UK fixed broadband speeds, November/December 2010

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

Research Report

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Contents

Section		Page
	Using this report	2
1	Executive summary	6
2	Introduction	12
3	Objectives and methodology	18
4	Overview of UK broadband speeds	24
5	Variation of speeds by geographic location	40
6	Variation of speeds by time of day	47
7	Variation of speeds by access technology	52
8	Variation of speeds by internet service provider (ISP) package	56
9	Other metrics affecting performance	77
10	Analysis of operator data	89
11	Conclusion and next steps	96

Annex		Page
1	Glossary	99
2	Technical methodology	102
3	Statistical methodology	105
4	Significance testing	115

Using this report

Purpose of this report

In order to understand the performance of UK fixed-line residential broadband connections, we commissioned research to identify the average actual download throughput speeds that they deliver, along with a number of other metrics, which determine the consumer experience of using broadband services. This is the second report from our current round of research, following the publication of a report in July 2010 (which was based on data collected in May 2010). We previously published Broadband Speeds reports from our first round of research in January 2009 and July 2009.

The results provide extremely useful insights into the factors that affect and determine broadband performance, but with the following limitations:

- The information presented in this report relates to broadband download speeds and other performance measures such as upload speeds, latency, jitter, etc. Other factors relevant to consumers purchasing broadband – such as price, customer service, etc. – are not discussed in this report.

- The performance of broadband delivered via ADSL depends to a large extent on where consumers are located. Reporting of average performance information in this report therefore does not necessarily reveal the performance available to any individual consumer. Furthermore, the broadband services available to any particular consumer will also depend on their location.

- In the UK there are over 200 different fixed-line broadband internet service providers (ISPs) offering different packages to residential consumers, and we have not been able to report on the performance of each of these packages. We did gain sufficient panellists to be able to report the performance of those ISP packages which collectively represent over 90% of total broadband subscribers in the UK, and also to be able to report on the two highest-profile 'superfast' services in the UK – Virgin Media's 'up to' 50Mbit/s cable package and BT Infinity (an 'up to' 40Mbit/s fibre-to-the-cabinet service). However, consumers should bear in mind that there are many other ISPs available, which may perform better or worse than those specifically featured in this report.

- Our research relates only to ADSL, VDSL (also known as fibre-to-the-cabinet or FTTC) and cable broadband services. Mobile broadband services were out of scope since the technical methodology we used was not suited to testing the performance of mobile broadband. We have commissioned separate research into mobile broadband performance and expect to publish a report in spring 2011 which will examine the drivers of variation in mobile broadband performance and compare it to fixed-line broadband performance. Other broadband platforms such as fibre-to-the-home and satellite broadband are also not currently included in our analysis as these connections represent only a small proportion of the total broadband market in the UK.

- This research report presents information on the state of fixed-line residential broadband performance in the UK in November and December 2010. However, the broadband market continues to evolve rapidly, and the speeds and general performance results set out in this report are therefore liable to change.

- As with previous reports, despite these limitations we hope that this report can also serve as a useful reference source for consumers and our other stakeholders.

We welcome feedback on all of Ofcom's reports. Please email comments to Ofcom's Market Intelligence team at market.intelligence@ofcom.org.uk.

Key terms used to describe broadband speeds

In this report, we use four key terms to describe download speeds. (See the Glossary in Annex 1 for fuller definitions of these terms.)

- The '**headline speed**' or '**advertised speed**' is the download 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.

- The '**average actual download throughput**' speed, or '**average actual download**' speed, represents the average actual speed that a consumer receives, which drives the speed at which web pages and files can be downloaded. The average actual download throughput speed is referred to throughout this document as "**average download speed**", unless specified otherwise.

- The '**maximum speed**' is the maximum download speed that a customer actually receives.

Key statistical concepts used in this report

This report presents the findings from research which has involved the collection and interpretation of 765 million[1] data points. It has been a complex process, both technically and statistically, and as a consequence the analysis may not be as easy to understand as that in many of our research publications.

