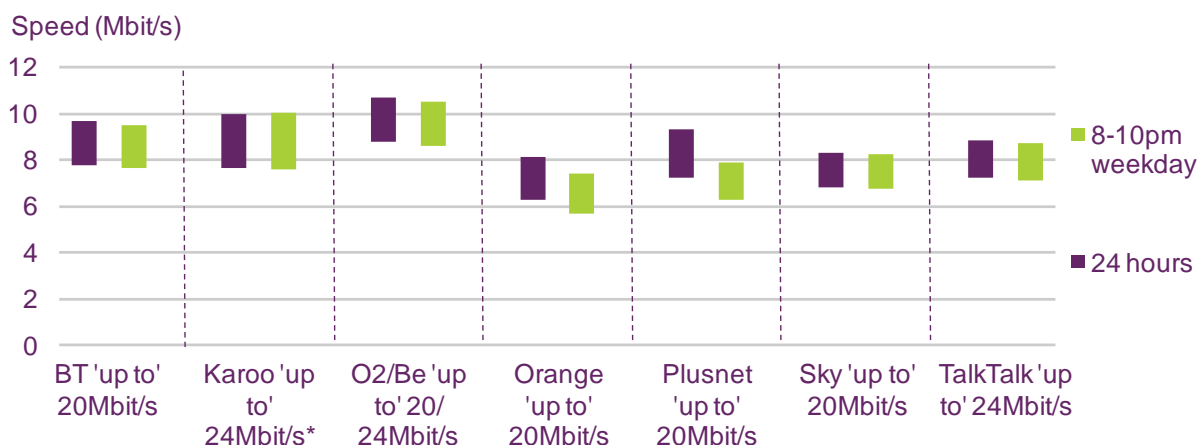
### ‘Up to’ 20Mbit/s and ‘up to’ 24Mbit/s connections

2.9 There were few differences between the average speeds delivered by the ‘up to’ 20Mbit/s and ‘up to’ 24Mbit/s ISP packages covered by our research, a result of the fact that these all used the same ADSL2+ technology (Figure 2.4). Over the 24-hour period, the average speeds recorded by O2/Be’s ‘up to’ 20/24Mbit/s service (9.7Mbit/s) were faster than those of the ‘up to’ 20Mbit/s services provided by Orange (7.2Mbit/s) and Sky (7.5Mbit/s).

2.10 There was a similar result for the 8pm to 10pm weekday peak period, when the average speed of O2/Be’s ‘up to’ 20/24Mbit/s service (9.5Mbit/s) was faster than that

of Plusnet's 'up to' 20Mbit/s service (7.1Mbit/s) as well as those provided by Orange (6.5Mbit/s) and Sky (7.5Mbit/s). Additionally, Karoo's 'up to' 24Mbit/s service (which had an average speed of 8.8Mbit/s) and BT's 'up to' 20Mbit/s service (which had an 8.6Mbit/s average speed) were faster than Orange's service. Among the 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, the proportion of 24-hour average speeds delivered during the weekday peak period ranged from 86% for Plusnet to 100% for Karoo and Sky.

**Figure 2.4 Average download speeds for 'up to' 20Mbit/s and 'up to' 24Mbit/s connections by package, overall and in the peak period, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011. 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; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

2.11 Figure 2.5 summarises the statistically significant differences in the download speed performance of the 'up to' 20Mbit/s and 'up to' 24Mbit/s ISP packages included in our research.

**Figure 2.5 Significant differences to a 95% level of confidence between average download speeds for 'up to' 20Mbit/s and 'up to' 24Mbit/s connections by package, overall and in the peak period, November 2011**

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

Source: Ofcom

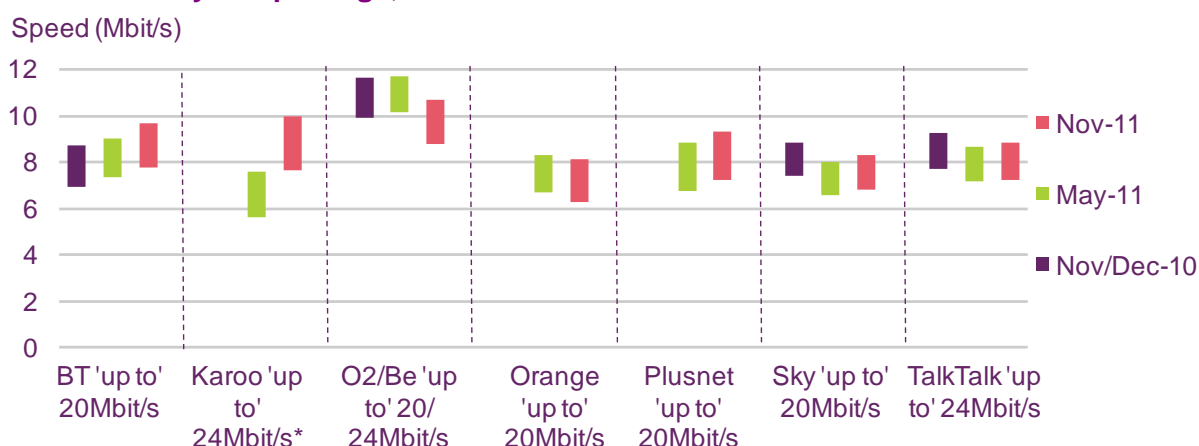
\*Caution: Small sample size (<50)

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

2.12 The average download speeds recorded in the last three periods of testing for the 'up to' 20Mbit/s and 'up to' 24Mbit/s ISP packages included in this report are shown in Figure 2.6 below. This shows that there were no statistically significant changes in

the performance of any of these packages during the three periods in which comparable testing took place.

**Figure 2.6 Average download speeds for ‘up to’ 20Mbit/s and ‘up to’ 24Mbit/s connections by ISP package, November/December 2010 to November 2011**



Source: SamKnows measurement data for all panel members.

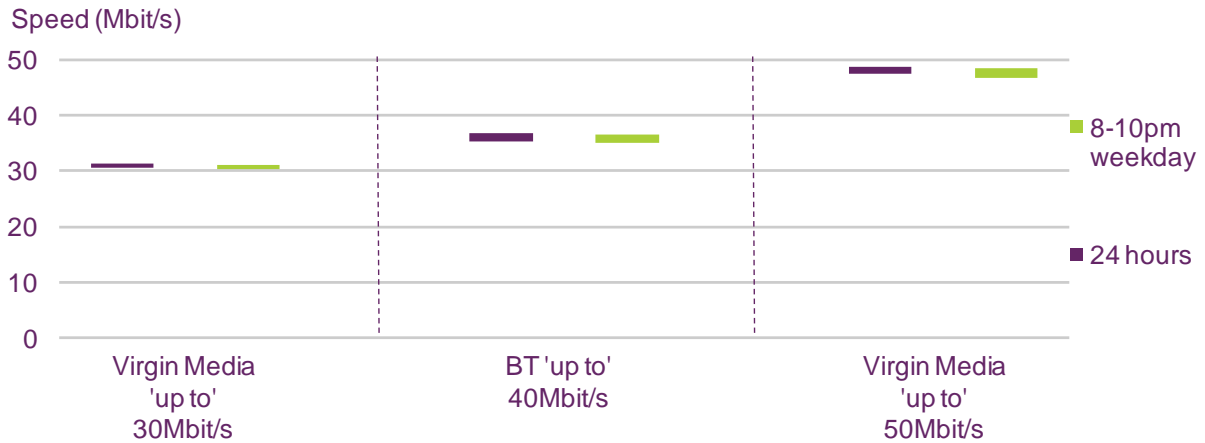
\*Caution: Small sample size (<50)

Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

### Above ‘up to’ 24Mbit/s connections

- 2.13 Average actual speeds delivered by the three ‘superfast’ ISP packages of above ‘up to’ 24Mbit/s covered in our research in November 2011 closely reflected the speeds at which they were advertised (Figure 2.7). Over the 24-hour period, the fastest average speeds measured across these ISP packages were delivered by Virgin Media’s ‘up to’ 50Mbit/s cable service (48.1Mbit/s). BT’s ‘up to’ 40Mbit/s FTTC connections (*BT Infinity*) had an average speed of 36.0Mbit/s, and Virgin Media’s ‘up to’ 30Mbit/s delivered an average of 31.0Mbit/s (i.e. average speeds exceeded the headline speed).
- 2.14 The results were similar for the 8pm to 10pm weekday peak period, with Virgin Media’s ‘up to’ 50Mbit/s cable service delivering an average speed of 47.7Mbit/s, BT’s ‘up to’ 40Mbit/s FTTC connections averaging 35.8Mbit/s and Virgin Media’s ‘up to’ 30Mbit/s cable service averaging 30.8Mbit/s. For all three of these ISP packages, average peak time speeds during the peak period were 99% of those recorded across the 24-hour period.

**Figure 2.7 Average download speeds for above ‘up to’ 24Mbit/s connections by package, overall and in the peak period, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011. 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.

2.15 Figure 2.8 summarises the statistically significant differences in the download speed performance of the above ‘up to’ 24Mbit/s ISP packages included in our research.

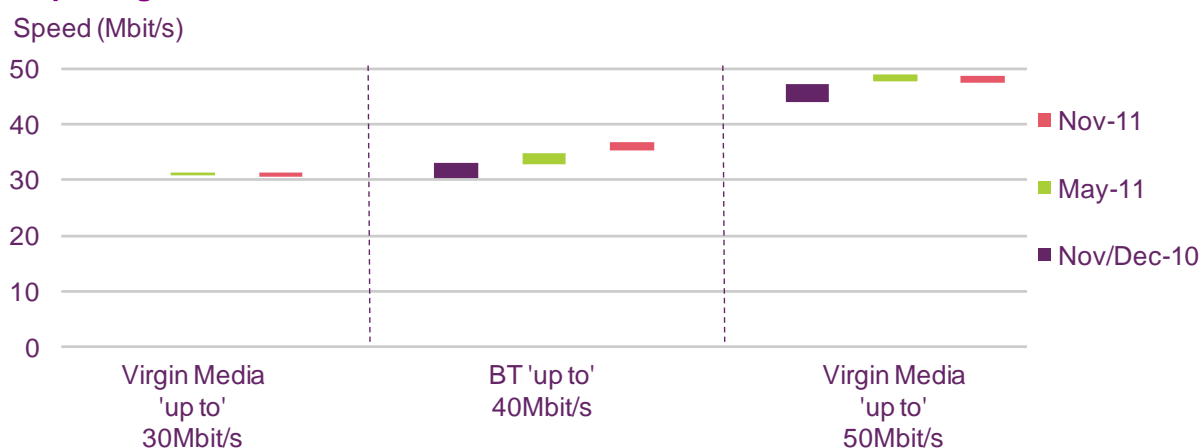
**Figure 2.8 Significant differences to a 95% level of confidence between average download speeds for above ‘up to’ 24Mbit/s connections by package, overall and in the peak period, November 2011**

	24 hours	8-10pm weekday
ISP package	Is faster than...	Is faster than...
Virgin Media 50	BT and Virgin Media 30	BT and Virgin Media 30
BT	Virgin Media 30	Virgin Media 30

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

2.16 Figure 2.9 shows the average download speeds recorded for the above ‘up to’ 24Mbit/s ISP packages covered in this report between November/December 2010 and November 2011, and shows that the average speed of BT’s ‘up to’ 40Mbit/s FTTC service increased in May 2011 (to 33.8Mbit/s from 31.8Mbit/s in November/December 2010) and again in November 2011 (to 36.0Mbit/s). There were no statistically significant changes in the performance of Virgin Media’s ‘superfast’ services over the same period.

**Figure 2.9 Average download speeds for above 'up to' 24Mbit/s connections by ISP package, November/December 2010 to November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011.  
 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.

### Summary of download speeds of all ISP packages

2.17 Figure 2.10 summarises the download speeds achieved by all ISP packages on average and in the peak evening period in November 2011. As previously, it shows the 95% confidence interval around the mean.

**Figure 2.10 Summary of average download speed by ISP package, November 2011**

	Average download speed during period	
	24 hours	8 to 10pm weekdays
BT 'up to' 8Mbit/s	4.0Mbit/s to 5.0Mbit/s	3.9Mbit/s to 4.8Mbit/s
Plusnet 'up to' 8Mbit/s*	3.7Mbit/s to 4.9Mbit/s	3.5Mbit/s to 4.7Mbit/s
Virgin Media 'up to' 10Mbit/s	9.3Mbit/s to 9.6Mbit/s	8.8Mbit/s to 9.3Mbit/s
BT 'up to' 20Mbit/s	7.8Mbit/s to 9.7Mbit/s	7.6Mbit/s to 9.5Mbit/s
Karoo 'up to' 24Mbit/s*	7.7Mbit/s to 10.0Mbit/s	7.6Mbit/s to 10.0Mbit/s
O2/Be 'up to' 20/24Mbit/s	8.8Mbit/s to 10.7Mbit/s	8.6Mbit/s to 10.5Mbit/s
Orange 'up to' 20Mbit/s	6.3Mbit/s to 8.1Mbit/s	5.7Mbit/s to 7.4Mbit/s
Plusnet 'up to' 20Mbit/s	7.2Mbit/s to 9.3Mbit/s	6.3Mbit/s to 7.9Mbit/s
Sky 'up to' 20Mbit/s	6.8Mbit/s to 8.3Mbit/s	6.8Mbit/s to 8.2Mbit/s
TalkTalk 'up to' 24Mbit/s	7.2Mbit/s to 8.8Mbit/s	7.1Mbit/s to 8.7Mbit/s
Virgin Media 'up to' 30Mbit/s	30.6Mbit/s to 31.4Mbit/s	30.4Mbit/s to 31.2Mbit/s
BT 'up to' 40Mbit/s	35.4Mbit/s to 36.7Mbit/s	35.2Mbit/s to 36.5Mbit/s
Virgin Media 'up to' 50Mbit/s	47.4Mbit/s to 48.8Mbit/s	46.8Mbit/s to 48.5Mbit/s

Source: SamKnows measurement data for all panel members with a connection in November 2011.

\*Caution: Small sample size (<50)

Panel Base: 1,118

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.

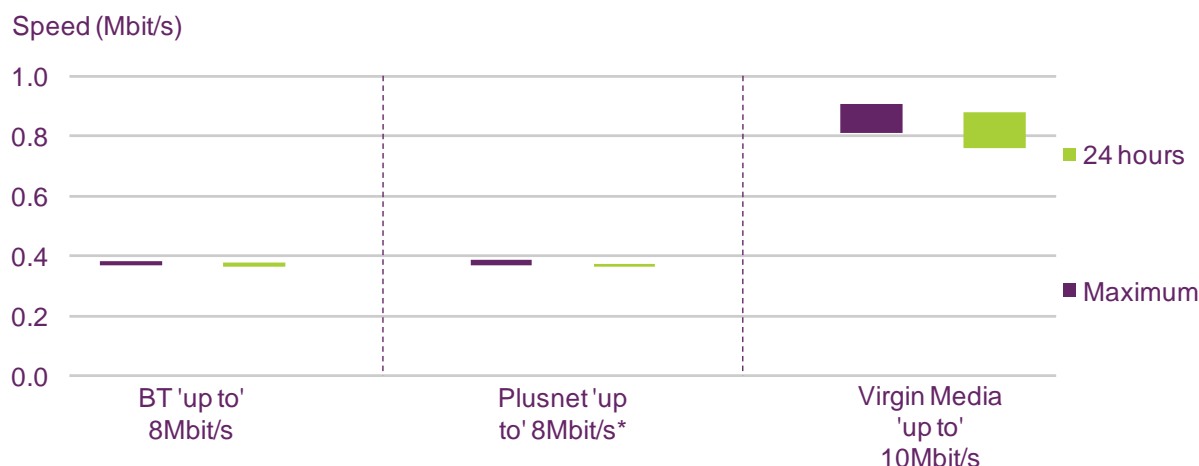
## Upload speeds

2.18 Broadband connections work both ways, and have an upstream as well as a downstream. While the advertising of broadband 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 considered upload speeds in our research.

### 'Up to' 8Mbit/s and 'up to' 10Mbit/s connections

2.19 Residential broadband connections are typically configured to deliver upload speeds which are much lower than download speeds. Average actual upload speeds were around 0.4Mbit/s both over the 24-hour period and during the 8pm to 10pm weekday peak period for the two 'up to' 8Mbit/s ADSL ISP packages included in our research. This was around half the average upload speed for Virgin Media's 'up to' 10Mbit/s cable service, which was 0.9Mbit/s across the whole day and 0.8Mbit/s at peak times (Figure 2.11).

**Figure 2.11 Average upload speeds for ‘up to’ 8Mbit/s and ‘up to’ 10Mbit/s packages, overall and in the peak period, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011.

\*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 2.12 Significant differences to a 95% level of confidence between average upload speeds for ‘up to’ 8Mbit/s and ‘up to’ 10Mbit/s packages, overall and in the peak period, November 2011**

	24 hours	Maximum
ISP package	Is faster than...	Is faster than...
Virgin Media	BT and Plusnet*	BT and Plusnet*

Source: Ofcom

\*Caution: small sample size (<50)

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

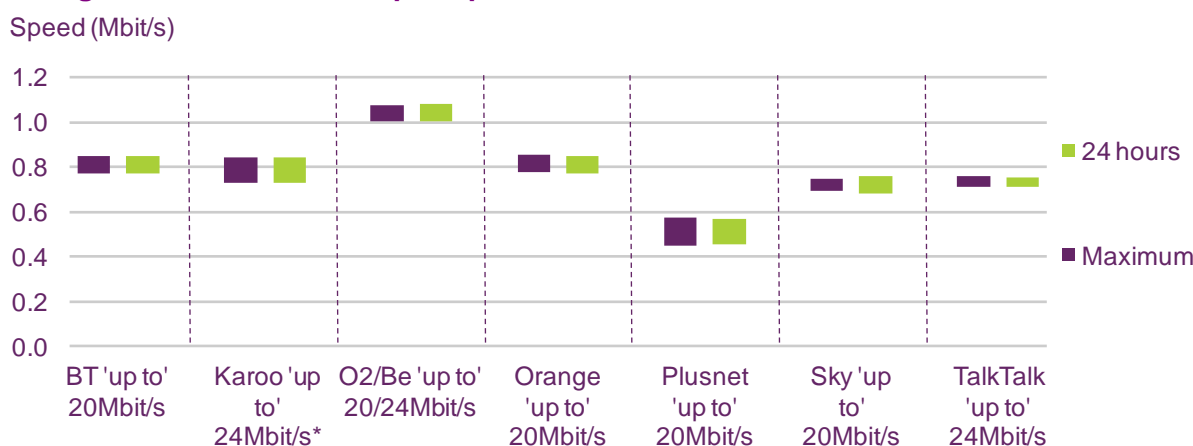
### ‘Up to’ 20Mbit/s and ‘up to’ 24Mbit/s connections

2.20 The upload speeds of ‘up to’ 20Mbit/s and ‘up to’ 24Mbit/s ADSL packages were around twice those of ‘up to’ 8Mbit/s ADSL-based services, averaging around 0.8Mbit/s over both the 24-hour and 8pm to 10pm weekday peak periods (Figure 2.13).

