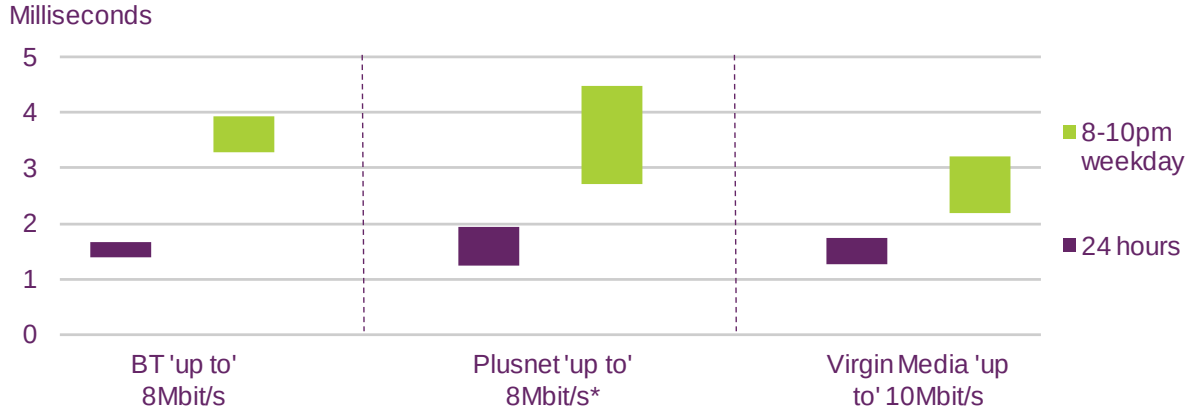
Figure 8.39 Average and peak time downstream jitter for 'up to' 8Mbit/s and 10Mbit/s packages, May 2011



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

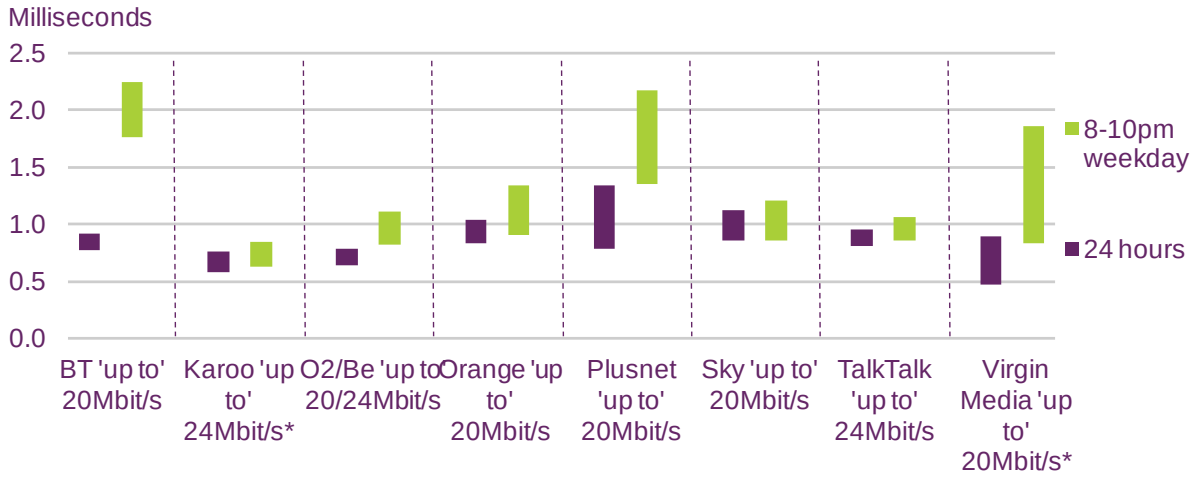
Figure 8.40 Significant differences to a 95% level of confidence between average and peak time downstream jitter for 'up to' 8Mbit/s and 10Mbit/s packages, May 2011

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

Source: Ofcom

8.31 Karoo had comparatively low downstream jitter compared to the other 'up to' 20Mbit/s and 24Mbit/s ISP packages included in our research both over the 24-hour period and during the 8 to 10pm weekday peak period (Figure 8.41). Again, in this chart better performance is indicated by lower jitter, which is indicated by lower bars.

Figure 8.41 Average and peak time downstream jitter for 'up to' 20Mbit/s and 24Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: small sample size (<50)*
Notes: (1) Only includes 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.