The Glossary in Annex 1 provides a detailed definition 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.

- 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 also 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

[1] Over 740 million of these were to test connection latency.

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 order to ensure that the national headline data we present are representative of UK broadband users as a whole, we have weighted the data by ISP package, technology (LLU, Non-LLU and cable), rural/urban split, distance from the exchange and market classification.

- We have similarly weighted the data where we are comparing the performance of individual ISPs' packages in order to ensure that the analysis provides a fair comparison of actual performance rather than reflecting random differences in the ISP package customer profiles in the sample. A difficulty in comparing ADSL broadband providers is that with this technology, speed varies by the length and quality of the particular consumer's telephone line. Therefore, providers 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[2]. 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.

  A detailed explanation of our statistical methodology is provided in Annex 3.

[2] 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.

Section 1

Executive summary

Background

1.1 Ofcom's primary duty under the Communications Act 2003 (the "Act") is to further the interests of UK citizens and consumers in carrying out our functions. In addition to securing the availability of a wide range of electronic communications services including broadband services, encouraging investment and innovation in relevant markets and the availability and use of high-speed data services, we must have regard to the interests of consumers in respect of price, quality of service and value for money. Our duties include the requirement to carry out research into consumers' experiences of the way services are provided and to publish and take account of the results of such research.

1.2 In the last decade internet access speeds across the UK have increased as consumers have migrated from dial-up to broadband and ISPs have offered packages at higher advertised 'up to' speeds. The next phase of this evolution is now getting under way as operators invest in superfast broadband services. It is therefore becoming more important than ever for consumers to have reliable and accurate information on how different broadband services perform – otherwise consumers may not be able to make an informed choice about which broadband service is most suitable for them.

1.3 This is the fourth report into fixed-line broadband speeds that Ofcom has published using data collected by research partner SamKnows Limited (SamKnows)[3]. It sets out the findings from data collected during the period 1 November 2010 to 15 December 2010, during which 765 million tests were run across a panel of 1,710 UK residential broadband users. We believe that the integrity of our hardware-based technical methodology, combined with the scale of the project and the sophistication of the statistical analysis, makes this research the most robust analysis of fixed-line broadband speeds in the UK.

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

UK broadband speeds increased during 2010

1.5 Our results show that in November/December 2010 average actual broadband speeds in the UK were 6.2Mbit/s based on multi-thread testing[4]. We do not have time-series data for multi-thread tests, but single-thread test data suggests that average download speeds in the UK increased by 5% between May and

[3] http://www.samknows.com/broadband/.

[4] In this report we focus on multi-thread testing, and unless otherwise stated download speeds are based on those collected via multi-thread testing. Multi-thread testing represents the speeds achieved when three files are downloaded simultaneously and is increasingly representative of the way in which applications and browsers retrieve data, and when more than one connected device is using the same broadband connection. In previous reports we focused more on single-thread tests (when a single file is downloaded), and did not run sufficient multi-thread test results to be able to calculate robust average speeds for multi-thread testing.

November/December 2010, this following an increase of 27% between April 2009 and May 2010.

1.6 This increase in average speeds is the result of consumers increasingly moving to faster broadband services: 42% of UK broadband connections had a headline speed above 10Mbit/s in November/December 2010, compared to 24% in May 2010 and 8% in April 2010.

Speeds for ADSL services varied widely and were typically much lower than advertised speeds

1.7 The theoretical 'up to' speed of broadband services continues to feature in many broadband advertisements. This is despite the fact that various constraints on broadband performance (including distance from the premises to the exchange, quality of lines and home wiring, and congestion on ISPs' networks and the wider internet) combine to make actual speeds significantly lower than headline speeds. We found that average download speeds remain well below the advertised speeds which some ISPs continue to use: the average download speed for all UK residential connections of 6.2Mbit/s compares to an average advertised speed of 'up to' 13.8Mbit/s, equivalent to 45% of the advertised speed[5].