2.21 Among the ‘up to’ 20Mbit/s and ‘up to’ 24Mbit/s ISP packages included in the research, O2/Be’s ‘up to’ 20/24Mbit/s services delivered significantly faster upload speeds than the other ISP packages included in this research, averaging 1.0Mbit/s over both the 24-hour and weekday 8pm to 10pm peak periods – O2’s basic broadband packages offer an advertised maximum 1.3Mbit/s upload speed, and its highest-tier package offers an advertised maximum upload speed of 2.5Mbit/s (our panel does not differentiate between these two packages – but from our results it is likely that the large majority of panellists are on the lower-tier packages).

- 2.22 In addition, BT’s and Orange’s ‘up to’ 20Mbit/s services (which both had average upload speeds of 0.8Mbit/s over the 24-hour period and during the 8pm to 10pm weekday peak period) were faster than Plusnet’s ‘up to’ 20Mbit/s service, Sky’s ‘up to’ 20Mbit/s service and TalkTalk’s ‘up to’ 24Mbit/s service across the whole day and at peak times.
- 2.23 The average upload speeds delivered by Plusnet’s ‘up to’ 20Mbit/s service were lower than those of the other ‘up to’ 20Mbit/s and 24Mbit/s services, at 0.5Mbit/s during both the 24-hour and peak periods (Plusnet’s advertised upload speed is 0.4Mbit/s (448kbit/s)).

**Figure 2.13 Average upload speeds for ‘up to’ 20Mbit/s and ‘up to’ 24Mbit/s packages, overall and in the peak period, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011.

\*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 2.14 Significant differences to a 95% level of confidence between average upload speeds for ‘up to’ 20Mbit/s and ‘up to’ 24Mbit/s packages, overall and in the peak period, November 2011**

ISP package	24 hours	Maximum
	Is faster than...	Is faster than...
O2/Be	BT, Karoo*, Orange, Plusnet, Sky and TalkTalk	BT, Karoo*, Orange, Plusnet, Sky and TalkTalk
BT	Plusnet, Sky** and TalkTalk**	Plusnet, Sky** and TalkTalk**
Orange	Plusnet, Sky** and TalkTalk**	Plusnet, Sky** and TalkTalk**
Karoo*	Plusnet	Plusnet
Sky	Plusnet	Plusnet
TalkTalk	Plusnet	Plusnet

Source: Ofcom

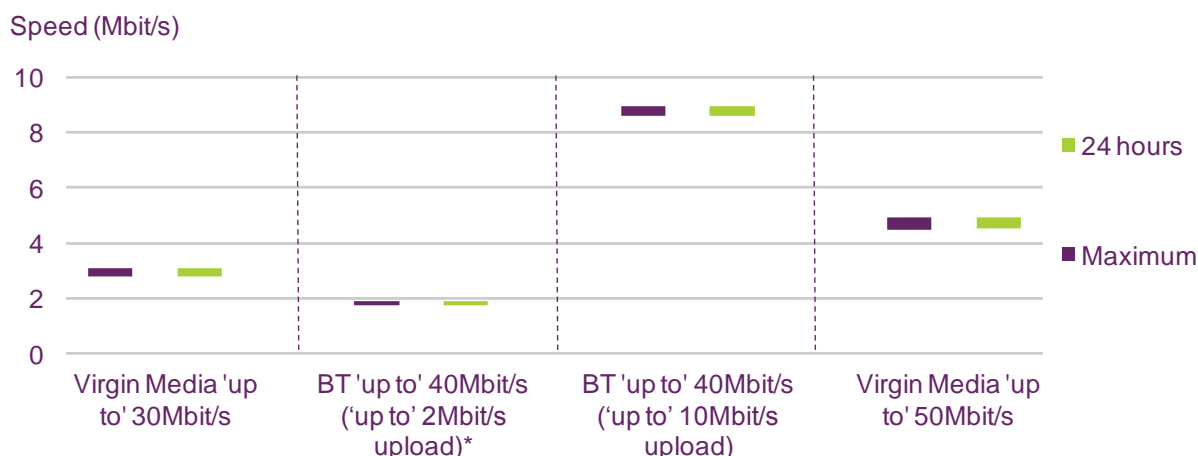
\*Caution: small sample size (<50)

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

## Above 'up to' 24Mbit/s connections

- 2.24 BT offers two 'up to' 40Mbit/s FTTC packages: *More Broadband... with BT Infinity* which offers upload speeds of 'up to' 2Mbit/s (and a 40GB usage cap), and *Unlimited Broadband... with BT Infinity* which offers upload speeds of 'up to' 10Mbit/s (and unlimited usage). In this section we consider these packages separately.
- 2.25 BT's FTTC package, with an advertised 'up to' 10Mbit/s upload speed, delivered higher upload speeds than any other ISP package within our research, averaging 8.8Mbit/s over the 24-hour period (Figure 2.15). Its FTTC package with an advertised upload speed of 'up to' 2Mbit/s delivered average upload speeds of 1.8Mbit/s across the whole day. Virgin Media's 'up to' 50Mbit/s cable service delivered average upload speeds of 4.7Mbit/s over the 24-hour period, while its 'up to' 30Mbit/s cable service delivered average upload speeds of 2.9Mbit/s.
- 2.26 There were no significant differences between 24-hour 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 2.15 Average upload speeds for above 'up to' 24Mbit/s packages, overall and in the peak period, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011).

\*Caution: small sample size (<50)

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 2.16 Significant differences to a 95% level of confidence between average upload speeds for above 'up to' 24Mbit/s packages, overall and in the peak period, November 2011**

	24 hours	Maximum
ISP package	Is faster than...	Is faster than...
BT (10Mbit/s upload)	Virgin Media 50, Virgin Media 30 and BT (2Mbit/s upload)	Virgin Media 50, Virgin Media 30 and BT (2Mbit/s upload)
Virgin Media 50	Virgin Media 30 and BT (2Mbit/s upload)	Virgin Media 30 and BT (2Mbit/s upload)
Virgin Media 30	BT (2Mbit/s upload)	BT (2Mbit/s upload)

Source: Ofcom

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

- 2.27 In addition to upload and download speeds, other metrics influence the overall experience of using a broadband connection, the most important of which are outlined in Figure 2.17. 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.
- 2.28 The performance of the ISP packages included in this report against these metrics can be found in Annex 1 of this report (Figure 30 onwards).

**Figure 2.17 Summary of additional metrics covered in the research**

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

Source: Ofcom

## Conclusion and next steps

- 2.29 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 November 2011. The broadband market is changing rapidly as operators invest in their networks in order to make faster broadband available, and the results

set out in this report will therefore not necessarily reflect the future performance of networks and providers.

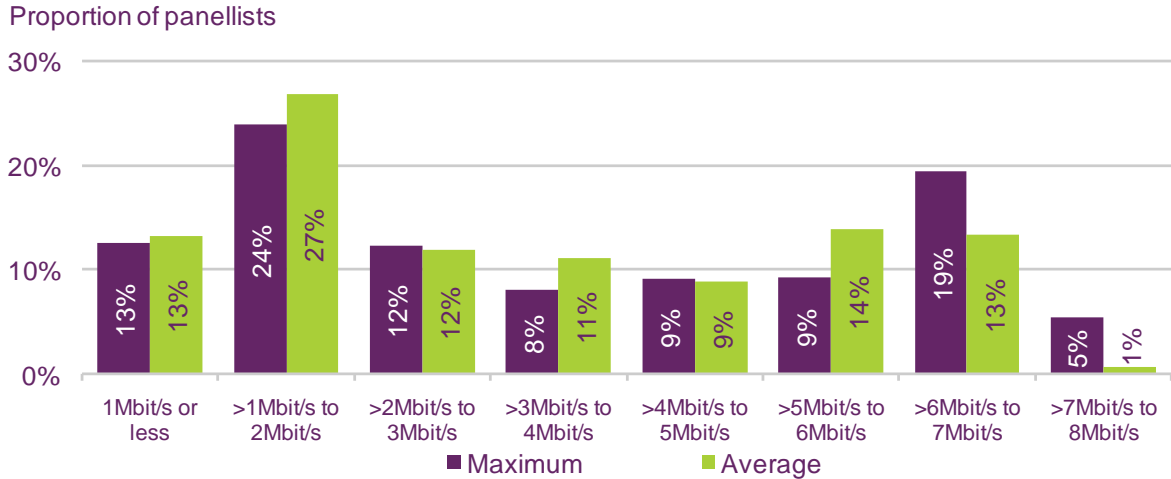
- 2.30 Despite these anticipated changes, in order to help ISPs' current and new customers to make more informed purchasing decisions based on their individual needs, it is important that consumers understand that there are significant variations in the performance of ISP packages and that these are largely attributable to the technology used by the ISP. This information is particularly useful for users of high-bandwidth services such as high-definition video and online gaming.
- 2.31 We plan to publish the next UK fixed-line broadband performance report in July 2012, using data collected from tests run in May 2012.

Annex 1

# Research data update

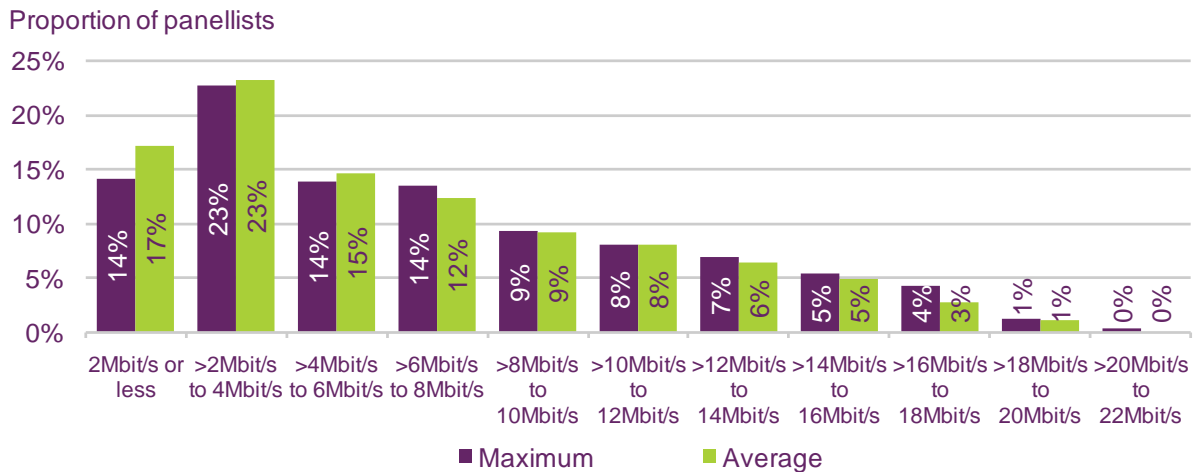
## The distribution of actual broadband speeds

**Figure 1** Distribution of maximum and average download speeds for consumers on 'up to' 8Mbit/s ADSL packages, November 2011



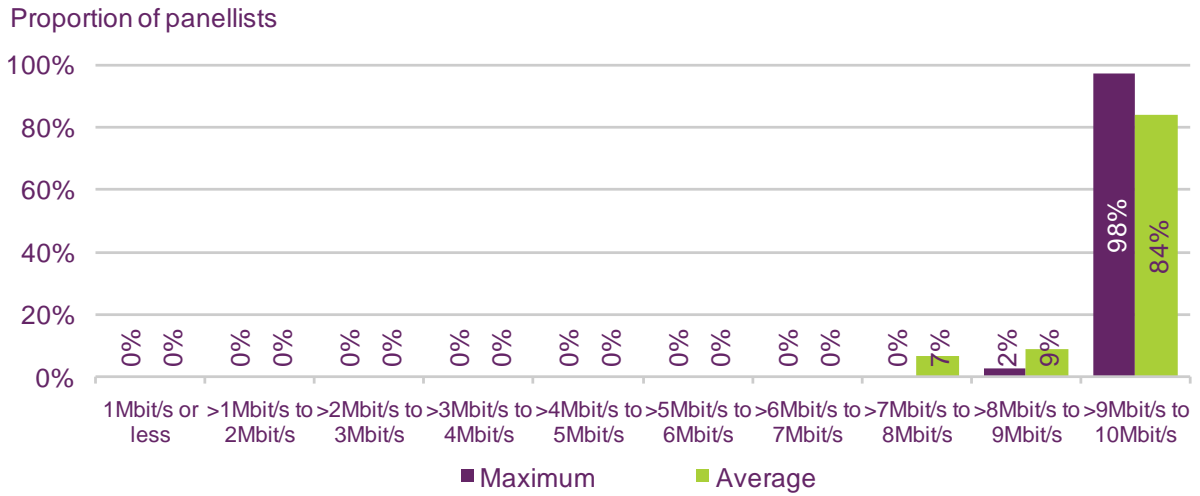
Source: SamKnows measurement data for panel members with a connection in November 2011. Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK ADSL 'up to' 8Mbit/s and 10Mbit/s 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' 20Mbit/s and 'up to' 24Mbit/s ADSL packages, November 2011



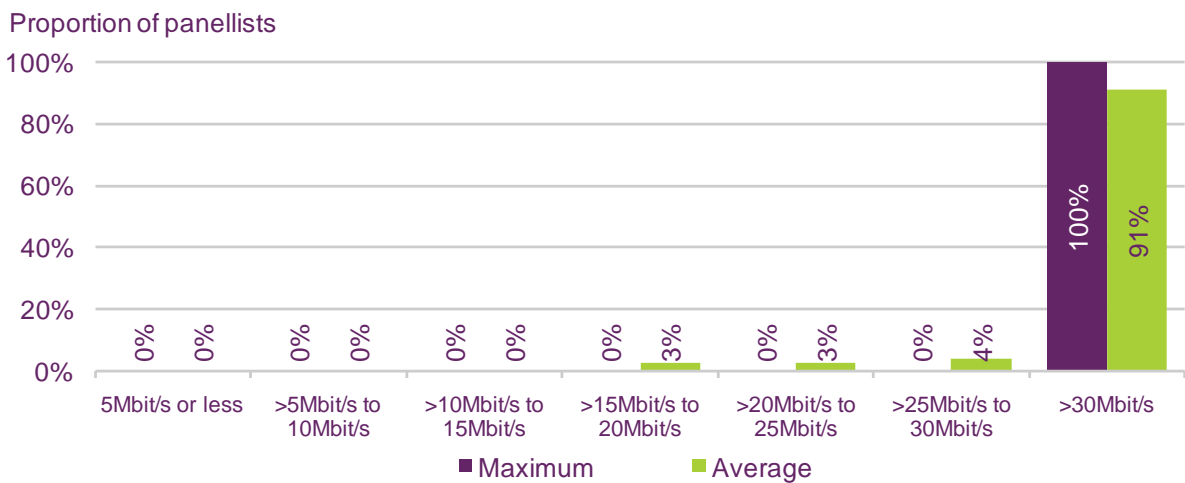
Source: SamKnows measurement data for panel members with a connection in November 2011. Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK ADSL 'up to' 20Mbit/s and 24Mbit/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' 10Mbit/s cable packages, November 2011



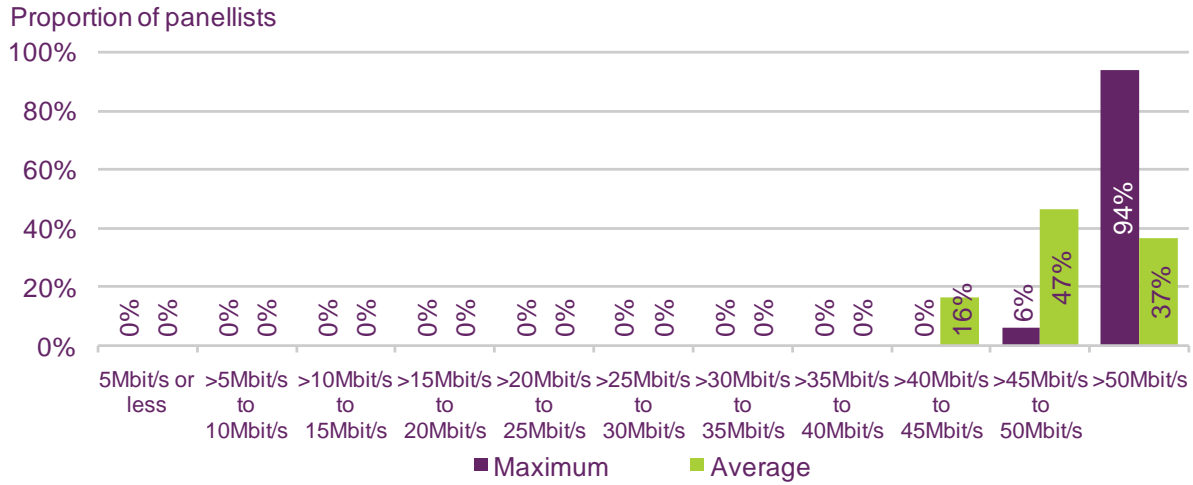
Source: SamKnows measurement data for panel members with a connection in November 2011.  
 Notes: (1) Data have been weighted to regional coverage to ensure that they are representative of UK cable 'up to' 10Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

**Figure 4** Distribution of maximum and average download speeds for consumers on 'up to' 30Mbit/s cable packages, November 2011