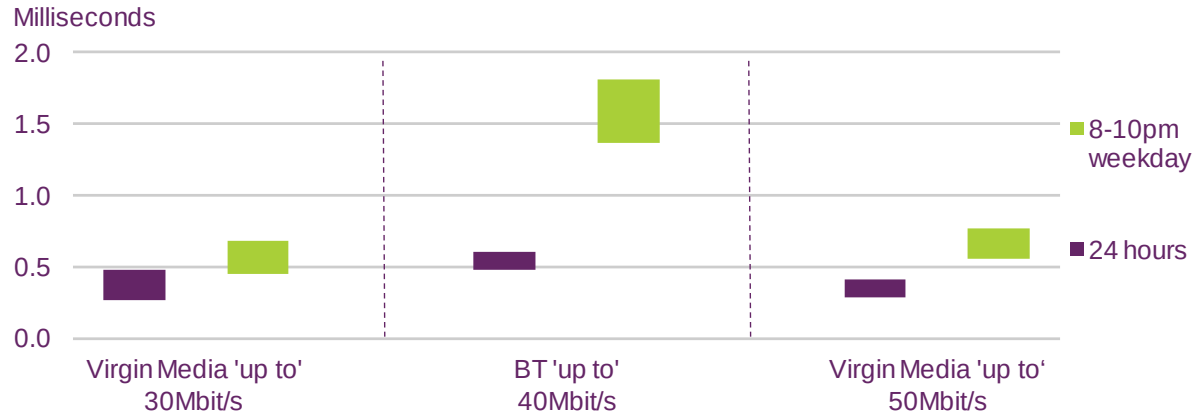
Figure 8.42 Significant differences to a 95% level of confidence between average and peak time downstream jitter for 'up to' 20Mbit/s and 24Mbit/s packages, May 2011

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

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

8.32 BT's 'up to' 40Mbit/s service had higher levels of downstream jitter than Virgin Media's 'up to' 30Mbit/s and 50Mbit/s services both across the whole day and during the weekday peak period (Figure 8.43). Again, in this chart better performance is indicated by lower jitter, which is indicated by lower bars.

Figure 8.43 Average and peak time downstream jitter for above 'up to' 24Mbit/s packages, May 2011



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

Figure 8.44 Significant differences to a 95% level of confidence between average and peak time downstream jitter for 'up to' 20Mbit/s and 24Mbit/s packages, May 2011

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

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

Section 9

Conclusion and next steps

Implications for consumers

9.1 This research report is a representative snapshot of broadband performance of the ISP packages included in the research in May 2011. The broadband market is changing rapidly as operators are continuing to invest in their networks in order to make faster broadband available. The results set out in this report will not necessarily reflect the future performance of networks and providers.

9.2 However, we believe our research is valuable in understanding the key factors that currently determine and affect broadband performance and it has some important findings of interest to consumers. In particular, our results indicate that there is significant variation in the performance of different ISP packages and that these variations are largely attributable to the access technology used by the ISP and the capacity of ISPs' networks. We believe this will be useful information for consumers, particularly those who make greater use of high-bandwidth services such as high-definition video or online gaming, which benefit from faster speeds, higher stability of connection and/or greater responsiveness.

9.3 It is also clear that geographical location is the key determining factor of the actual speeds available to consumers. The location of a household determines the range of technologies available (ADSL1, ADSL2+, cable, fibre-to-the-cabinet and – outside the scope of this research – mobile broadband, satellite and fibre-to-the-home). For ADSL broadband, although there are some differences in performance of different ISP packages due to differing levels of contention in the ISPs' networks, the most important determinant of actual speeds is the length of the copper telephone line between the premises and the local exchange; for consumers living further than 3km from the exchange, the upgrade from ADSL1 to ADSL2+ technology, and the increase in theoretical headline speeds from 'up to' 8Mbit/s or 10Mbit/s to 'up to' 20Mbit/s or 24Mbit/s is unlikely to make any difference to the actual speeds delivered.