1.8 The average download speed received for 'up to' 20Mbit/s or 24Mbit/s ADSL packages was 6.2Mbit/s (29% of average advertised 'up to' speeds), while for 'up to' 8Mbit/s or 10Mbit/s ADSL services it was 3.4Mbit/s (42% of average advertised 'up to' speeds).

1.9 Very few ADSL broadband customers achieved average actual download speeds close to advertised 'up to' speeds. Just 14% of customers on 'up to' 20Mbit/s or 24Mbit/s ADSL services received average download speeds of over 12Mbit/s, while 58% received average download speeds of 6Mbit/s or less.

Cable and fibre services were faster than ADSL and much closer to advertised speeds

1.10 Virgin Media's 'up to' 10Mbit/s cable service delivered average speeds of 9.6Mbit/s, 96% of advertised 'up to' speeds and significantly faster than the average speeds delivered by ADSL services advertised at 'up to' 20Mbit/s or 24Mbit/s (Figure 1.1). Virgin Media's 'up to' 20Mbit/s cable service averaged 18.0Mbit/s (90% of advertised speeds) and its 'up to' 50Mbit/s service averaged 45.6Mbit/s (92% of the advertised 'up to' speed).

1.11 The roll-out of BT's 'up to' 40Mbit/s FTTC service (which is currently available to 15% of UK premises) meant that for the first time we were also able to include fibre-to-the-cabinet (FTTC) services within our research. We found that download speeds averaged 31.8Mbit/s[6] (80% of the advertised 'up to' 40Mbit/s speed).

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[5] Note that these are average speeds delivered across the UK; when we compare the performance of ISP packages later in the report we typically find higher speeds by ISP – this is because for ISP-specific panellists we only include panellists who are served by an exchange where at least one LLU operator is present, and only include on-net customers for LLU operators (see paragraphs 8.4 to 8.9).

[6] BT's 'up to' 40Mbit/s service experienced a fault during three days in December when all customers on our panel had their speeds capped at 2Mbit/s during the evening hours of 6pm to 12am as a result of an incorrect traffic management profile being applied. We have excluded test results from these

Figure 1.1 Summary of average download speed by ISP package, November/December 2010 (multi-thread tests)

	Average download throughput speed during period	
	24 hours	8 to 10pm weekdays
BT 'up to' 8Mbit/s	4.1 to 4.8Mbit/s	3.8 to 4.4Mbit/s
Orange 'up to' 8Mbit/s	3.3 to 4.3Mbit/s	2.7 to 3.5Mbit/s*
Plusnet 'up to' 8Mbit/s	3.4 to 4.4Mbit/s*	3.3 to 4.2Mbit/s
Virgin Media 'up to' 10Mbit/s	9.5 to 9.7Mbit/s	8.9 to 9.4Mbit/s
BT 'up to' 20Mbit/s	6.9 to 8.7Mbit/s	6.8 to 8.5Mbit/s
O2/Be 'up to' 20/24Mbit/s	9.9 to 11.6Mbit/s**	9.5 to 11.0Mbit/s**
Sky 'up to' 20Mbit/s	7.4 to 8.8Mbit/s	7.3 to 8.7Mbit/s
TalkTalk 'up to' 24Mbit/s	7.7 to 9.3Mbit/s	7.5 to 9.0Mbit/s
Virgin Media 'up to' 20Mbit/s	17.4 to 18.6Mbit/s	16.5 to 18.0Mbit/s
BT 'up to' 40Mbit/s	30.5 to 33.1Mbit/s	27.4 to 30.3Mbit/s
Virgin Media 'up to' 50Mbit/s	43.9 to 47.2Mbit/s	43.1 to 46.6Mbit/s

Source: SamKnows measurement data for all panel members with a connection in November/ December 2010
**Caution: Small sample size (<50)*
*** Results should be treated with some caution as normalisation may not be as effective for O2/Be due to the lower incidence of panellists with longer than average line lengths*
Panel Base: 1081
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3[7]; (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