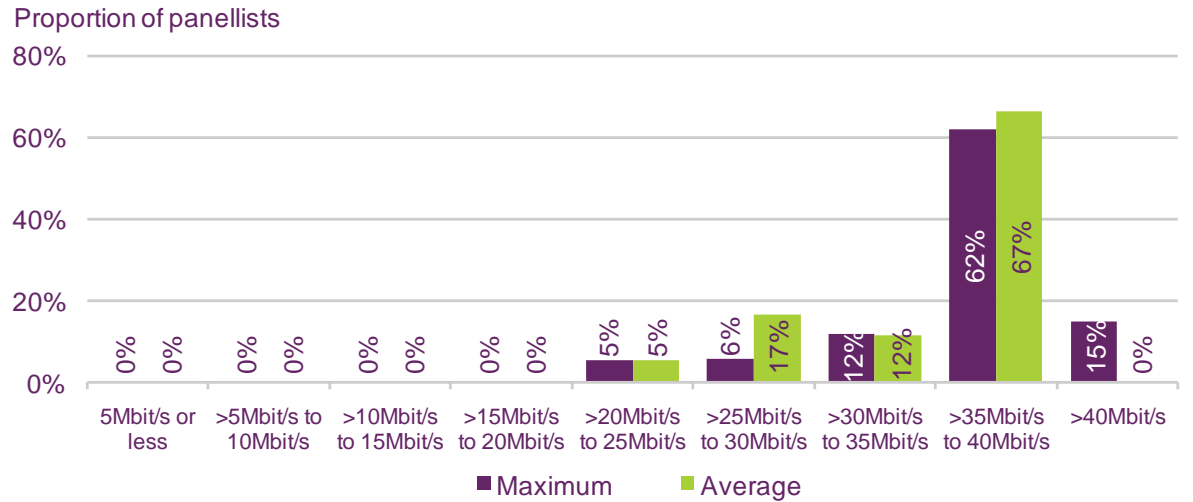
Source: SamKnows measurement data for panel members with a connection in November 2011.  
 Notes: (1) Data have been weighted to regional coverage to ensure that they are representative of UK cable 'up to' 30Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

**Figure 5 Distribution of maximum and average download speeds for consumers on 'up to' 50Mbit/s cable packages, November 2011**



Source: SamKnows measurement data for panel members with a connection in November 2011.  
 Notes: (1) Data have been weighted to regional coverage to ensure that they are representative of UK cable 'up to' 50Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

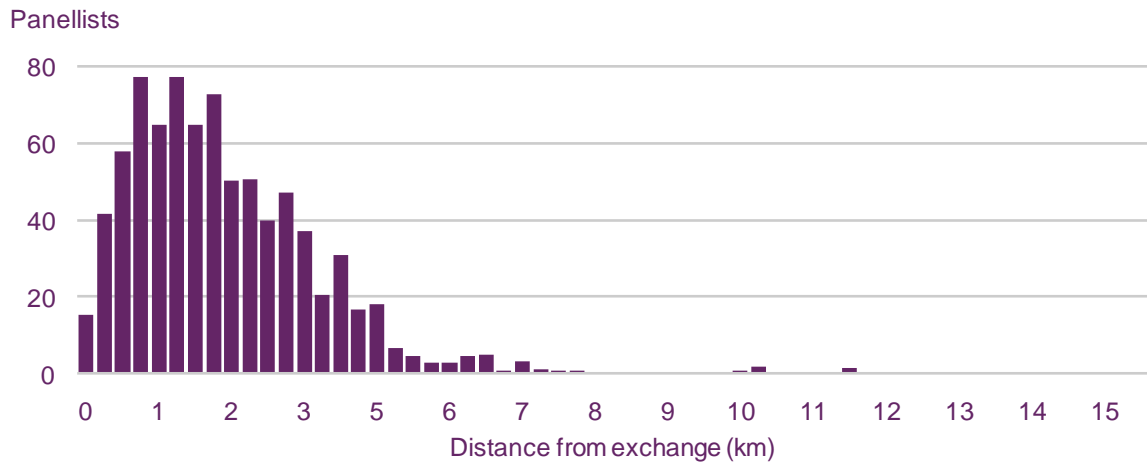
**Figure 6 Distribution of maximum and average download speeds for consumers on 'up to' 40Mbit/s FTTC packages, November 2011**



Source: SamKnows measurement data for panel members with a connection in November 2011.  
 Notes: (1) Data collected from multi-thread download speed tests.

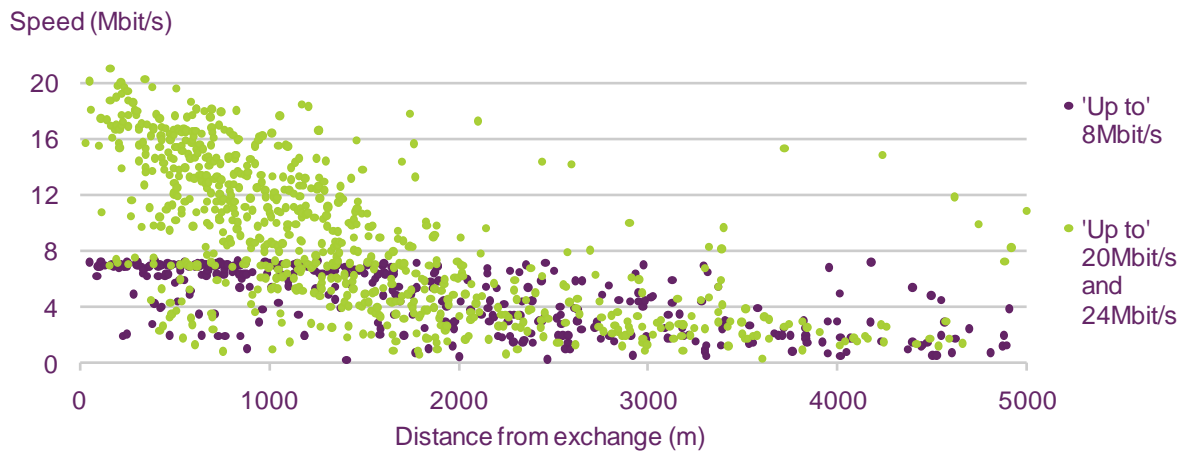
### Variation of speeds by geographic location

**Figure 7** Distribution of panellists, by distance from exchange



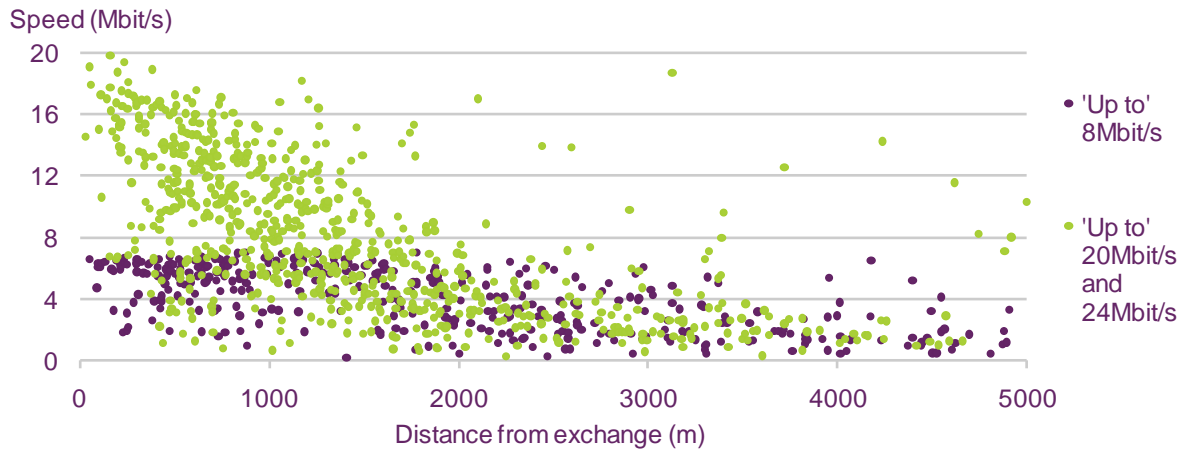
Source: Ofcom using data supplied by SamKnows

**Figure 8** Distance from exchange and maximum download speeds achieved by panellists on 'up to' 8Mbit/s and 'up to' 20Mbit/s and 'up to' 24Mbit/s ADSL packages, November 2011



Source: SamKnows measurement data for all panellists with an ADSL connection in November 2011. 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 'up to' 8Mbit/s and 'up to' 20Mbit/s and 'up to' 24Mbit/s ADSL packages, November 2011



Source: SamKnows measurement data for all panellists with an ADSL connection in November 2011. 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**

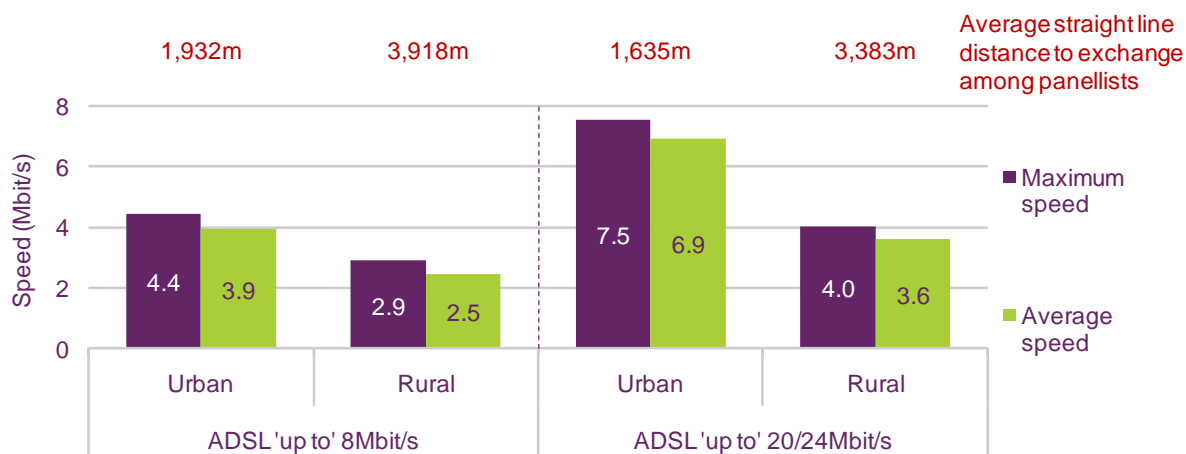
**Figure 10** Estimated average and maximum download speeds for broadband connections in rural & urban areas, November 2011



Source: SamKnows measurement data for all panel members with a connection in November 2011. Panel Base: 1325

Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in November 2011 and an estimated split between rural and urban areas; (3) Data collected from multi-thread download speed tests.

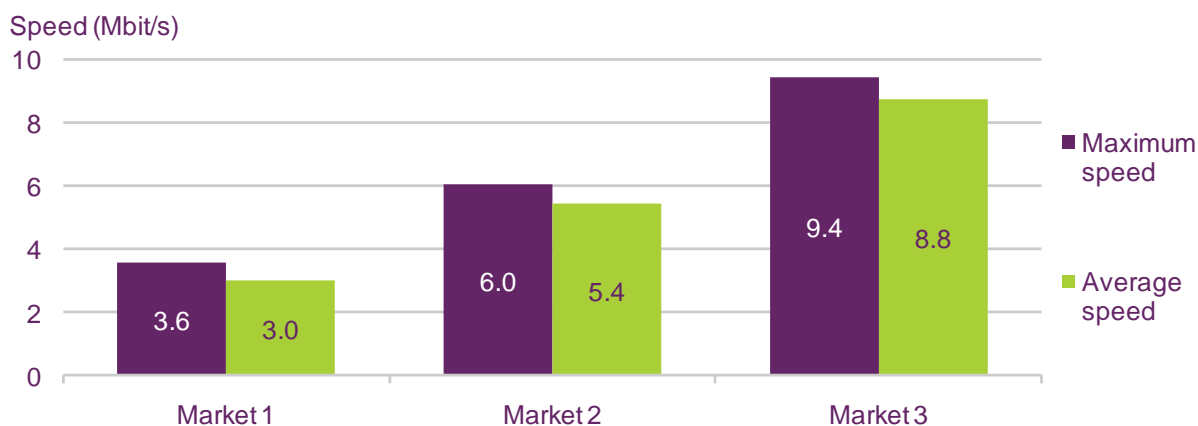
**Figure 11 Average and maximum download speeds for ADSL broadband connections in rural & urban areas, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011, 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, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011. Panel Base: 1325  
 Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in November 2011 and an estimated split between rural and urban areas; (3) Data collected from multi-thread download speed tests.

**Figure 13** Estimated average and maximum download speeds by UK nation, November 2011

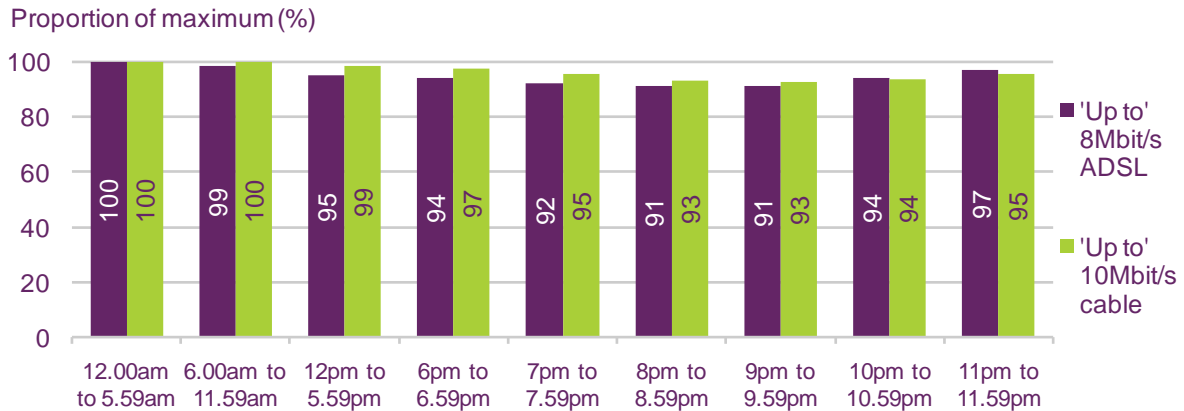


Source: SamKnows measurement data for all panel members with a connection in November 2011. Panel Base: 1325

Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in November 2011 and an estimated split between nations; (3) Data collected from multi-thread download speed tests.

**Variation of speeds by time of day**

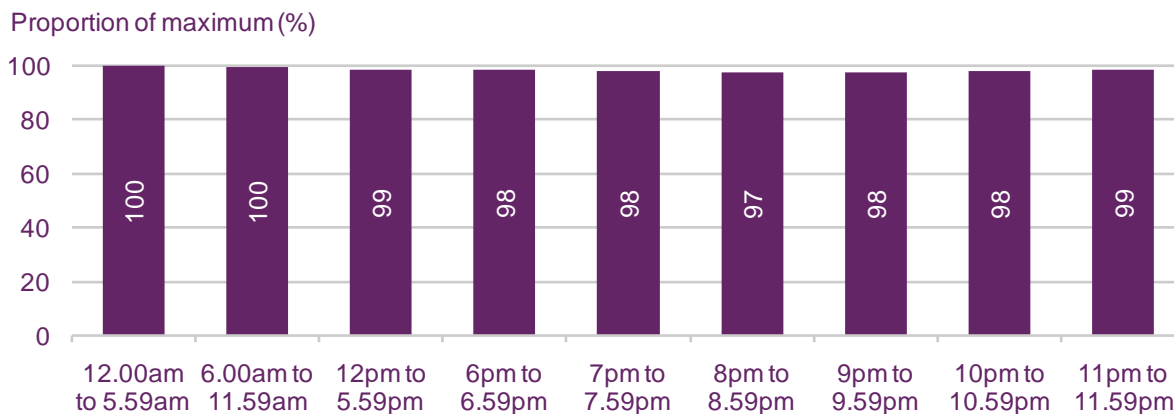
**Figure 14** Average download speed as a proportion of maximum speed by time of day for 'up to' 8Mbit/s and 'up to' 10Mbit/s ISP packages, November 2011



Source: SamKnows measurement data for all panel members with a connection in November 2011.