9.4 The research data shows that consumers are currently getting a very wide variety of actual speeds. They also suggest that many consumers could significantly improve the speeds they obtain if they took some relatively simple steps, such as fitting a micro-filter (also known as an iPlate). Further information is available in Ofcom's consumer guide, which also details the factors we think consumers might wish to consider when buying broadband services.[32]

9.5 Consumers do, of course, have alternatives to fixed-line broadband, and we have detailed the performance of the UK's mobile broadband providers in separate research[33]. As with fixed broadband, mobile broadband depends very much on location and before making a decision between them consumers should check both the speed available on their line from fixed broadband providers and the level of

[32] http://stakeholders.ofcom.org.uk/market-data-research/telecoms-research/broadband-speeds/main/
[33] http://stakeholders.ofcom.org.uk/market-data-research/telecoms-research/broadband-speeds/main/mobile-bb-10

mobile broadband coverage offered by mobile operators (postcode checkers are available on the websites of all the mobile network operators).

Implications for ISPs

9.6 The research has again given us valuable insight into the performance of broadband services delivered by the ISP packages included in the research. The results suggest that ISPs need to do more to ensure that they are giving their customers sufficient information, which is clear and accurate, about the services they provide and the factors that may impact on the actual speed they will receive. This is important to help consumers make more informed choices, and to manage customers' expectations about a particular service once they are signed up (which should reduce customer complaints).

- **Complying with the strengthened Voluntary Code of Practice on Broadband Speeds**. The strengthened Code, among other things, commits all ISPs who have signed up to explain to new customers the access line speed they are likely to obtain in practice, and to attempt to resolve problems for those customers whose access line speed is significantly below the estimate provided. If the problem cannot be resolved then customers will be able to leave their provider within the first three months of their contract period without penalty. The updated Code comes into force on 27 July 2011.

- **Advertising and promoting broadband services clearly.** As our research has shown, the deployment of faster broadband services has led to a bigger gap between the headline speeds that some ISPs use in their advertising and the actual speeds being delivered to consumers. There is therefore a possibility that some consumers could be misled about the performance of different broadband services as a result. ISPs should ensure that this is not the case and we welcome broadband advertising which emphasises that speeds vary by line length and which encourages consumers to get an estimate of the speed their line is capable of. Earlier this year Ofcom recommended to CAP and BCAP, the committees that write the advertising codes enforced by the Advertising Standards Authority, that a Typical Speeds Range (TSR) should be included in advertisements by ISPs who advertise based on the speed of the service.

- **Ensuring they continue to meet the changing needs of consumers.** Some consumers are moving to faster broadband services as they expand their use of internet-based services, and increasingly use services which benefit from higher download speeds. As a result ISPs are continuing to invest in their networks to ensure that consumers' internet experience meets their needs, including through the deployment of super-fast broadband services, which increasing numbers of consumers may want to use in the future.

Next steps

9.7 We recognise the dynamic nature of this market and the importance of continuing this research to take into account the rapidly changing broadband market. Our research into residential fixed-line broadband speeds is continuing and we expect to publish our next report into fixed-line broadband performance in early 2012.

9.8 We will continue to monitor compliance with the Voluntary Code of Practice on Broadband Speeds, and in particular to the new requirements which come into force from 27 July 2011.

Annex 1

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/ADSL2+ Improved versions 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.

ADSL Max BT Wholesale's 'up to' 8Mbit/s ADSL1 broadband service.

ATM Asynchronous Transfer Mode (a telecommunications protocol used in networking. ATM enables all types of information (data, voice and video in any combination) to be transported by a single network infrastructure.

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.

Bit-rate The rate at which digital information is carried within a specified communication channel.

Bitstream A wholesale service providing conveyance of data traffic from an end user's premises to a point of interconnection made available by the incumbent to a competitive provider.

BRAS Broadband remote access server. Routes traffic to and from the digital subscriber line access multiplexers (DSLAM) on an Internet service provider's (ISP) network. The BRAS sits at the core of an ISP's network and its functions include enforcing quality of service policies and routing traffic into an ISP's backbone network.

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.

Contention ratio An indication of the number of customers who share the capacity available in an ISP's broadband network. Figures of 50:1 for residential broadband connections and 20:1 for business are typical.

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).

DSLAM Digital Subscriber Line Access Multiplexer. Allows telephone lines to make faster connections to the Internet.

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 February 2011 all of BT's nationally available ADSL broadband services are advertised as "up to 20Mbit/s").

IP (internet protocol) The packet data protocol used for routing and carriage of messages across the internet and similar networks.

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.