Download speeds fell during peak times – but by more for some ISPs than others

1.12 Download speeds can fall during peak periods as a result of capacity constraints on ISPs' networks (caused by simultaneous users sharing the same bandwidth). We found that in November/December 2010, speeds measured using multi-thread tests during the peak weekday hours of 8 to 10pm (which on average were the hours in the week when speeds were slowest) were 93% of the maximum speeds delivered (typically during 'off-peak' hours such as 12am to 6am) and 95% of the average speeds delivered over a 24-hour period.

1.13 Our results showed, however, that some ISP packages suffered greater slowdowns in the peak period of 8 to 10pm on weekdays, indicating differing levels of contention

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days from our analysis in this report. However, including these results would have had the impact of reducing average speeds by around 0.7Mbit/s and reducing speeds during the peak period by around 2.7Mbit/s.

[7] In Ofcom's definition of geographic broadband markets, Markets 2 and 3 represent 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 facilitates comparison of operators on a like-for-like basis. See paragraph 3.12 for details.

in the relevant ISPs' networks. Among the 'up to' 8Mbit/s and 10Mbit/s ADSL packages, BT was significantly faster than Orange during the peak period.

1.14 Among the 20Mbit/s and 24Mbit/s ADSL packages, Sky suffered the least slowdown during peak periods, with average speeds in the period 8 to 10pm around 99% of those over a 24-hour period, and 94% of the maximum speed.

BT Infinity service delivers significantly better upload speeds than other packages

1.15 Download speed is typically the most important single metric in determining broadband performance and, along with price, continues to be the most important metric in the advertising of broadband. However, there are of course many other metrics that determine the overall performance of a broadband connection, and our research findings include a number of these: upload speeds (the time taken to send information over a broadband connection), latency (the time it takes a single packet of data to travel from a user's PC to a third-party server and back again), packet loss (the loss of data packages during transmission over an internet connection), the performance of ISP's DNS servers (which translate domain names into IP addresses) and jitter (a measure of the stability of a connection).

1.16 Upload speeds are particularly important for users looking to share large files, use real-time video communications and for some games. As use of such services has increased, so too has the focus on upload speeds, which has become more of a source of differentiation in recent months, with BT Infinity advertising upload speeds of 'up to' 10Mbit/s, and Virgin Media increasing the upload speeds associated with its cable services.

1.17 Our results showed that BT's 'up to' 40Mbit/s FTTC service delivered average upload speeds of 7.8Mbit/s, significantly higher than any other service we measured. Virgin Media's 'up to' 50Mbit/s delivered average upload speeds of 2.8Mbit/s, with all other ISP packages delivering average upload speeds of less than half this.

Conclusion and next steps

1.18 This research report is a representative snapshot of the state of residential broadband performance in November/December 2010, and we have noted the limitations of the research. The broadband market is changing rapidly as operators are continuing to invest in their networks in order to make faster broadband available. Therefore, the results set out in this report will not necessarily reflect the future performance of networks and providers. The research continues and we have also separately commissioned research into mobile broadband performance, with a report scheduled for publication in spring 2011.

1.19 The results of our research show continuing improvements in average broadband speeds. We also note that the highest speed cable services and fibre-to-the-cabinet services are consistently delivering speeds that are sufficient for virtually all applications likely to be used by residential broadband consumers.

1.20 Nevertheless, most broadband is still delivered via ADSL, over copper lines which were originally designed for phone services and which have been stretched to the very edge of their capability in order to provide broadband. An inescapable characteristic of ADSL broadband is that performance is constrained by the length and quality of the copper line. Our research finds that for many consumers the speeds available to them via ADSL are not sufficient for a high-quality experience of

high-bandwidth services such as internet TV, or for connecting multiple devices to the internet.