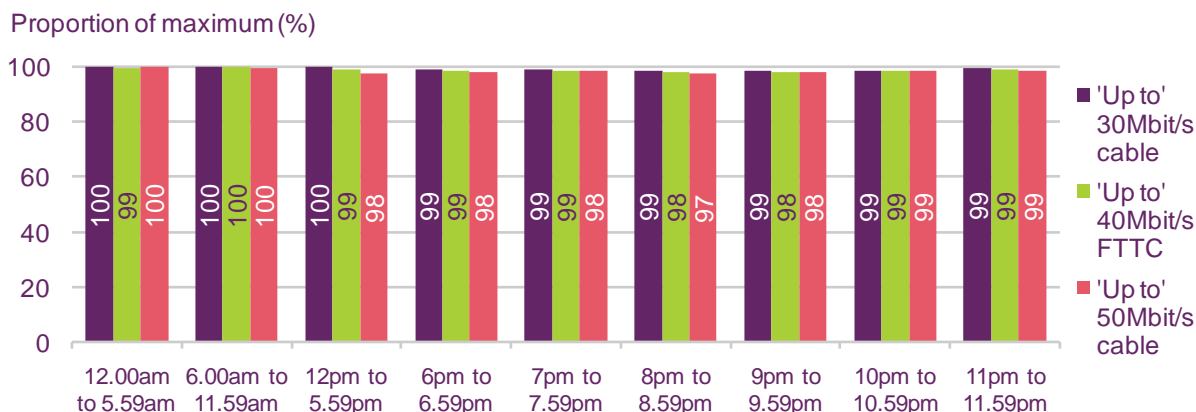
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK 'up to' 8Mbit/s and 10Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

**Figure 15** Average download speed as a proportion of maximum speed by time of day for 'up to' 20Mbit/s and 'up to' 24Mbit/s ADSL ISP packages, November 2011



Source: SamKnows measurement data for all panel members with a connection in November 2011. 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' 20Mbit/s and 24Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

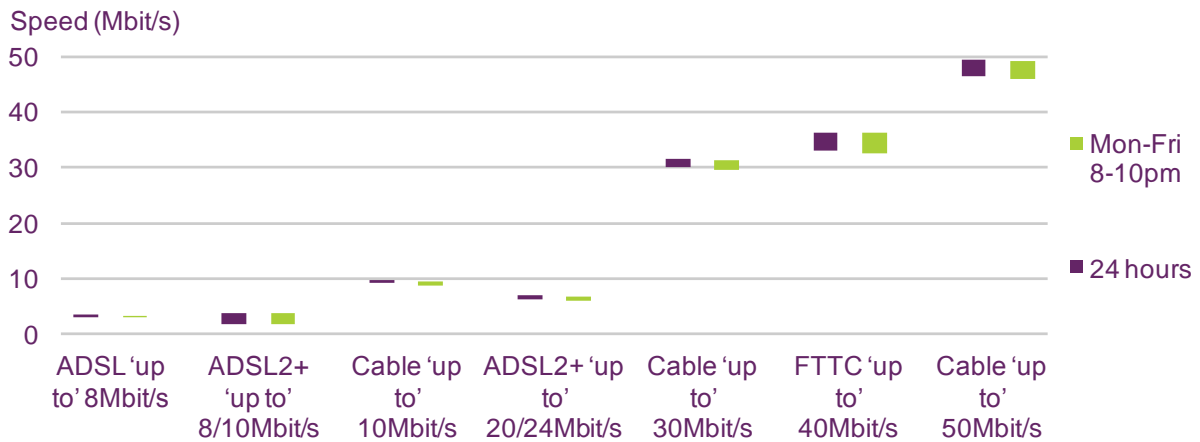
**Figure 16** Average download speeds as a proportion of maximum speed by time of day for above 'up to' 24Mbit/s ISP packages, November 2011



Source: SamKnows measurement data for all panel members with a connection in November 2011. 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' 30Mbit/s, 40Mbit/s and 50Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

**Variation in speeds by access technology**

**Figure 17 Average download speeds by technology and headline speed, November 2011**

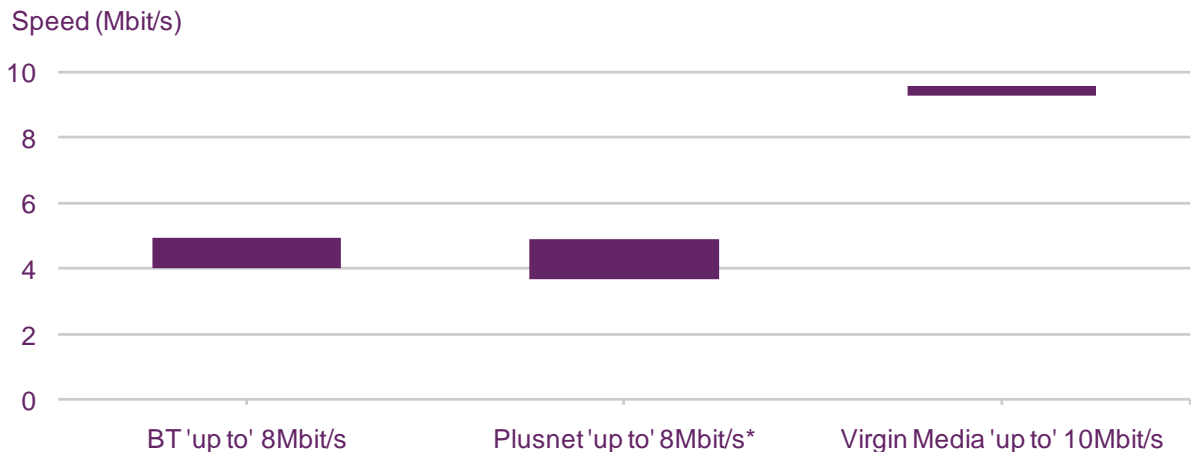


Source: SamKnows measurement data for all panel members with a connection in November 2011. Panel Base: 1325

Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, rural/urban, geographic market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in November 2011; (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**

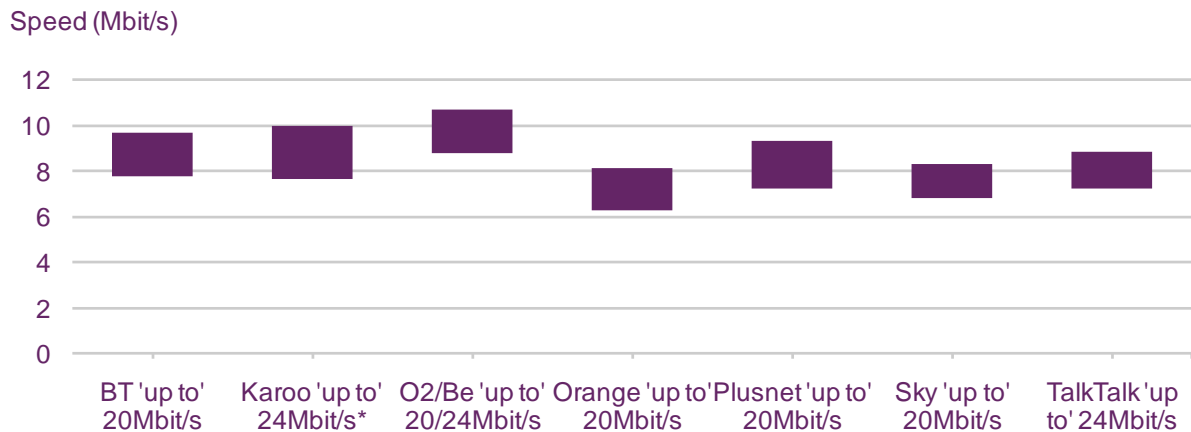
**Figure 18 Average download speeds for 'up to' 8Mbit/s and 'up to' 10Mbit/s ISP packages, 24 hours, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011. \*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 19 Average download speeds for 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, 24 hours, November 2011**

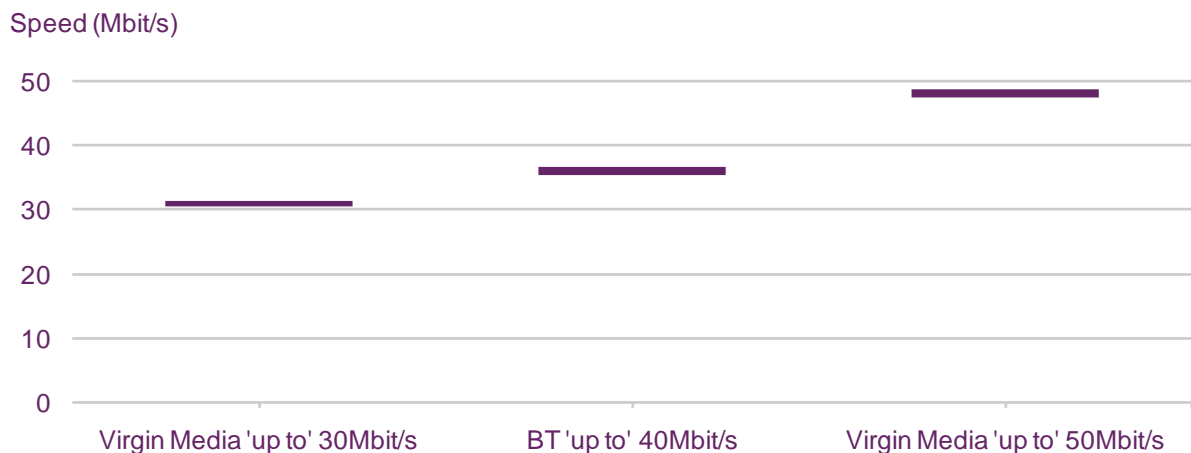


Source: SamKnows measurement data for all panel members with a connection in November 2011.

\*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 20 Average download speeds for above 'up to' 24Mbit/s packages, 24 hours, November 2011**

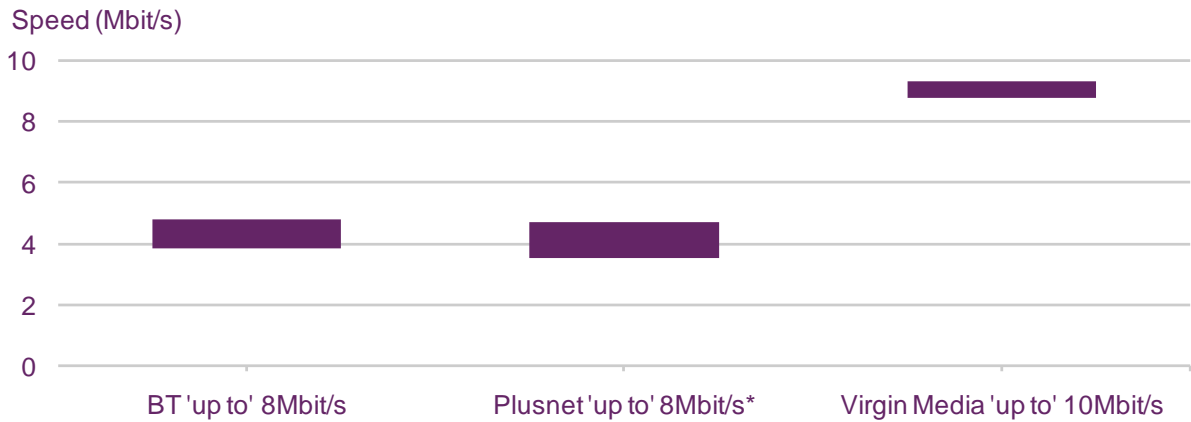


Source: SamKnows measurement data for all panel members with a connection in November 2011

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

**Results during peak periods**

**Figure 21 Average download speeds for ‘up to’ 8Mbit/s and ‘up to’ 10Mbit/s packages, 8pm to 10pm weekdays, November 2011**

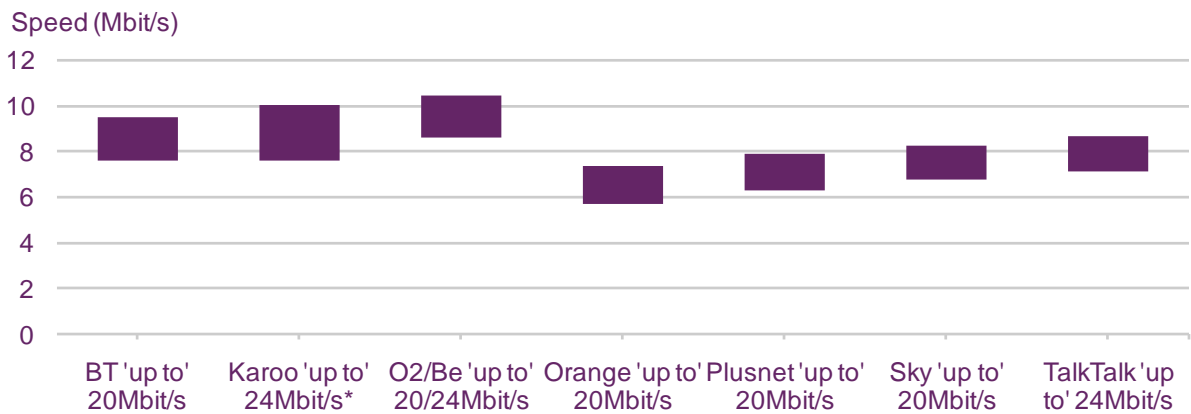


Source: SamKnows measurement data for all panel members with a connection in November 2011

\*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 22 Average download speeds for ‘up to’ 20Mbit/s and ‘up to’ 24Mbit/s packages, 8pm to 10pm weekdays, November 2011**

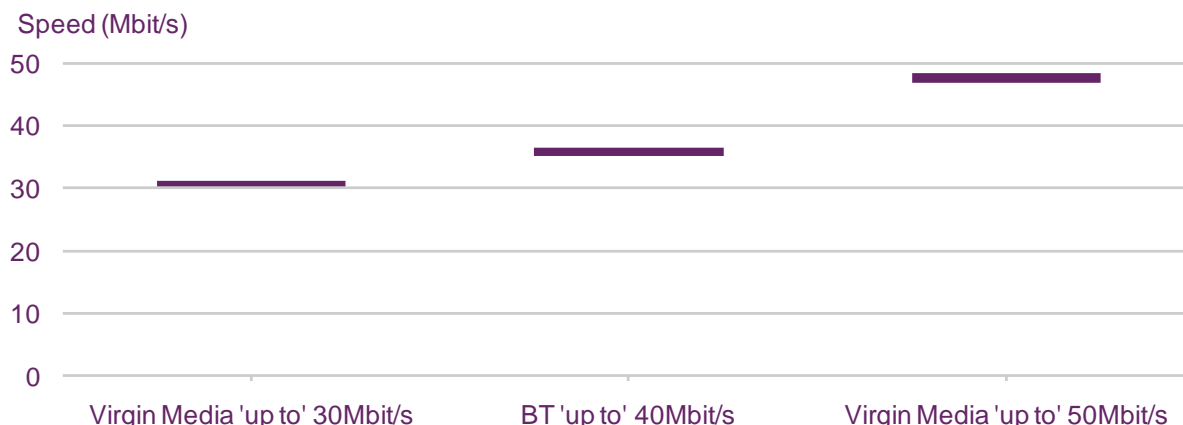


Source: SamKnows measurement data for all panel members with a connection in November 2011.

\*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 23 Average download speeds for above 'up to' 24Mbit/s packages, 8pm to 10pm weekdays, November 2011**

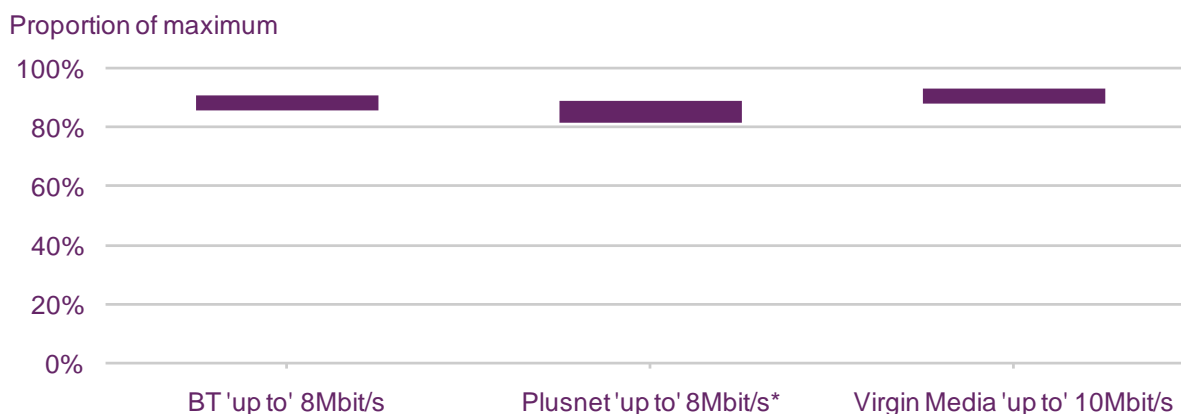


Source: SamKnows measurement data for all panel members with a connection in November 2011.

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**

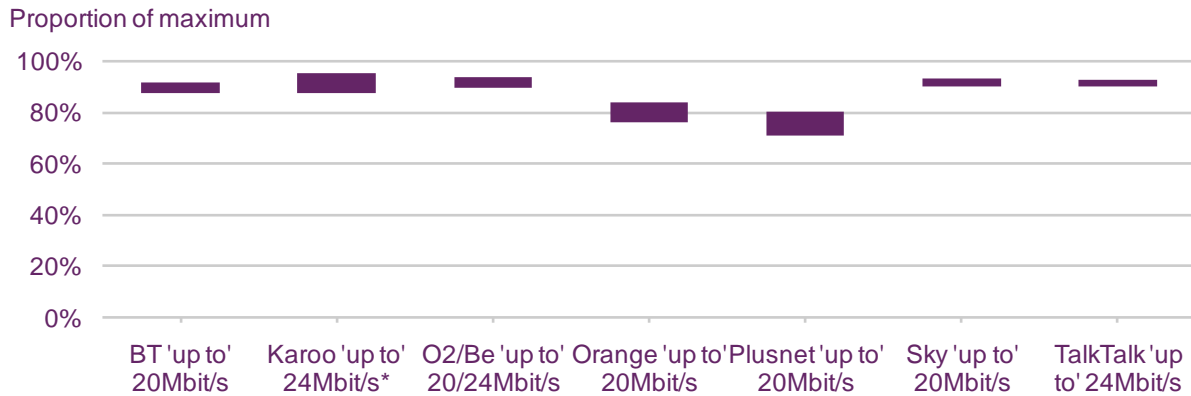
**Figure 24 Peak (8 to 10pm weekday) speeds as a proportion of maximum speeds for 'up to' 8Mbit/s and 'up to' 10Mbit/s connections by ISP package, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011. \*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.

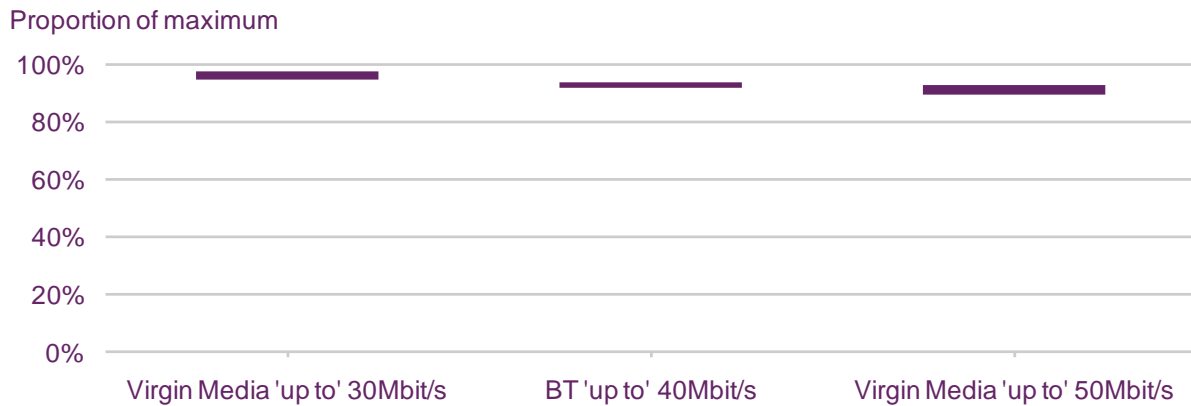
**Figure 25 Peak (8 to 10pm weekday) speeds as a proportion of maximum speeds for 'up to' 20Mbit/s and 'up to' 24Mbit/s connections by ISP package, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011.  
 \*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.