Kbit/s Kilobits per second. A unit measuring the bit-rate in multiples of 1,024 bits per second. 1,000Kbit/s is the same as 1Mbit/s.

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.

Microfilter A small device which plugs into a normal phone socket and splits the line into both a standard BT telephone socket and an ADSL broadband socket. It is used to protect the ADSL signal from being contaminated by signal noise from a voice service, allowing both voice and data to share common inside wiring. Microfilters should be installed into all phone sockets within a house; if they are not installed broadband performance may suffer.

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).

Next-generation access networks (NGA) Broadband access networks that connect the end-user to the core network, capable of a bandwidth quantity and quality significantly in excess of current levels (a benchmark of 20Mbit/s or more is often used).

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

Router A broadband router enables a connection between more than one computer and the internet (unlike a broadband modem which is used to connect just one computer to the broadband connection). Wireless routers enable computers to connect to the broadband connection via a WiFi network.

Single-thread test A test involving the download of a single data file (see Technical Methodology – Annex 2).

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.

TCP The Transmission Control Protocol (TCP) is one of the core protocols of the Internet Protocol Suite.

Throughput speed The actual speeds delivered to consumers over a broadband connection, usually measured in Megabits per second, and generally referring to the download speed.

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).

USB modem A way of connecting to the internet via the USB socket on a computer. Unlike a router, a USB modem allows only one computer to connect at any one time to a broadband connection.

VoIP Voice over Internet Protocol. A technology that allows users to send calls using internet protocol, using either the public internet or private IP networks, rather than the PSTN.

Wholesale Broadband Connect (WBC) BT Wholesale's ‘up to’ 20Mbit/s ADSL2+ broadband service.

Annex 2

Technical and research methodologies

1. Technical methodology

The technical methodology chosen is the same as that used in Ofcom's first round of research into broadband performance in 2008/9 and was based on that created by broadband performance company SamKnows Ltd, 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 to the analysis. Also see paragraph 2.5 onwards.

All panellists were sent a hardware monitoring unit which they were instructed to connect to their router. The unit sits between the participant's existing router and the rest of their network, so allowing the performance monitoring 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, 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 performs 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 a significant improvement from any other research into UK broadband performance, which has typically relied on software monitoring solutions that do not account for the impact on speed of PC set-up, or 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 our 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. Typically the download speeds achieved using the multi-thread tests in the early hours determine 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 constantly 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 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 our solution, *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.

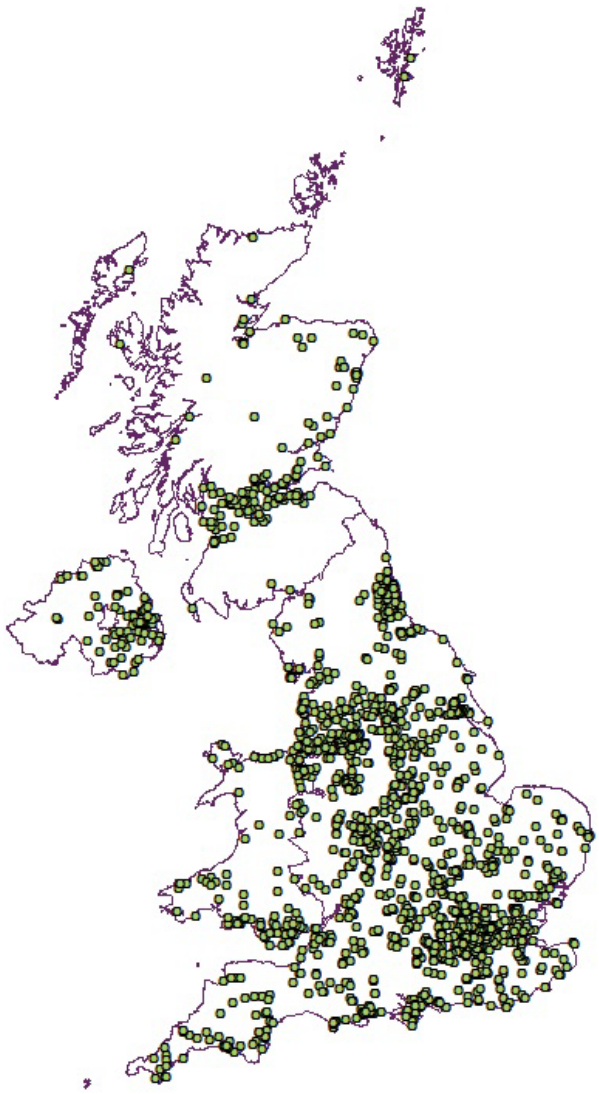
Connections with usage caps

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 May 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

broadband providers is that with this technology, speed varies by the length and quality of the particular consumer's telephone line. Therefore, providers that have a higher proportion of consumers 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[36]. 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 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) which we expect to become standard over the period of research.