1.21 The research results underline the importance of consumers getting clear, accurate and consistent information on speeds, including the maximum speeds that consumers' individual lines are capable of receiving (access line speeds). In this context in July 2010 we introduced a strengthened Voluntary Code of Practice on Broadband Speeds[8] with the co-operation and agreement of ISPs.

1.22 The new, strengthened, Code ensures that consumers are given the clearest possible information on access line speeds at point of sale. It also ensures that consumers' speed-related problems will be resolved by their ISP if possible, and if this is not possible, consumers whose speed is significantly less than expected will have be permitted to leave their provider without penalty within three months of the start of their contract. The new Code comes into force in July 2011 and we have published a list of signatories to it on our website[9].

1.23 In addition to the protection offered to consumers by the Code, it is our view that when speeds are used in broadband advertising they should reflect the actual speeds that consumers receive. It is our view that a change in the rules around advertising is necessary in order to better promote speed-based competition between providers and ensure that consumers can effectively compare the services available to them.

1.24 The Advertising Standards Authority (the ASA) has responsibility for broadband advertising and in May 2010 it asked the Committee for Advertising Practice (CAP) and Broadcast Committee for Advertising Practice (BCAP) to conduct a separate review of the advice provided to ISPs on advertising practices. We have contributed to this review, which includes a public consultation into the use of speed claims in advertising. This consultation closed on 25 February 2011, and we have published our response to the consultation alongside this research report. In summary, we make the following recommendations:

- that if speed is used in advertising it must include a 'Typical Speed Range' (TSR), which should be based on average actual speeds that the 25th to 75th percentile of customers receive (i.e. the inter-quartile range);
- that this TSR must have at least equal prominence to any 'up to' claims made;
- that if an 'up to' speed is used it must represent the actual speed that a materially significant proportion of customers are capable of receiving; and
- that any TSR or 'up to' speed used must be based on statistically robust analysis of connection data, with the data and methodology available for scrutiny.

[8] The current version of the Code of Practice, which 50 ISPs have signed up to, can be found at http://stakeholders.ofcom.org.uk/telecoms/codes-of-practice/broadband-speeds-cop/voluntary-codes-of-practice/.

[9] http://stakeholders.ofcom.org.uk/telecoms/codes-of-practice/broadband-speeds-cop-2010/

1.25 Figure 1.2 shows Ofcom's estimates of the TSR by technology and headline speed based on data collected in November/December 2010[10].

Figure 1.2 Estimated typical speed ranges (25th to 75th percentile), by technology and headline speed

Current packages	Typical speed range
ADSL 'up to' 8Mbit/s	2 to 5Mbit/s
ADSL 'up to' 20/24Mbit/s	3 to 9Mbit/s
Cable 'up to' 10Mbit/s	10Mbit/s
Cable 'up to' 20Mbit/s	18 to 19Mbit/s
Cable 'up to' 50Mbit/s	47 to 49Mbit/s
FTTC 'up to' 40Mbit/s	30 to 36Mbit/s

Source: Ofcom / operator data / SamKnows measurement data for all panel members with a connection in November/December 2010
Note: Figures are rounded to the nearest Mbit/s

[10] The TSRs for ADSL are calculated by using the inter-quartile range from the modem synchronisation speed data collected from operators (detailed in Section 10 of this report), and adjusting this range in proportion to the difference between the average modem synchronisation speed and the average measured speed for panellists; TSRs for cable and FTTC packages represent the inter-quartile range of average download speeds received by panellists. We believe this is the most robust way of calculating the TSR from the data available to us, although, as noted in our response to the CAP/BCAP consultation on the use of speed claims in broadband advertising, we recognise that there are alternative methodologies for collecting and analysing data and reporting a TSR, which may be equally robust.