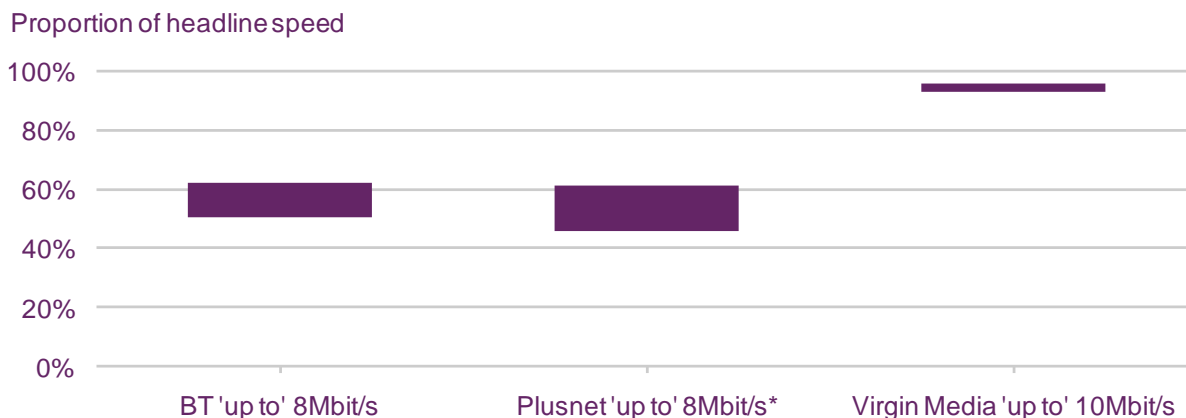
**Figure 26 Peak (8 to 10pm weekday) speeds as a proportion of maximum speeds for above 'up to' 24Mbit/s connections by ISP package, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011.  
 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.

### Average download speeds as a proportion of headline speeds

**Figure 27** Average download speeds (24 hours) as a proportion of headline speeds for 'up to' 8Mbit/s and 'up to' 10Mbit/s connections by ISP package, November 2011

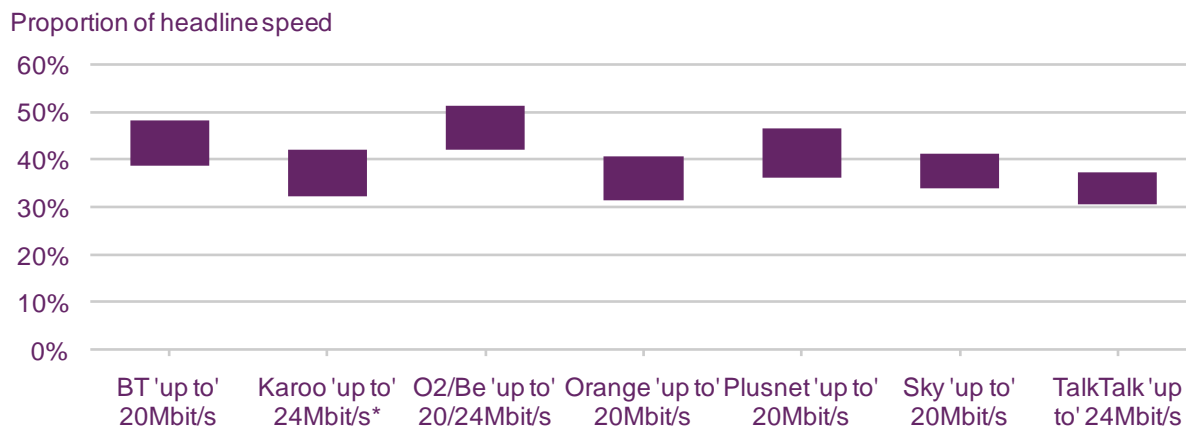


Source: SamKnows measurement data for all panel members with a connection in November 2011

\*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 28** Average download speeds (24 hours) as a proportion of headline speeds for 'up to' 20Mbit/s and 'up to' 24Mbit/s connections by ISP package, November 2011

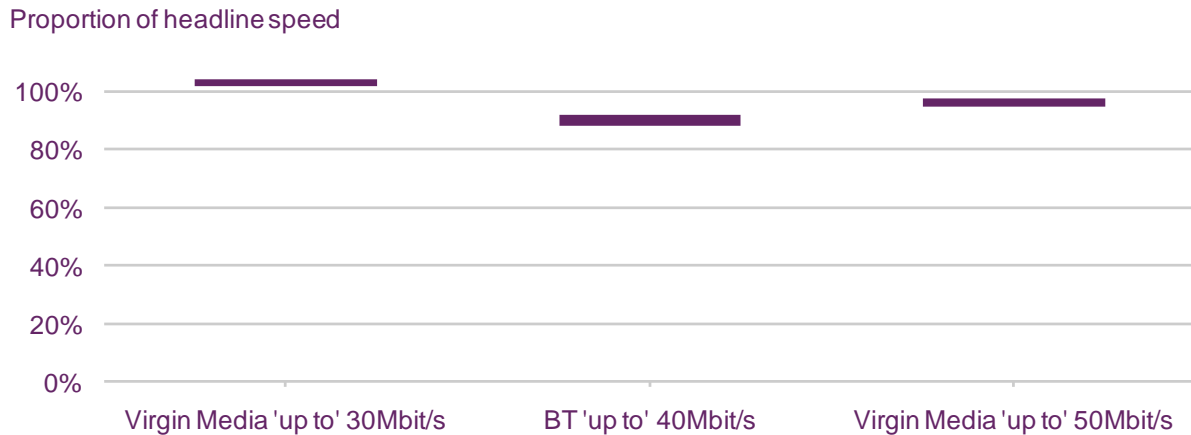


Source: SamKnows measurement data for all panel members with a connection in November 2011

\*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.

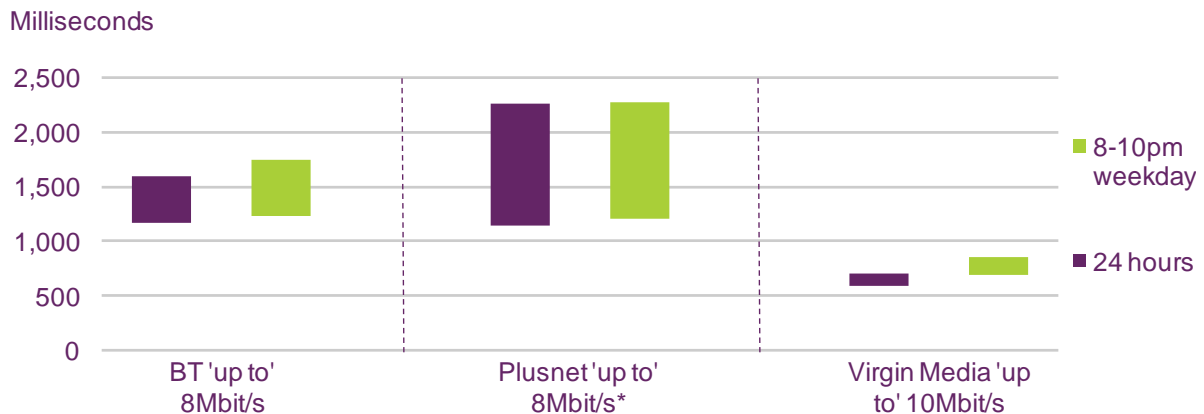
**Figure 29 Average download speeds (24 hours) as a proportion of headline speeds for above 'up to' 24Mbit/s connections by ISP package, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011. 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.

**Web browsing**

**Figure 30 Average and peak time loading of web pages for 'up to' 8Mbit/s and 'up to' 10Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011. \*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 31 Significant differences to a 95% level of confidence between average and peak time to load web pages for 'up to' 8Mbit/s and 'up to' 10Mbit/s packages, November 2011**

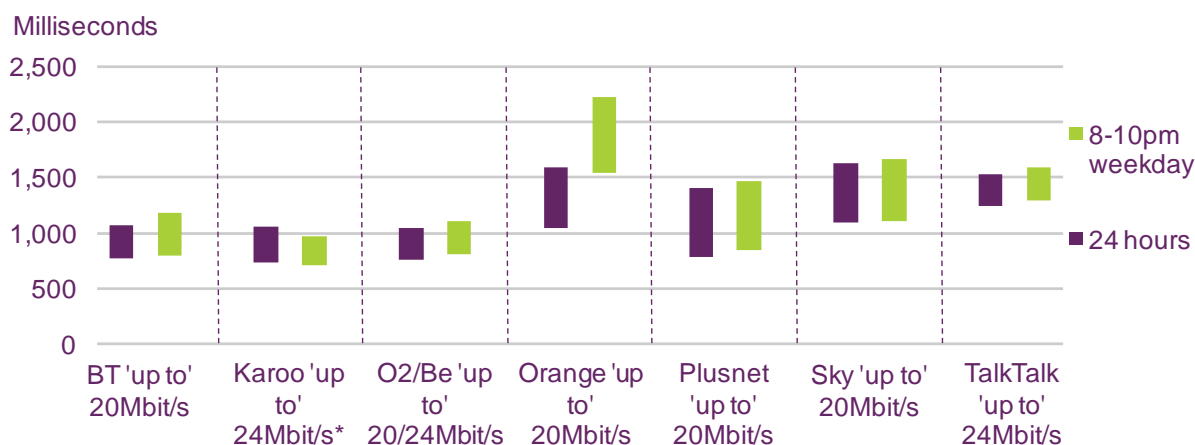
	24 hours	8-10pm weekday
<b>ISP package</b>	<b>Is faster than...</b>	<b>Is faster than...</b>
Virgin Media	BT and Plusnet*	BT and Plusnet*

Source: Ofcom

\*Caution: small sample size (<50)

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

**Figure 32 Average and peak time loading of web pages for 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011.

\*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 33 Significant differences to a 95% level of confidence between average and peak time to load web pages for 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, November 2011**

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

Source: Ofcom

\*Caution: small sample size (<50)

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

**Figure 34 Average and peak time loading of web pages for above ‘up to’ 24Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011. Notes: (1) Includes only ADSL customers within 5km of the exchange and in geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media’s cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Better performance is indicated by a faster loading time, i.e. lower values.

**Figure 35 Significant differences to a 95% level of confidence between average and peak time to load web pages for above ‘up to’ 24Mbit/s and above packages, November 2011**

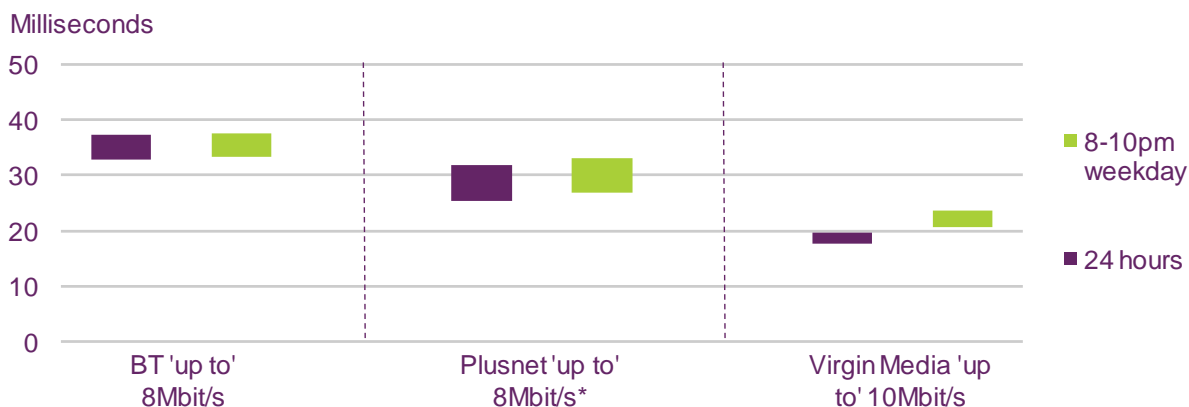
	24 hours	8-10pm weekday
<b>ISP package</b>	<b>Is faster than...</b>	<b>Is faster than...</b>
BT	No differences	Virgin Media 30*

Source: Ofcom

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

**Latency**

**Figure 36 Average and peak time latency for 'up to' 8Mbit/s and 'up to' 10Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011.

\*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 37 Significant differences to a 95% level of confidence between latency for 'up to' 8Mbit/s and 'up to' 10Mbit/s ISP packages, average and peak times, November 2011**

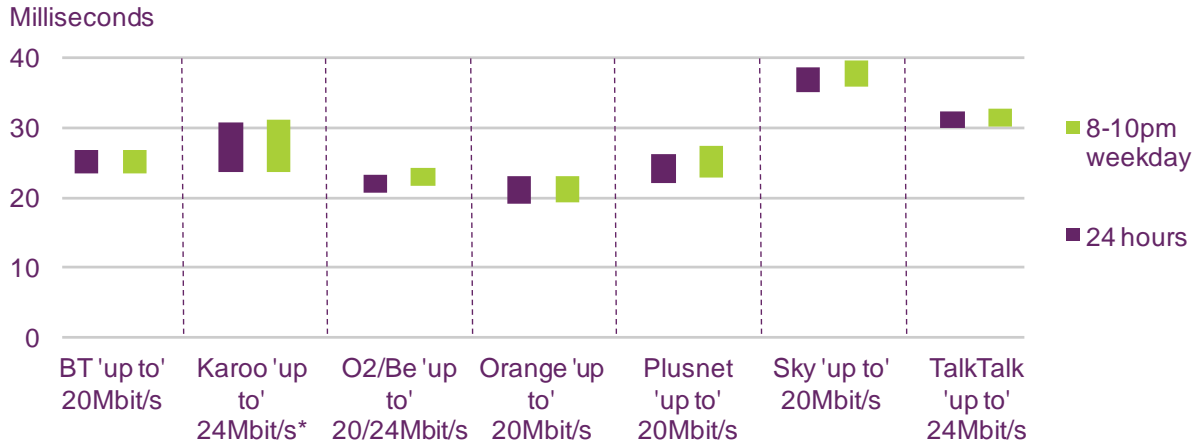
	24 hours	8-10pm weekday
ISP package	Is better than...	Is better than...
Virgin Media	BT and Plusnet*	BT and Plusnet*
Plusnet*	BT	BT**

Source: Ofcom

\*Caution: small sample size (<50)

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

**Figure 38 Average and peak time latency for 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011.

\*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 39 Significant differences to a 95% level of confidence between average and peak time latency for 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, November 2011**

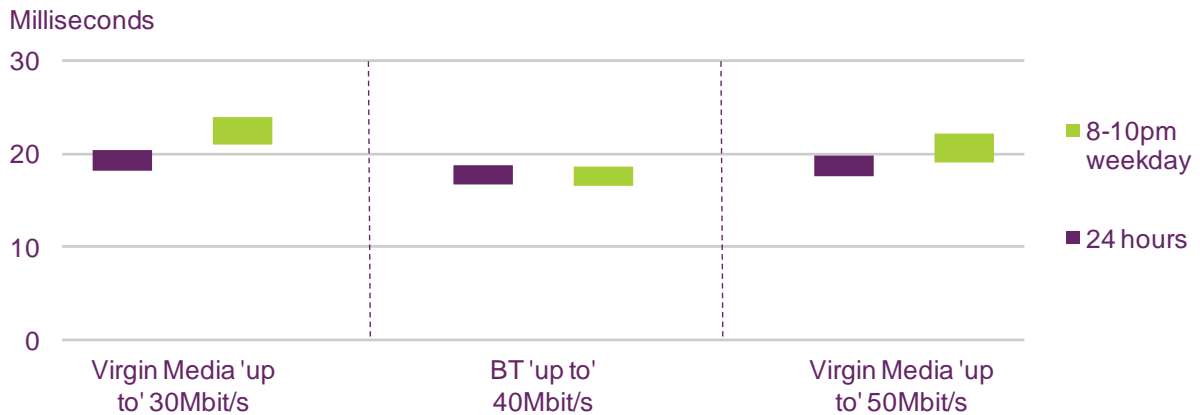
ISP package	24 hours	8-10pm weekday
	Is better than...	Is better than...
Orange	BT**, Karoo***, Sky and TalkTalk	BT**, Karoo***, Plusnet**, Sky and TalkTalk
O2/Be	BT**, Karoo***, Sky and TalkTalk	Sky and TalkTalk
BT	Sky and TalkTalk	Sky and TalkTalk
Plusnet	Sky and TalkTalk	Sky and TalkTalk
Karoo*	Sky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

Source: Ofcom

\*Caution: small sample size (<50)

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

**Figure 40 Average and peak time latency for above 'up to' 24Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011. 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 41 Significant differences to a 95% level of confidence between average and peak time latency for above 'up to' 24Mbit/s packages, November 2011**

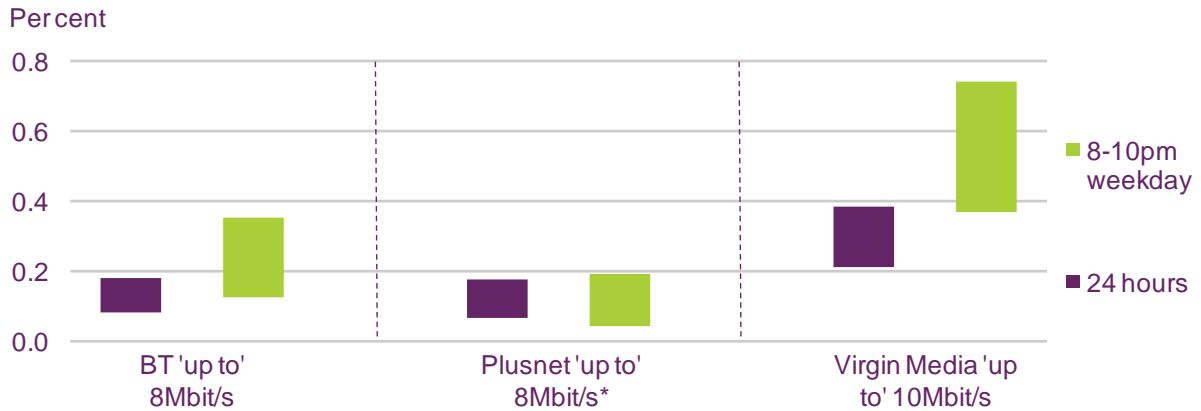
	24 hours	8-10pm weekday
<b>ISP package</b>	<b>Is better than...</b>	<b>Is better than...</b>
BT	No differences	Virgin Media 30 and Virgin Media 50*

Source: Ofcom

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

**Packet loss**

**Figure 42 Average and peak time packet loss for 'up to' 8Mbit/s and 'up to' 10Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011