A third round of recruitment took place between January and April 2011 to maintain and improve the panel and to enable reporting of the following ISP packages which had not previously been included: Karoo 'up to' 24 Mbit/s, Orange 'up to' 20 Mbit/s, Plusnet 'up to' 20 Mbit/s and Virgin Media 'up to' 30 Mbit/s. A further 234 boxes were sent out to ensure a minimum sample of 50 panellists for each of these.

Quotas were set by Geographic Market classification (see paragraph 3.7 of the main report), LLU (see section 2.10 of the main report), ISP market and package shares, rural/urban, region (for ten regions in England, and for 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 39% of the sample contributing less than 0.5 a response towards the UK average; this is a decrease of

[36] 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.

Average speeds are generally very accurately measured, so the main factor limiting the accuracy of the analysis reported here is the number of panellists and 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 criterion above and achieve 100-150 panellists per package, only ISP packages with over 250,000 subscribers in total were targeted.

Karoo's 'up to' 24Mbit/s (62), Plusnet's 'up to' 20Mbit/s (55) and 'up to' 8Mbit/s (58) packages achieved the minimum threshold of 50 against the specific criteria required and are included in these findings with a warning regarding small sample size. Virgin Media's 'up to' 20Mbit/s package achieved a sample size of 42 – this is included for completeness and because no weighting for this package was necessary.

Sample panels

The results and analysis of the 1,760 panellists' measurement results were divided into two separate datasets, each weighted to targets.

- **National Panel** (over 'up to' 2Mbit/s packages): 1,325 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, TalkTalk) and Virgin Media were on-net only. There was a target of 100 valid panellists for each ISP package, but criteria for including in the reporting was an effective sample minimum of 50 valid panellists (those with a base of less 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 April/May 2010, 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 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 in paragraph 3.3, 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 as well.

- The conclusion was that allowing for variance across the sample based on line length would not necessarily lead to the widening the 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 upon 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	13.9591	3.736188
2	68	11.60854	9.426042	3.070186
3	74	8.73505	10.31055	3.211005
4	78	5.877479	9.555718	3.091232
5	67	2.902841	5.732561	2.394277

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 +/- 0.3 Mbit/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 participants to ISP and broadband package

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

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

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

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

    - 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, a box dispatched if sample required for both stated and assessed package.

- Once the volunteer correctly connected the measurement box 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 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 8 M/bits to 20/24 M/bits by some ISPs before the fieldwork commenced.

    - The second check was to reassign any participant 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 participants 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 participants from the ‘up to’ 20Mbit/s or 24Mbit/s analysis.

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

    - Finally, those participants whose stated and measured package assignments or ISP were not consistent and could not be definitively reconciled were excluded from comparison data. Only panellists with an ADSL connection who were connected to an ADSL2+ enabled exchange were considered for the ‘up to’ 20Mbit/s and 24Mbit/s package allocation. The above modification (upload speed assignment) was necessary to identify those customers using ADSL Max on a ADSL2+ exchange.

Weighting to distance from exchange

As performance of ADSL broadband is significantly affected by the length of the line between 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 (April 2009), 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 post-codes of premises and local exchange. Different weights by distance were applied to each of the UK National, 'up to' 8Mbit/s and 10Mbit/s and 20Mbit/s and 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 (see section 3.7 of the main report), 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 10Mbit/s packages and those on 'up to' 20Mbit/s or 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 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 offering 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 10 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 72%. The under 0.5's 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	429	39%
0.5 to 1	400	36%
1 to 1.5	142	13%
1.5 to 2	94	9%
2 to 3	40	3%

Source: Ofcom

Overall, against the entire weight frame, the ISP Package Panel achieved a weighting efficiency of 80%. 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	87	7%
0.5 to 1	883	70%
1 to 1.5	150	12%
1.5 to 2	88	7%
2+	48	4%