Section 2

Introduction

Objective to ensure the provision of clear information to broadband consumers

2.1 Ofcom's primary duty under the Act is to further the interests of UK citizens and consumers in carrying out our functions11. In doing so we are required to secure a number of things, in particular, the availability throughout the UK of a wide range of electronic communications services12. When carrying out our duties we must have regard to the desirability of encouraging investment and innovation in relevant markets and encouraging the availability and use of high-speed data services throughout the UK13. We are also required to have regard to the interests of consumers in respect of price, choice, quality of service and value for money[14]. 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 their experiences of these services[15]. 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[16].

2.2 We have been working on a number of measures in order to achieve our objective:

- **Implementation of the Voluntary Code of Practice on Broadband Speeds**. In June 2008, Ofcom and a number of ISPs agreed a Voluntary Code of Practice (the Code), which came into force on 5 December 2008. 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. An updated Code was agreed in July 2010 which includes the requirement for ISPs to use a consistent methodology to provide a speed estimate in the form of a range, and gives consumers the right to exit the contract without penalty if actual speeds are significantly slower than those indicated[17]. Signatories are required to conform to the strengthened Code by July 2011.

- **Consumer education and information initiatives**. We have published consumer guides to broadband speeds[18] and to buying broadband[19], as well as a video guide[20]. These are designed to inform consumers about how to increase

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[11] Section 3(1) of the Act.
[12] Section 3(2)(b).
[13] Section 3(4)(a) and (e).
[14] Section 3(5).
[15] Section 14.
[16] Section 15.
[17] 2010 Voluntary Code of Practice: Broadband Speeds: http://stakeholders.ofcom.org.uk/telecoms/codes-of-practice/broadband-speeds-cop-2010/
[18] Broadband Guide, http://consumers.ofcom.org.uk/files/2009/07/bbchoice.pdf
[19] http://consumers.ofcom.org.uk/2010/07/broadband-speeds-2/.
[20] http://stakeholders.ofcom.org.uk/market-data-research/telecoms-research/broadband-speeds/main/

the broadband speeds they receive and about the considerations they may wish to take into account when purchasing a broadband service.

- **Publication of research into actual broadband speeds**. This research report follows reports that we published in January 2009, July 2009 and July 2010[21], detailing research into the average download speeds delivered by different ISP packages to UK residential consumers.

- **Contact with other regulatory bodies**. Consumers often form expectations about their broadband services as a result of advertising, which is usually the first point of contact an ISP makes with consumers. The Advertising Standards Authority (ASA) has responsibility for the rules around broadband advertising, and Ofcom has engaged with the ASA on how broadband advertising should develop as higher-speed services are rolled out. In June 2010 the ASA asked its Committee for Advertising Practice (CAP) and Broadcast Committee for Advertising Practice (BCAP) to conduct a review of the advice provided to ISPs on advertising practices, and on 26 January 2011 it opened a consultation into the use of 'up to' speed claims in advertising. Ofcom contributed to the ASA's pre-consultation, and has also responded to this public consultation, which closed on 25 February 2011. Our response to the public consultation includes some of the analysis in this report, and also includes consumer research conducted to test consumers' reactions to different ways of communicating broadband speeds. We have published our consultation response alongside this research report.

2.3 We believe that the measures outlined above have helped us to get closer to achieving our objective to provide better information to consumers on broadband performance; of course, there is always more that can be done. As regards the research which is the subject of this report, this will allow consumers to compare the broadband services offered by ISPs (bearing in mind, however, that not all ISP packages are included and that therefore other services are available[22]) on the basis of actual network performance.

Rationale for the report

2.4 The rationale of this report is the same as that for the 2009 and 2010 reports. As explained in the July 2009 report, it was necessary to commission our own independent research into actual broadband speeds as there is currently limited robust research available in this area. Other research into UK broadband performance has typically relied on software monitoring solutions that do not account for the impact on speed of PC set-up, or that of having more than one computer using a broadband connection. In order to ensure that the research results are representative of the experience of UK residential broadband consumers as a whole, and that comparisons between providers are provided on a like-for-like basis, it is also important to apply appropriate statistical analysis. For example, we believe it is necessary to weight the sample to ensure that it is representative of residential broadband users, and also to apply appropriate statistical techniques to 'normalise' the data for ADSL broadband by distance from exchange. Normalisation ensures that the final results enable like-for-like comparison between ISP packages.