\*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 43 Significant differences to a 95% level of confidence between average packet loss for 'up to' 8Mbit/s and 'up to' 10Mbit/s connections, November 2011**

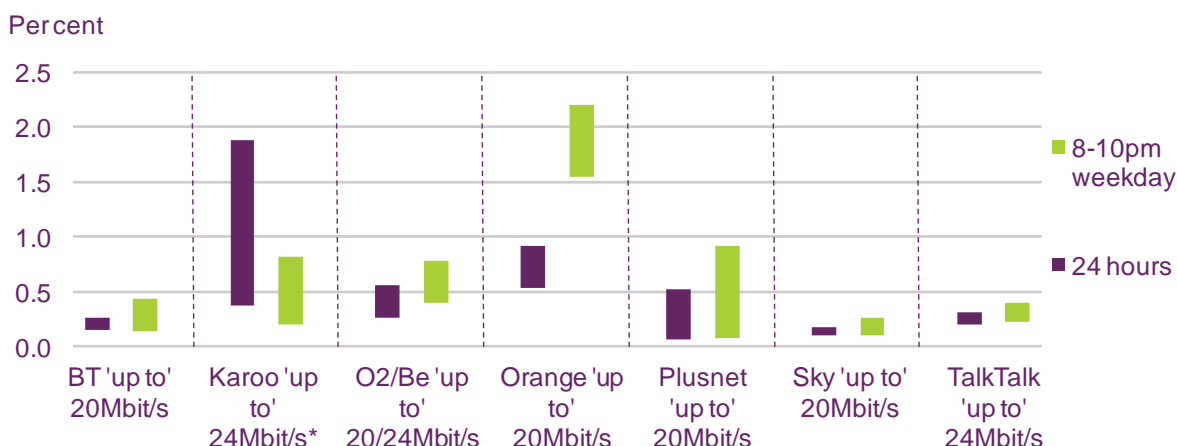
	24 hours	8-10pm weekday
ISP package	Is better than...	Is better than...
Plusnet*	Virgin Media	Virgin Media
BT	Virgin Media	Virgin Media**

Source: Ofcom

\*Caution: small sample size (<50)

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

**Figure 44 Average and peak time packet loss for 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011.

\*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 45 Significant differences to a 95% level of confidence between average packet loss for 'up to' 20Mbit/s and 'up to' 24Mbit/s connections, November 2011**

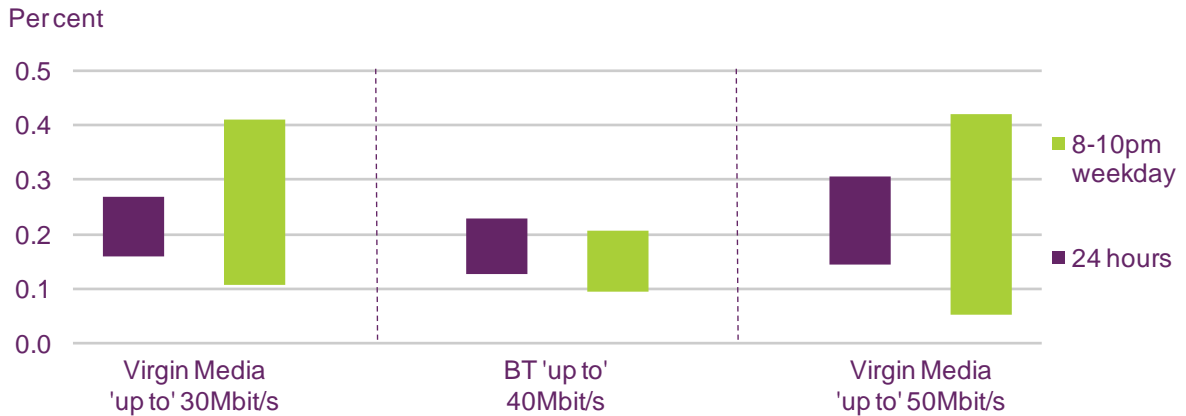
ISP package	24 hours	8-10pm weekday
	Is better than...	Is better than...
Sky	Karoo***, O2/Be and Orange	O2/Be and Orange
BT	Karoo***, O2/Be** and Orange	Orange
Plusnet	Orange**	Orange
Karoo*	No differences	Orange
O2/Be	No differences	Orange
TalkTalk	No differences	Orange

Source: Ofcom

\*Caution: small sample size (<50)

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

**Figure 46 Average and peak time packet loss for above 'up to' 24Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011. 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).

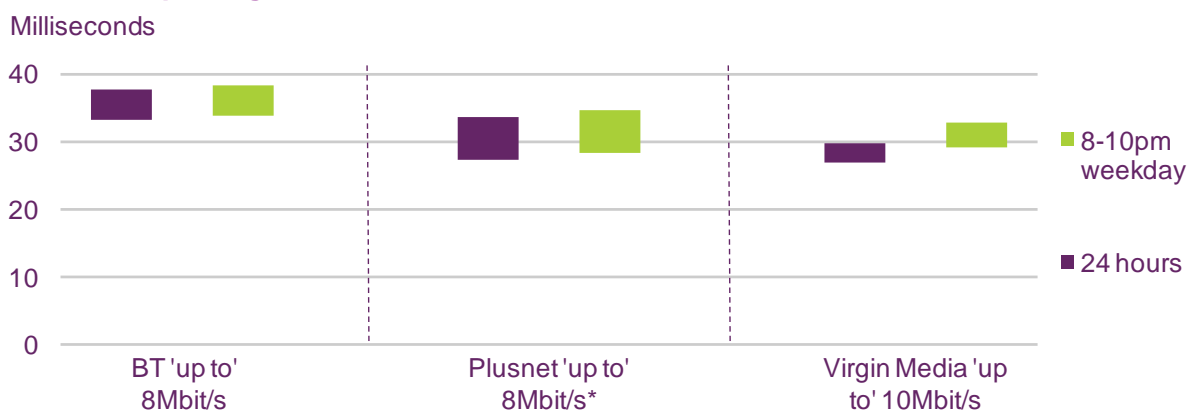
**Figure 47 Significant differences to a 95% level of confidence between average packet loss for above 'up to' 24Mbit/s connections, November 2011**

	24 hours	8-10pm weekday
<b>ISP package</b>	<b>Is better than...</b>	<b>Is better than...</b>
No differences	No differences	No differences

Source: Ofcom

## DNS resolution

**Figure 48** Average and peak time DNS resolution time for 'up to' 8Mbit/s and 'up to' 10Mbit/s packages, November 2011



Source: SamKnows measurement data for all panel members with a connection in November 2011.

\*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 49** Significant differences to a 95% level of confidence between DNS resolution time for 'up to' 8Mbit/s and 'up to' 10Mbit/s packages, November 2011

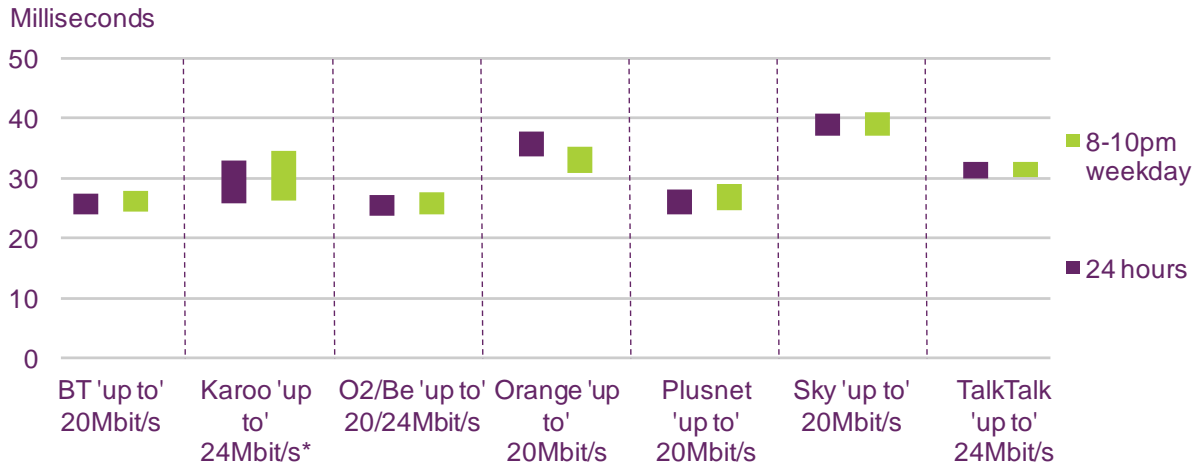
	24 hours	8-10pm weekday
ISP package	Is faster than...	Is faster than...
Virgin Media	BT	BT

Source: Ofcom

\*Caution: small sample size (<50)

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

**Figure 50 Average and peak time DNS resolution time for 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011.

\*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 51 Significant differences to a 95% level of confidence between DNS resolution time for 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, November 2011**

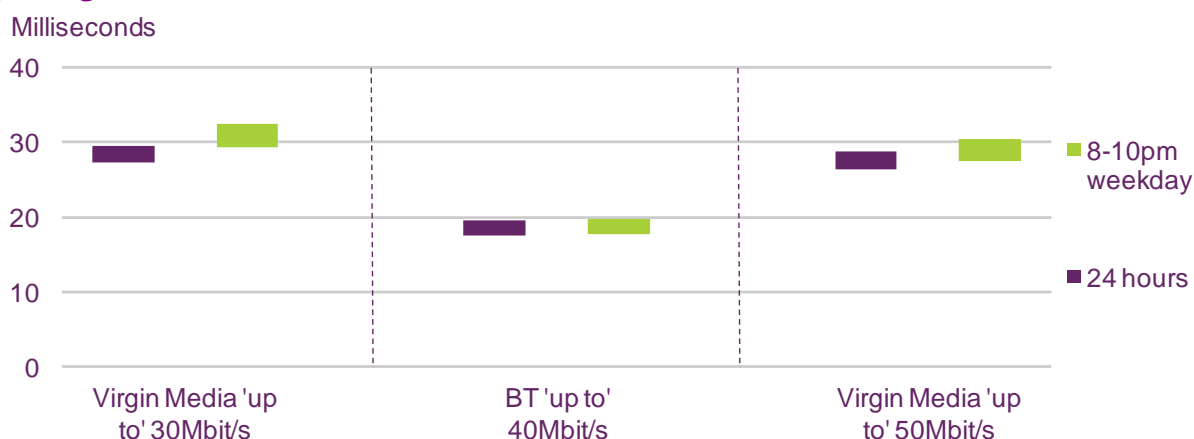
ISP package	24 hours	8-10pm weekday
BT	Orange, Sky and TalkTalk	Orange, Sky and TalkTalk
O2/Be	Orange, Sky and TalkTalk	Orange, Sky and TalkTalk
Plusnet	Orange, Sky and TalkTalk	Orange, Sky and TalkTalk
TalkTalk	Orange** and Sky	Sky
Karoo*	Orange** and Sky	Sky**

Source: Ofcom

\*Caution: small sample size (<50)

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

**Figure 52 Average and peak time DNS resolution time for above 'up to' 24Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011. 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 53 Significant differences to a 95% level of confidence between DNS resolution time for above 'up to' 24Mbit/s packages, November 2011**

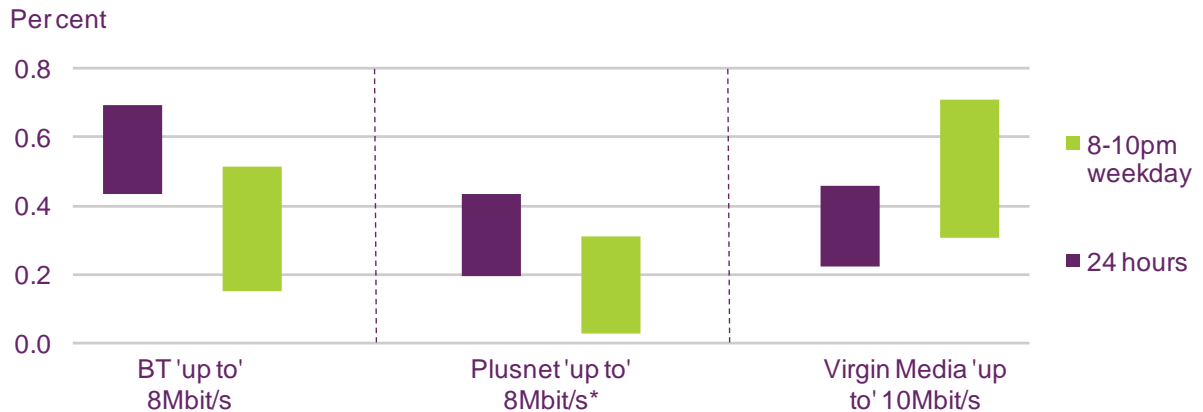
	24 hours	8-10pm weekday
<b>ISP package</b>	<b>Is faster than...</b>	<b>Is faster than...</b>
BT	Virgin Media 30 & Virgin Media 50	Virgin Media 30 & Virgin Media 50

Source: Ofcom

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

**DNS failure**

**Figure 54 Average and peak time DNS failure rates for 'up to' 8Mbit/s and 'up to' 10Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011.

\*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 55 Significant differences to a 95% level of confidence between DNS failure rates for 'up to' 8Mbit/s and 'up to' 10Mbit/s packages, November 2011**

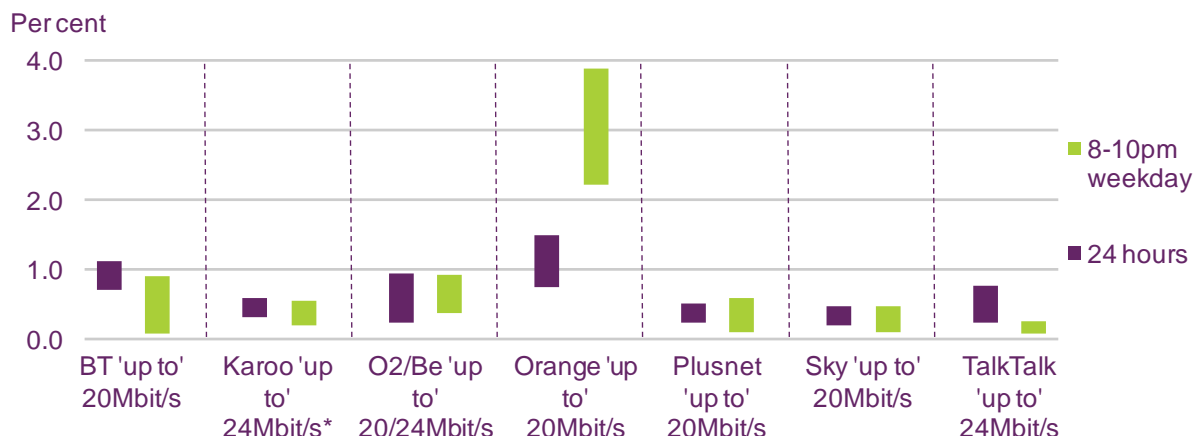
	24 hours	8-10pm weekday
ISP package	Is better than...	Is better than...
Virgin Media	BT and Plusnet	No differences
Plusnet	BT**	Virgin Media

Source: Ofcom

\*Caution: small sample size (<50)

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

**Figure 56 Average and peak time DNS failure rates for 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011  
 \*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 57 Significant differences to a 95% level of confidence between DNS failure rates for 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, November 2011**

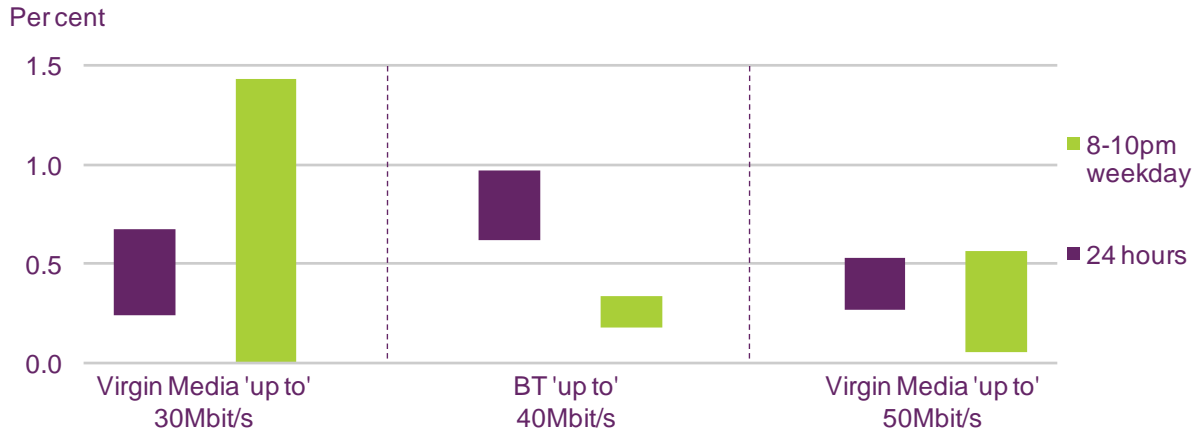
ISP package	24 hours	8-10pm weekday
	Is better than...	Is better than...
Sky	BT and Orange	Orange
Plusnet	BT and Orange	Orange
Karoo*	BT** and Orange	Orange
TalkTalk	No differences	O2/Be** and Orange
BT	No differences	Orange
O2/Be	No differences	Orange

Source: Ofcom

\*Caution: small sample size (<50)

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

**Figure 58 Average and peak time DNS failure rates for above 'up to' 24Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011. 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 59 Significant differences to a 95% level of confidence between DNS failure rates for above 'up to' 24Mbit/s packages, November 2011**

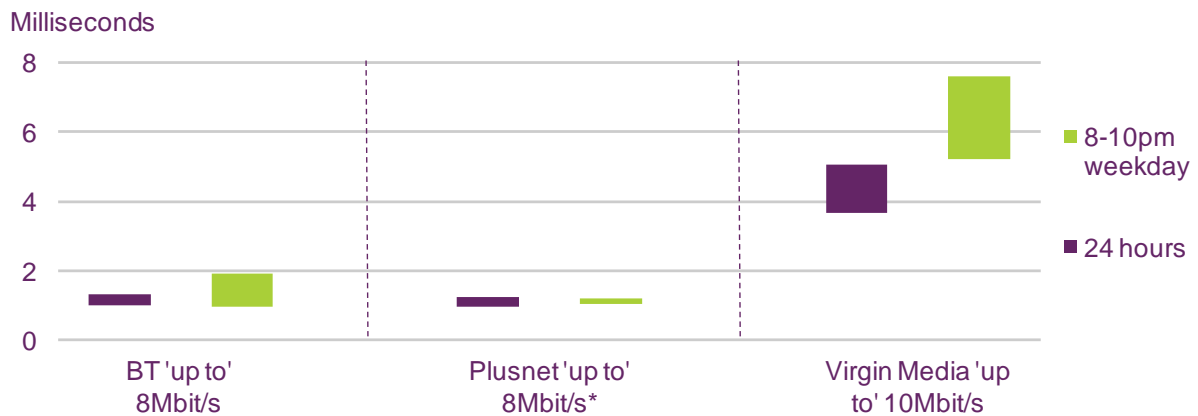
	24 hours	8-10pm weekday
<b>ISP package</b>	<b>Is better than...</b>	<b>Is better than...</b>
Virgin Media 50	BT*	No differences
Virgin Media 30	BT*	No differences

Source: Ofcom

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

**Jitter**

**Figure 60 Average and peak time upstream jitter for 'up to' 8Mbit/s and 'up to' 10Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011.