Source: Ofcom

Figure 5 Weighting efficiency by ISP package

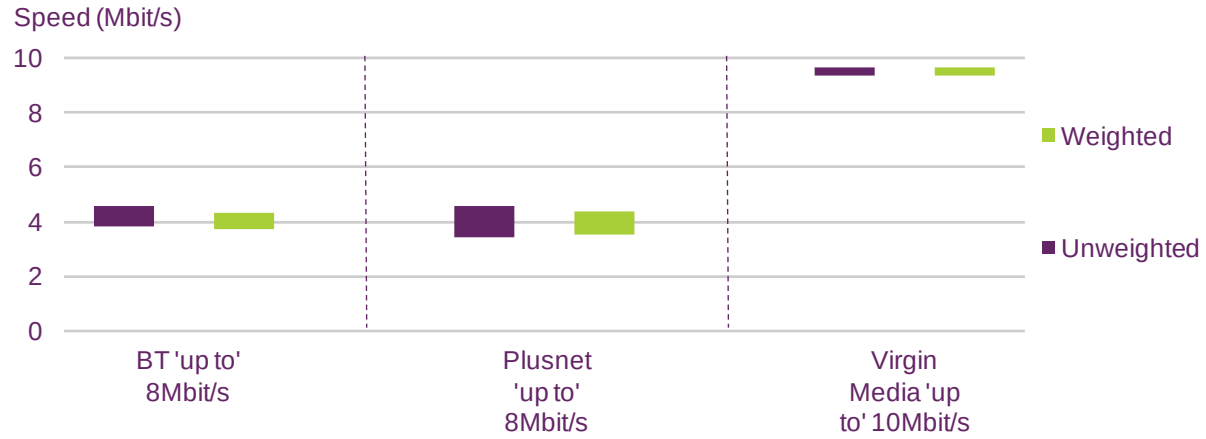
ISP package	Weighting efficiency
BT 'up to' 8Mbit/s	89%
Plusnet 'up to' 8Mbit/s	81%
Virgin Media 'up to' 10Mbit/s	100%
BT 'up to' 20Mbit/s	98%
Karoo 'up to' 24Mbit/s	71%
O2/Be 'up to' 20/24Mbit/s	84%
Orange 'up to' 20Mbit/s	84%
Sky 'up to' 20Mbit/s	95%
TalkTalk 'up to' 24Mbit/s	92%
Virgin Media 'up to' 20Mbit/s	100%
Virgin Media 'up to' 30Mbit/s	100%
BT 'up to' 40Mbit/s	95%
Virgin Media 'up to' 50Mbit/s	100%

Source: Ofcom

Weighted and unweighted measurement data

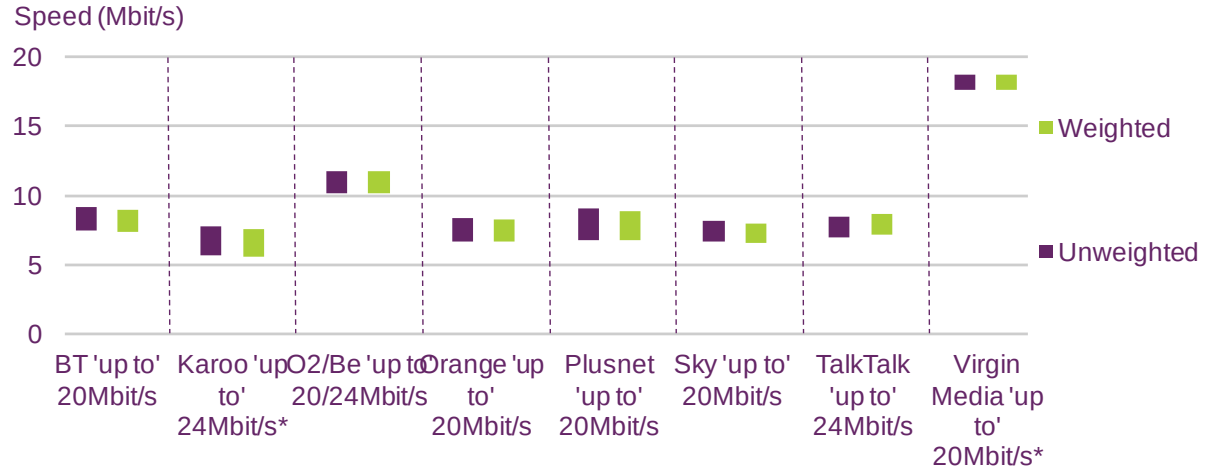
The effect of the combined overall ISP Panel weighting on the comparative relative ISP Package perform, is shown in the following tables