[21] See footnote [1].
[22] See the explanation of the limitations of the research on pages 2-3 above.

The scope of the research

2.5 We have commissioned broadband measurement company SamKnows to recruit a panel of UK residential broadband users who are also subscribers of certain ISP packages. This panel was assembled in spring 2010, but also included some of the same members of the panel that was used for data collection in the first phase of research (October 2009 to April 2010).

2.6 This report is the second report based on this panel performance data, and it presents performance data collected in the period 1 November 2010 to 15 December 2010 (inclusive). We used data collected over a 45-day period rather than the one-month of data used previously in order to incorporate an amended test schedule, a key component of which was the addition of more multi-thread download speed tests.

- During November 2010 we ran an identical download speed test schedule to that which was used in May 2010, consisting of hourly single-thread tests (the download of a single file), but with two multi-thread tests (the simultaneous download of multiple files) scheduled for each panellist, one of which ran between 4 and 6am (when typically there is little traffic on ISP's networks) and the other during the 8 to 10pm peak period. This enabled us to make direct comparisons with the test results in the July 2010 Broadband Speeds report (which used data collected in May 2010).

- From mid-November until the end of the testing period we ran additional multi-thread tests (using a different test to that used previously), which were scheduled throughout the day and ran more frequently during peak hours and less often during the off-peak period. There was therefore a two-week overlap between the two test cycles which allowed us to compare the results from the different sets of download tests.

- We also made some changes to the tests to measure other metrics that define the performance of broadband connections, which are discussed in more depth on section 9.

2.7 We include the results of both single and multi-thread tests in the report as each are relevant to the consumer experience, and we compare the performance of each. However, in this report (unlike previous reports) we have opted to use multi-thread tests for the majority of comparisons. This is because multiple-file download is increasingly being used to optimise delivery times, and, in particular, because multi-thread tests represent a better metric for the measurement of high-speed services. It should be noted that multi-thread tests typically deliver faster speeds than single-thread tests (see sections 4 and 8).

2.8 The focus of this report is on average download speed and how this varies by a range of variables including geographical location, time of day, access technology and ISP package.

2.9 Where appropriate, we also include data from May 2010 (as published in July 2010) and data collected from our first round of research (October 2008 to April 2009) to show how UK residential broadband performance has changed over time.

2.10 In this report we provide greater emphasis to upload speeds than in previous reports, due to greater prominence in the market and greater variation between providers than previously found. We also again include analysis of other factors which determine the performance of a broadband connection: web-page loading time,

latency, packet loss, DNS and jitter. However, the bulk of the analysis focuses on download speeds because this remains the main performance metric by which broadband is sold and because our research indicates that other performance indicators vary less and the level of performance offered is sufficient for most internet applications.

2.11 We include comparative data for those ISP packages for which we had large enough sample sizes to make the analysis statistically meaningful. This comprised the 'up to' 8Mbit/s ADSL packages from BT Retail, Orange and Plusnet; the 'up to' 20Mbit/s or 24Mbit/s ADSL packages from BT Retail, O2/Be, Sky and TalkTalk; Virgin Media's 'up to' 10, 20 and 50Mbit/s cable packages; and BT's 'up to' 40Mbit/s FTTC package.

2.12 For those ISPs which offer services via local loop unbundling (LLU) and have different packages for consumers living within their LLU network footprint (on-net) and those who do not (off-net), we report only on the performance of on-net customers. This is because on-net services are typically offered as different packages with different prices and headline speeds, and consumers can readily identify whether a service is on-net or off-net.

2.13 BT's 'up to' 40Mbit/s service experienced a fault during three days in December when all customers on our panel had their speeds capped at 2Mbit/s during the evening hours of 6pm to 12am as a result of an incorrect traffic management profile being applied. We have excluded test results on these days from our analysis in this report. However, including these results would have had the impact of reducing average speeds by around 0.7Mbit/s and reducing speeds during the peak period by around 2.7Mbit/s.