\*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 61 Significant differences to a 95% level of confidence between average and peak time upstream jitter for 'up to' 8Mbit/s and 'up to' 10Mbit/s packages, November 2011**

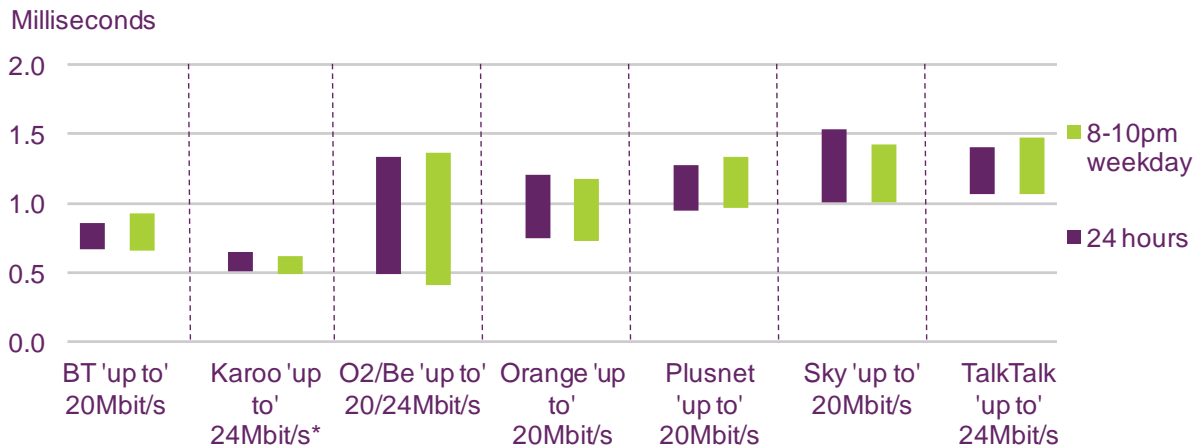
	24 hours	8-10pm weekday
ISP package	Is better than...	Is better than...
BT	Virgin Media	No Differences
Plusnet*	Virgin Media	No Differences

Source: Ofcom

\*Caution: small sample size (<50)

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

**Figure 62 Average and peak time upstream jitter for 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011.

\*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 63 Significant differences to a 95% level of confidence between average and peak time upstream jitter for 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, November 2011**

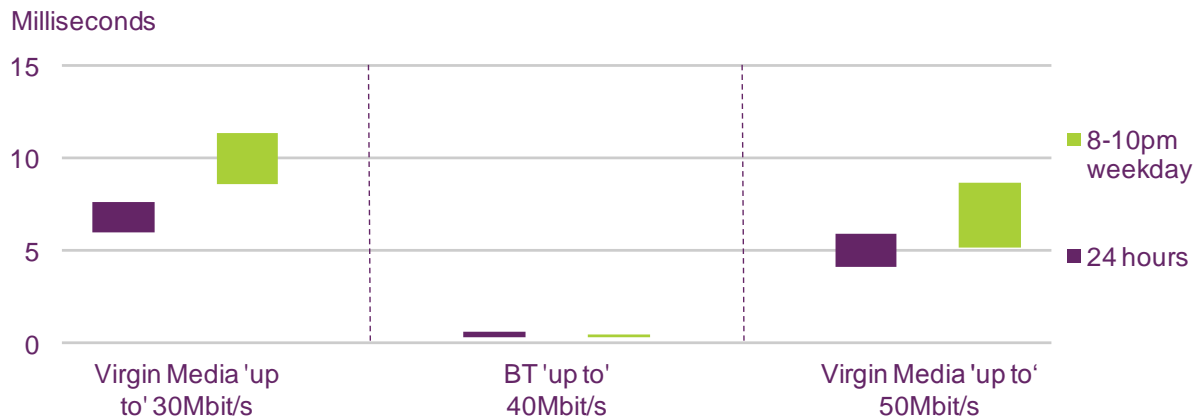
ISP package	24 hours	8-10pm weekday
	<b>Is better than...</b>	<b>Is better than...</b>
Karoo*	BT**, Orange, Plusnet, Sky and TalkTalk	Orange, Plusnet, Sky and TalkTalk
BT	Plusnet, Sky** and TalkTalk	Plusnet** and TalkTalk**

Source: Ofcom

\*Caution: small sample size (<50)

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

**Figure 64 Average and peak time upstream jitter for above 'up to' 24Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011.

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).

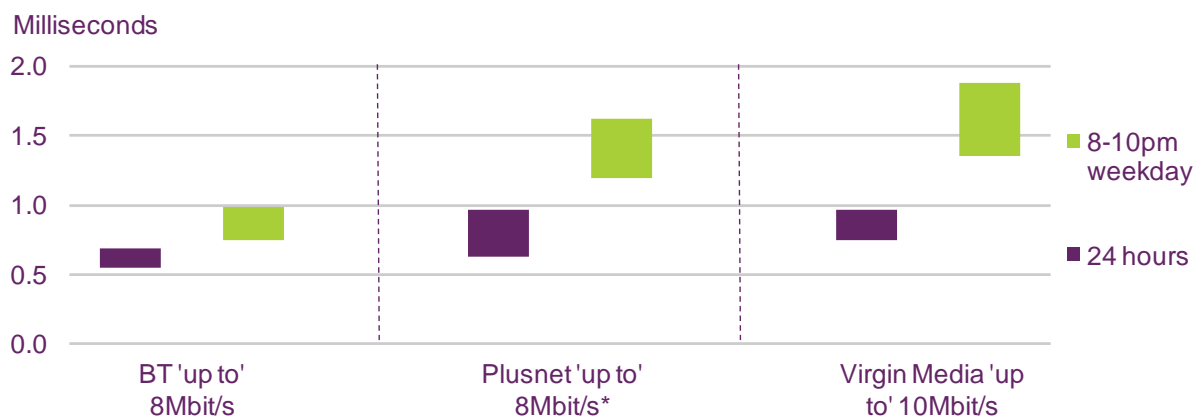
**Figure 65 Significant differences to a 95% level of confidence between average and peak time upstream jitter for above 'up to' 24Mbit/s packages, November 2011**

	24 hours	8-10pm weekday
ISP package	Is better than...	Is better than...
BT	Virgin Media 30 and Virgin Media 50	Virgin Media 30 and Virgin Media 50

Source: Ofcom

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

**Figure 66 Average and peak time downstream jitter for 'up to' 8Mbit/s and 'up to' 10Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011.

\*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 67 Significant differences to a 95% level of confidence between average and peak time downstream jitter for 'up to' 8Mbit/s and 'up to' 10Mbit/s packages, November 2011**

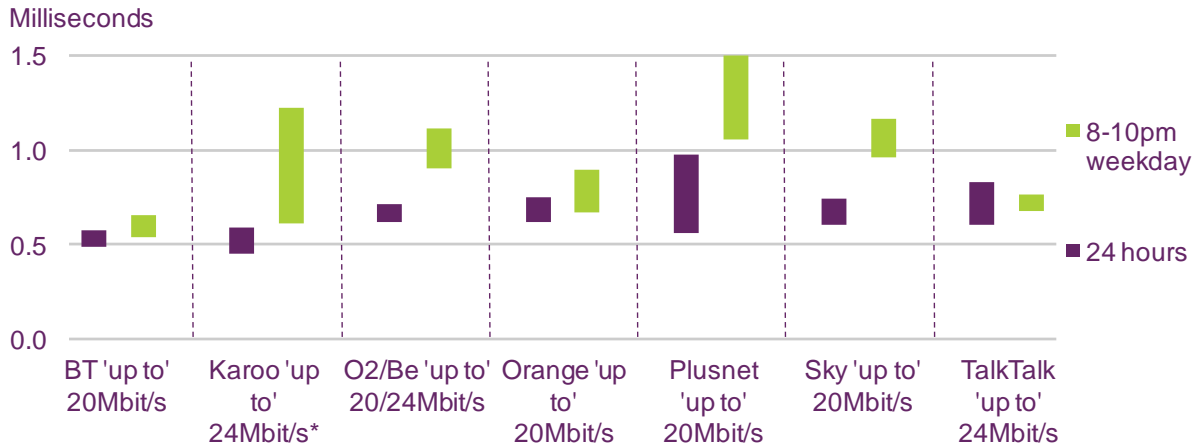
	24 hours	8-10pm weekday
ISP package	Is better than...	Is better than...
BT	Plusnet** ** and Virgin Media	Plusnet* and Virgin Media

Source: Ofcom

\*Caution: small sample size (<50)

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

**Figure 68 Average and peak time downstream jitter for 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011.

\*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.

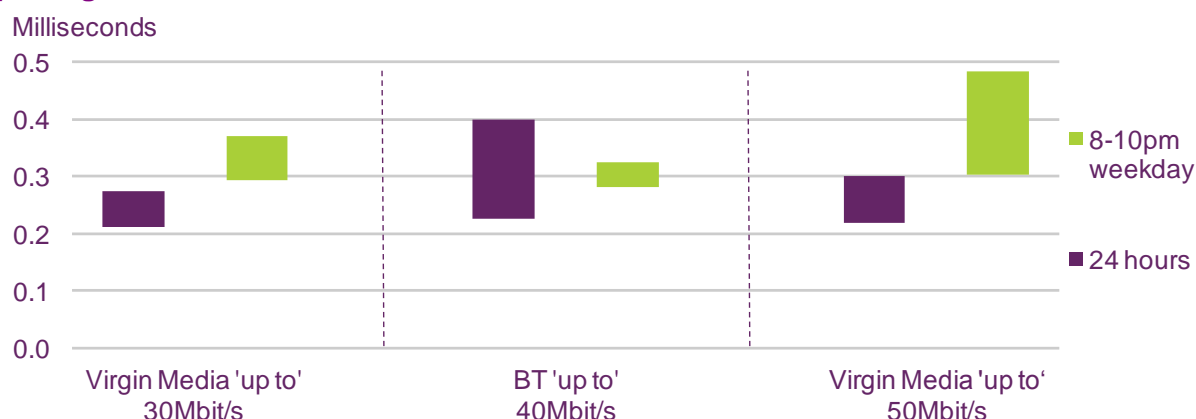
**Figure 69 Significant differences to a 95% level of confidence between average and peak time downstream jitter for 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, November 2011**

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

Source: Ofcom

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

**Figure 70 Average and peak time downstream jitter for above 'up to' 24Mbit/s packages, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011. 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 71 Significant differences to a 95% level of confidence between average and peak time downstream jitter for 'up to' 20Mbit/s and 24Mbit/s packages, November 2011**

	24 hours	8-10pm weekday
<b>ISP package</b>	<b>Is better than...</b>	<b>Is better than...</b>
No differences	No differences	No differences

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

## Annex 2

# Technical and research methodologies

## 1. Technical methodology

This report is Ofcom's sixth fixed-line residential broadband speeds report and the fifth 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 existing 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). 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.

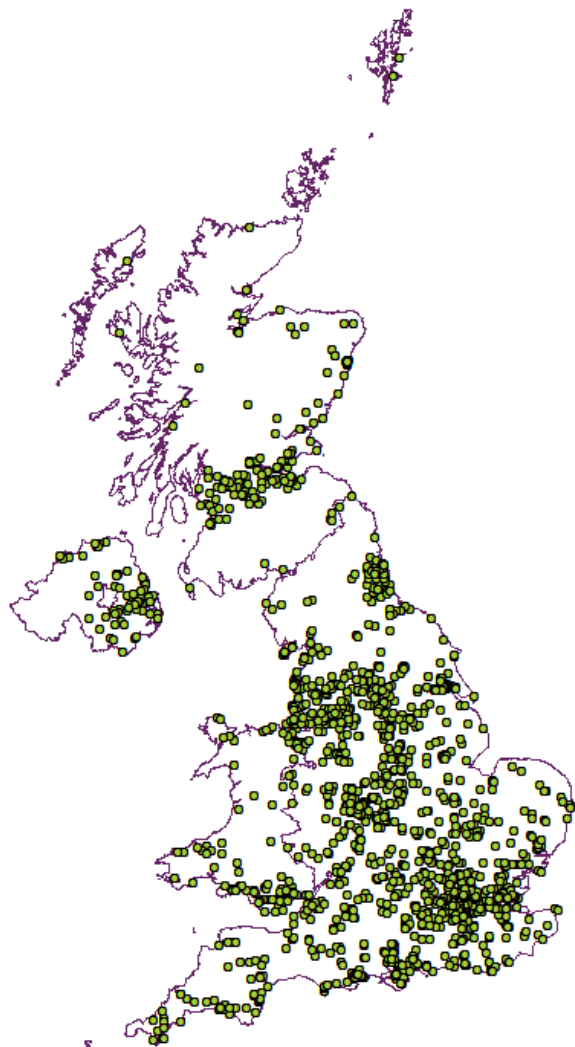
### Connections with usage caps

Some of the test units were deployed on broadband connection 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 is taken from a base of 1,710 panellists who had a broadband monitoring unit connected to their router in November 2011. 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<sup>15</sup>). These were an important consideration in recruiting our panel and applying statistical analysis because they enabled us to ensure that our panel was representative of the UK residential broadband market as a whole, and facilitated like-for-like comparison between ISP packages:

- Each panellist was assigned to one of the geographic markets, and we weighted the analysis accordingly to ensure that our overall findings were representative of UK residential broadband performance as a whole (for example, as Market 1 represents 11.7% of UK premises, we ensured that performance data from panellists in Market 1 contributed 11.7% towards the overall computation of UK residential broadband performance).
- For comparisons of ISP package performance we 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 to the data for 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
<b>The Kingston-upon-Hull area</b>	Those geographic areas covered by exchanges where Kingston Communications is the only operator	14	0.7%
<b>Market 1</b>	Those geographic areas covered by exchanges where BT is the only operator	3,388	11.7%
<b>Market 2</b>	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%
<b>Market 3</b>	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

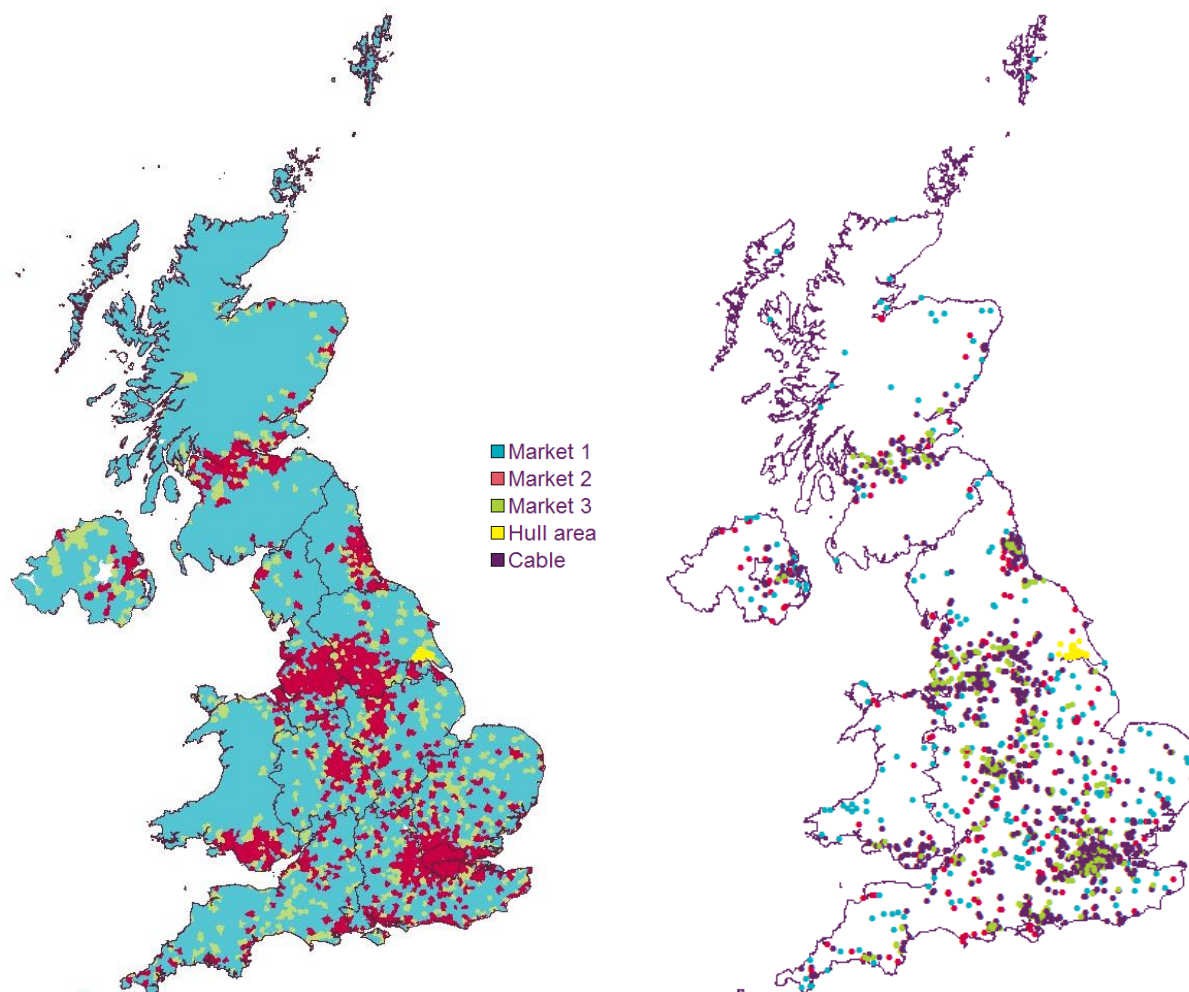
(<http://stakeholders.ofcom.org.uk/binaries/consultations/wba/statement/wbastatement.pdf>)

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.