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



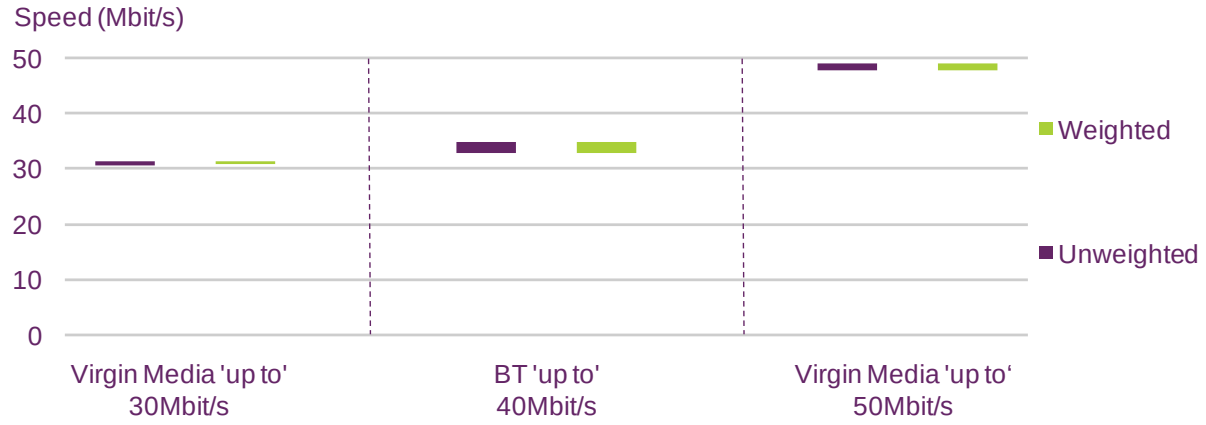
Source: SamKnows measurement data for all panel members with a connection in May 2011.
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been weighted to 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 24Mbit/s connections by ISP, 24 hours, weighted and unweighted figures, May 2011



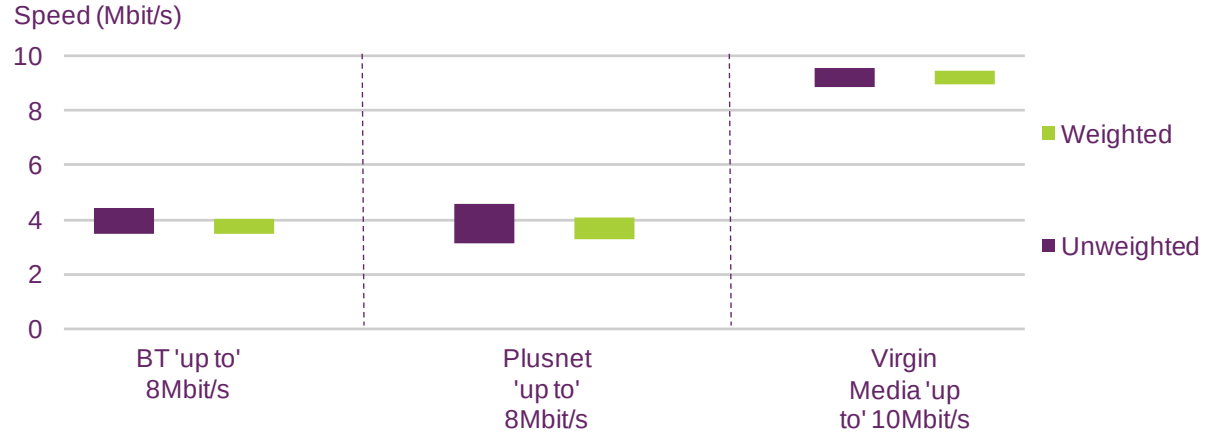
Source: SamKnows measurement data for all panel members with a connection in May 2011. Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been unweighted to 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, May 2011



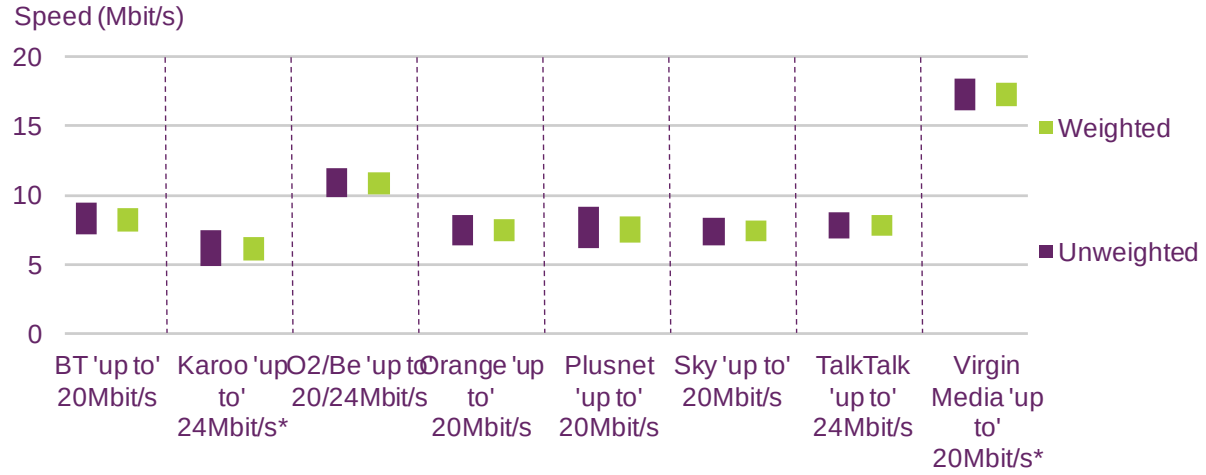
Source: SamKnows measurement data for all panel members with a connection in May 2011. Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been unweighted to 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 throughput speed for 'up to' 8Mbit/s and 10Mbit/s connections by ISP, weighted and unweighted figures, May 2011



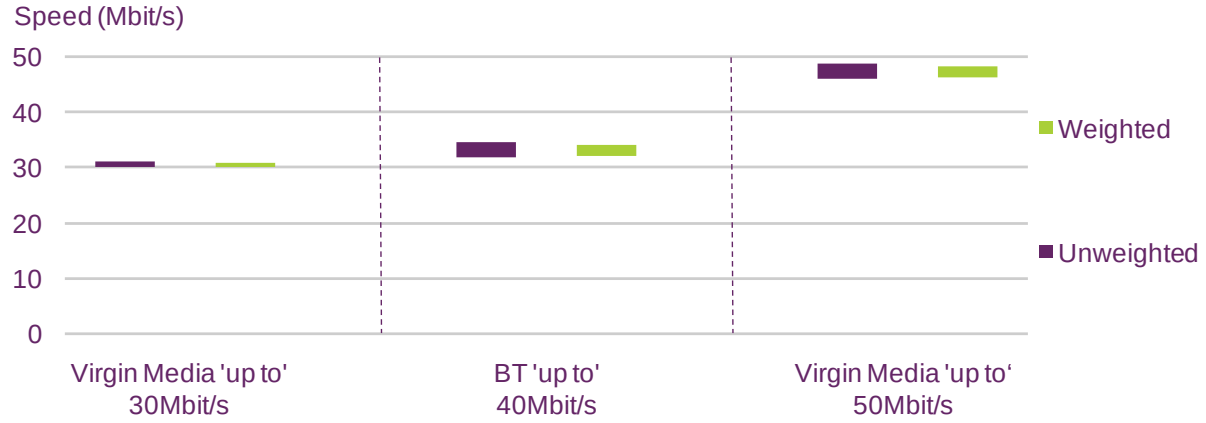
Source: SamKnows measurement data for all panel members with a connection in May 2011.
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been weighted to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



Source: SamKnows measurement data for all panel members with a connection in May 2011.
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) Weighted data for ADSL operators have been unweighted to distance from exchange and data for Virgin Media's cable and BT 'up to 40 Mbit/sis 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 throughput speed for above 'up to' 24Mbit/s connections by ISP, weighted and unweighted figures, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
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) Weighted data for ADSL operators have been unweighted to distance from exchange and data for Virgin Media's cable and BT 'up to 40 Mbit/sis unweighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.