<sup>15</sup> 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>.

**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<sup>16</sup> 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. Detail on the statistical methodology used is provided in Annex 3. The methods of analysis for the provider-specific comparison are based on those used in the July 2009 report which

<sup>16</sup> <http://www.sr-b.co.uk/>.

had expert review and endorsement by econometrician Professor Andrew Chesher of University College London<sup>17</sup>.

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<sup>17</sup> 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/](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 572 million<sup>18</sup> 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

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<sup>18</sup> 433 million of these were to test connection latency.

quality of the particular consumer's telephone line. Therefore, providers that 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<sup>19</sup>. 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.

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.

The panel is currently over-representative of the higher-speed packages, with 32% of the sample contributing less than 0.5 a response towards the UK average; this is a decrease of 7% since May 2011, as 'up to' 20/24Mbit/s services now represent a larger portion of the market. 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

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<sup>19</sup> 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.

(1.1% of the total in November 2011, and a reduction from 1.5% since May 2011). In our first round of research conducted between October 2008 and April 2009<sup>20</sup>, we found that the speeds delivered by 'up to' 2Mbit/s and less packages were consistent over time and between providers. In this report we have used data from 'up to' 2Mbit/s and less packages collected in April 2009 as representative of the performance of these packages, and have weighted them in accordingly when we present overall UK performance. There is only one remaining panellist that uses 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 regarding which package they were using on the sampling.

In total 2,795 measurement units were despatched, and 1,706 of these were connected by panellists between 1st and 31st November 2011. Of these, 1,226 supplied data to the UK average, and 1,118 to the named ISP package comparisons.

**Figure 1 Panellist numbers**

Sample set	Number
<b>Total number of boxes dispatched</b>	<b>2,561</b>
<b>Total number of boxes connected</b>	<b>1,706</b>
Excluded because of missing data, (i.e. measurements, packages, distance)	56
Excluded 'up to' 2Mbit/s	1
Other Exclusions to improve UK sample weighting (i.e. distance, market classification, region, ISP)	130
<b>Total participants included in UK Analysis</b>	<b>1,118</b>
<b>Total participants included in ISP Package Analysis</b>	<b>1,226</b>

Source: Ofcom

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

The average number of measurements per respondent for the 24-hour multi-thread download speed tests in November 2011 was 490, from a theoretical maximum of 662 per respondent (i.e. if all panellists had their monitoring unit connected on 1st May and all

<sup>20</sup> 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/](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/](http://stakeholders.ofcom.org.uk/market-data-research/telecoms-research/broadband-speeds/broadband_speeds/).

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 factor limiting the accuracy of the analysis reported here is 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.

Plusnet's 'up to' 8Mbit/s service and Karoo's 'up to' 24Mbit/s service achieved the minimum threshold of 40 against the specified criteria (with 41 and 43 panellists respectively) and are included in these findings with a warning regarding small sample size.

The results and analysis of the 1,706 panellists' measurement results were divided into two separate datasets, each weighted to targets.

- **National panel** (over 'up to' 2Mbit/s packages): 1,226 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**: 1,262 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 criteria 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 some 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 for 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):

- **‘Up to’ 8Mbit/s ADSL packages** were weighted to fit a modelled distribution of straight-line distance between premises and LLU exchanges, Gamma  $a=2.060$   $b=760$
  - **‘Up to’ 20Mbit/s and ‘up to’ 24Mbit/s ADSL 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 speed of connection. Such variation has greatest impact for 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 2010, 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](http://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=1000
Line Length Distribution May 2010:	Gamma a=1.863 b= 1203

#### 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 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 'up to' 8Mbit/s and 10Mbit/s ADSL 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 'up to' 8Mbit/s or 'up to' 10Mbit/s packages and those on 'up to' 20Mbit/s or 'up to' 24Mbit/s 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 'up to' 20Mbit/s and 'up to' 24Mbit/s packages were instead normalised by weighting each to the aggregate distribution of line length among all 20Mbit/s or 24Mbit/s panellists.

Aggregate 'up to' 20Mbit/s and 24Mbit/s 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 'up to' 20/24Mbit/s package was 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 & ISP 'up to' 8Mbit/s and 10Mbit/s packages, and one for ISP 'up to' 20Mbit/s and 24Mbit/s 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 71%. 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	356	32%
0.5 to 1	482	43%
1 to 1.5	216	19%
1.5 to 2	53	5%
2 to 3	11	1%

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 Infinity and Virgin Cable 50.

**Figure 4 ISP package panel range of weights**

Weights	Count	Column N %
Less than 0.5	88	7%
0.5 to 1	815	66%
1 to 1.5	201	16%
1.5 to 2	91	7%
2+	31	3%

Source: Ofcom

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

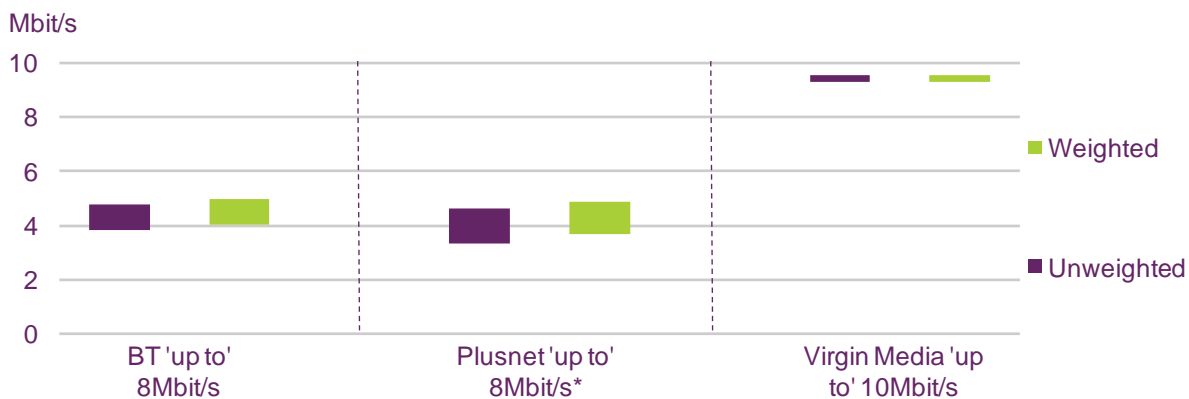
ISP package	Weighting efficiency
BT 'up to' 8Mbit/s	96%
Plusnet 'up to' 8Mbit/s	78%
Virgin Media 'up to' 10Mbit/s	100%
BT 'up to' 20Mbit/s	95%
Karoo 'up to' 24Mbit/s	93%
O2/Be 'up to' 20/24Mbit/s	92%
Orange 'up to' 20Mbit/s	94%
Plusnet 'up to' 20Mbit/s	95%
Sky 'up to' 20Mbit/s	95%
TalkTalk 'up to' 24Mbit/s	94%
Virgin Media 'up to' 30Mbit/s	100%
BT 'up to' 40Mbit/s	100%
Virgin Media 'up to' 50Mbit/s	100%

Source: Ofcom

**Weighted and unweighted measurement data**

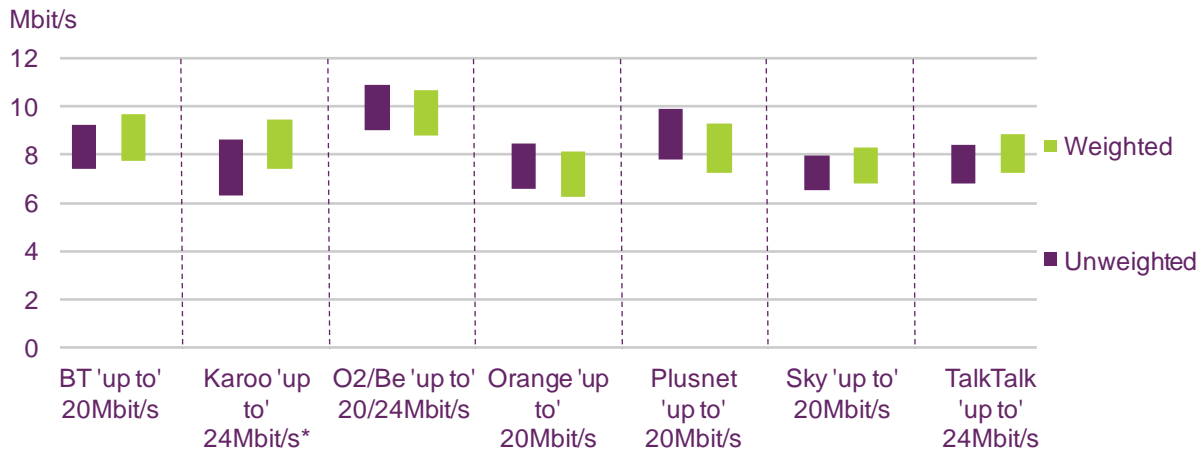
The effect of the combined overall ISP panel weighting on the comparative relative ISP package performance is shown in the following tables

**Figure 6 Average download speed for 'up to' 8Mbit/s and 'up to' 10Mbit/s connections by ISP, 24 hours, weighted and unweighted figures, November 2011**



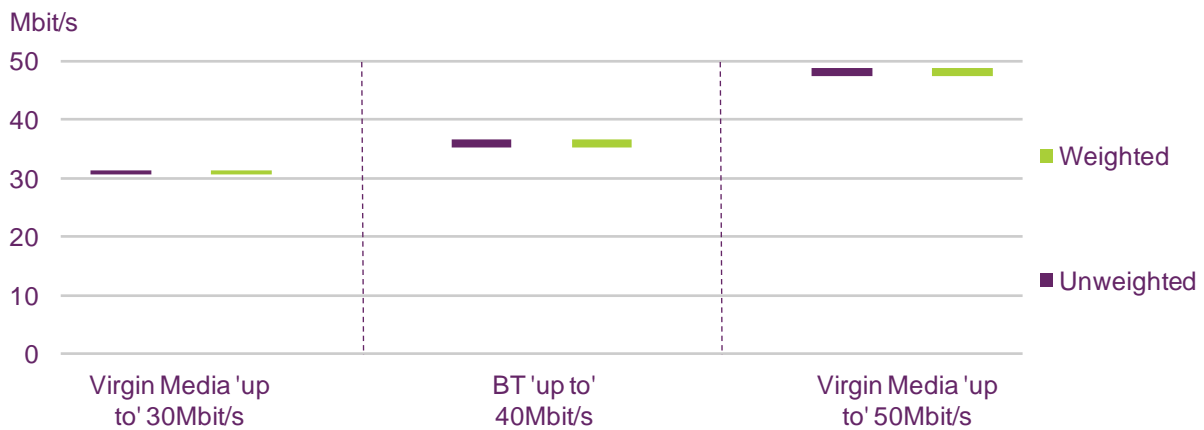
Source: SamKnows measurement data for all panel members with a connection in November 2011. Notes: (1) Includes only ADSL customers within 5km of the exchange and in geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been weighted to ISP distance from exchange, data for Virgin Media's cable service is unweighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

**Figure 7 Average download speeds for 'up to' 20Mbit/s and 'up to' 24Mbit/s connections by ISP, 24 hours, weighted and unweighted figures, November 2011**



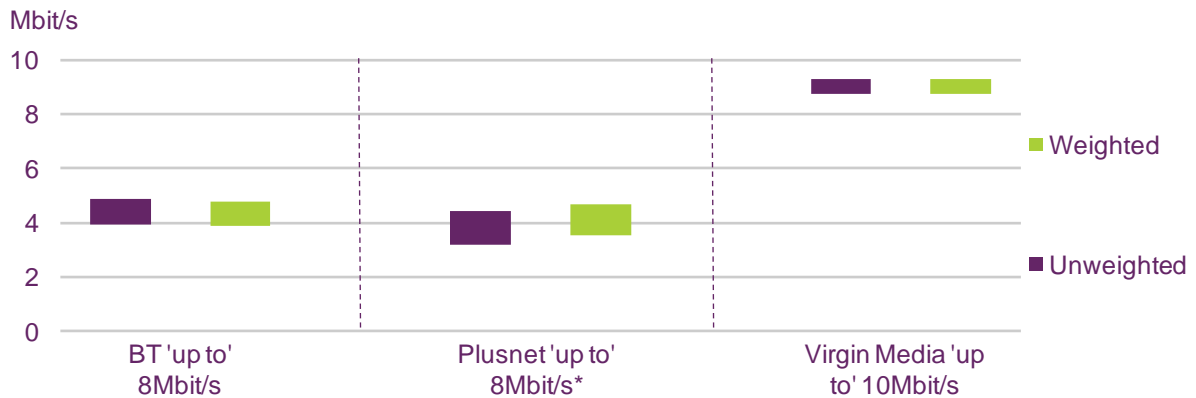
Source: SamKnows measurement data for all panel members with a connection in November 2011. Notes: (1) Includes only ADSL customers within 5km of the exchange and in geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been unweighted to distance from exchange and data for Virgin Media's cable and BT 'up to 40Mbit/s 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 above 'up to' 24Mbit/s connections by ISP, 24 hours, weighted and unweighted figures, November 2011**



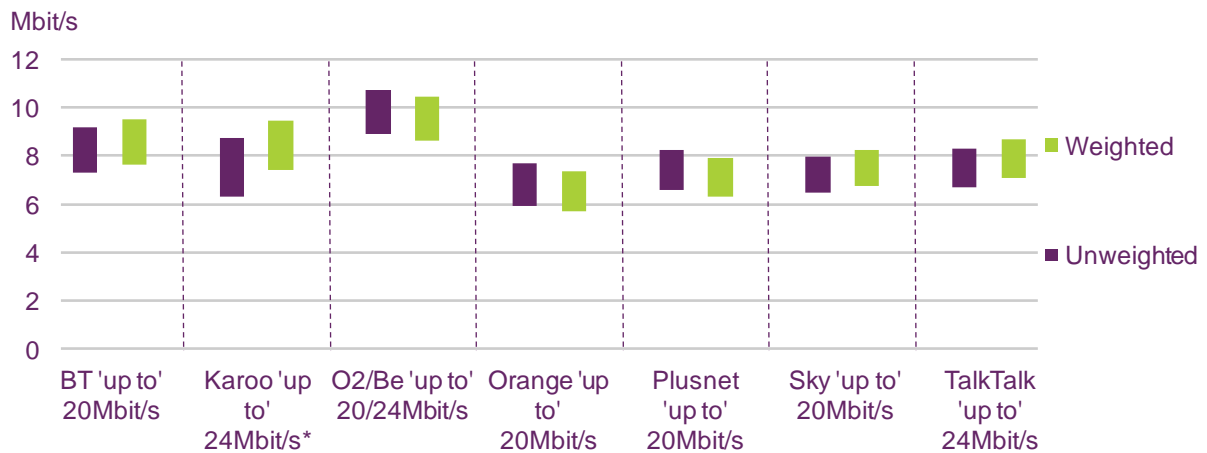
Source: SamKnows measurement data for all panel members with a connection in November 2011. Notes: (1) Includes only ADSL customers within 5km of the exchange and in geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been unweighted to distance from exchange and data for Virgin Media's cable and BT 'up to 40Mbit/s 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 Peak-time download speed for 'up to' 8Mbit/s and 'up to' 10Mbit/s connections by ISP, weighted and unweighted figures, November 2011**



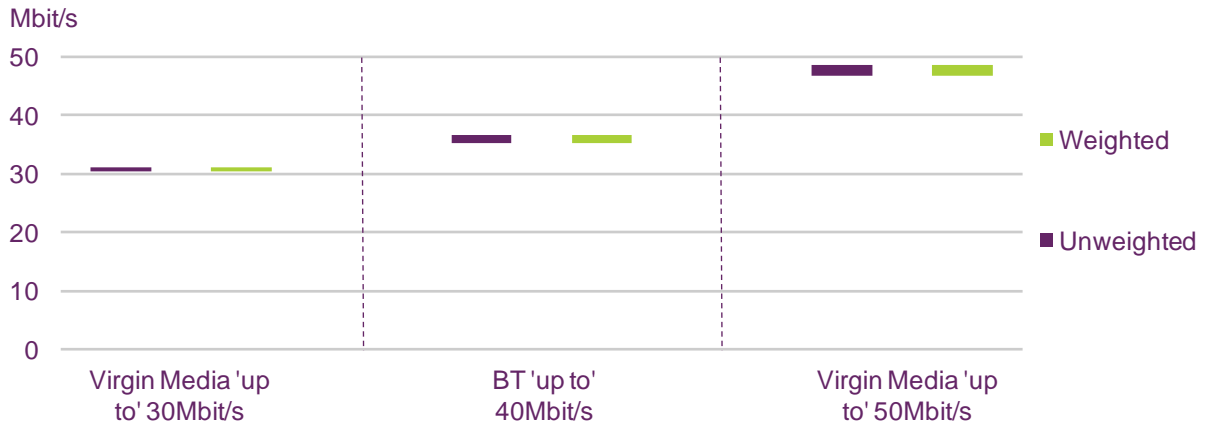
Source: SamKnows measurement data for all panel members with a connection in November 2011. Notes: (1) Includes only ADSL customers within 5km of the exchange and in geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been weighted to ISP distance from exchange, data for Virgin Media's cable service 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 speed for 'up to' 20Mbit/s and 'up to' 24Mbit/s connections by ISP, weighted and unweighted figures, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011. 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 'up to' 40Mbit/s 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 speed for above 'up to' 24Mbit/s connections by ISP, weighted and unweighted figures, November 2011**



Source: SamKnows measurement data for all panel members with a connection in November 2011. 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 'up to 40Mbit/s 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 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+, 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 January 2012 all of BT's nationally available ADSL broadband services are advertised as "up to 20Mbit/s").

**ISP** Internet Service Provider. A company that provides access to the internet.

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

**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, for ADSL1 connections, only those users who have a line length of less than 1km typically achieve maximum speeds of close to a headline speed of 8Mbit/s.

**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).

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

**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 Kilobits per second (Kbit/s).