2.14 In addition to the data collected from the consumer panel, in this report for the first time we also include technical data provided by Openreach, O2, Everything Everywhere, Virgin Media, Sky and TalkTalk. This details the broadband modem synchronisation speeds (sync speeds) for all of their broadband connections. This is the "raw" capacity available between the end user's modem and the operator's equipment in the exchange or cabinet. This large data set has allowed us to gain a greater insight into how broadband performance varies by technology, line characteristics and local geography.

Outside the scope of the research

2.15 ISPs' packages for which we were unable to recruit a sufficiently large number of panellists to allow statistically meaningful analysis of test results are not included in the research. We are keen to include smaller ISP packages in future research, if feasible. We would like to emphasise that there are many other ISPs available other than those named in the report, some of which may provide equivalent or better performance than some of those included.[23]

2.16 We have not examined the performance of services at headline speeds of 'up to' 2Mbit/s or less because they are no longer retailed. However, around 4% of UK broadband subscriptions are still on (legacy) packages of 2Mbit/s or less. In calculating UK average performance we have adjusted our findings accordingly by

[23] It should also be noted that Kingston Communications, the incumbent in Kingston-upon-Hull, was excluded from the scope of the research for the same reason as smaller providers. As Kingston Communications is the largest supplier by retail market share in the Hull area, the findings in this report are less relevant to consumers in the Hull area than to consumers in other parts of the UK.

using the average performance of 'up to' 2Mbit/s and below services as identified in the research conducted in April 2009 (and published in July 2009).

2.17 We looked only at the performance of residential fixed-line broadband, which accounts for around 90% of the UK's broadband connections. Outside the scope of our research was broadband accessed by dedicated fibre networks provided all the way to consumer's homes (this currently accounts for less than 0.5% of all broadband customers in the UK) and satellite broadband (which also has very low take-up).

2.18 In addition, 'mobile broadband', that is broadband delivered 'over the air' by cellular mobile network operators typically via a USB modem or 'dongle', was excluded. We have commissioned separate research into mobile broadband performance and collected data between October and December 2010, and plan to publish results in spring 2011.

2.19 This report is a research report. While the research was undertaken for Ofcom to improve its evidence base in order to inform our policy work, this report does not draw any policy conclusions.

Structure of this research report

2.20 This report is structured as follows:

- **Section 3** sets out the objectives of the research and provides an overview of the research methodology.
- **Section 4** provides an overview of residential fixed-line broadband speed performance indicating how and why the actual speeds delivered differ from headline speeds and maximum line speeds.
- **Section 5** examines how broadband speeds vary by geographic location, including the choice of services available and the distance from exchange (for ADSL customers).
- **Section 6** examines how broadband speeds vary by time of day, identifying why speeds in the peak evening periods are typically slower than those in off-peak periods.
- **Section 7** examines how broadband speeds vary by access technology, comparing the performance of ADSL, cable and FTTC broadband.
- **Section 8** looks in more detail at how ISPs and their packages vary in terms of upload and download speeds, and considers the reasons why this may be the case. This examines the differences between single-thread and multi-thread speed tests. upload speeds
- **Section 9** looks at metrics other than download speed which determine broadband performance and compares ISP package performance in terms of web browsing, latency, packet loss, DNS resolution and jitter.
- **Section 10** analyses operator-provided data on modem synchronisation speeds, attenuation and line length associated with broadband connections in order to provide additional insight into how broadband performance varies by technology, line characteristics and local geography.

- **Section 11** concludes the report with an overview of the implications of the findings for consumers and ISPs, and our proposed next steps.

- **Annex 1** contains a glossary explaining the technical terms used throughout the report.

- **Annex 2** explains our technical methodology.

- **Annex 3** explains our statistical methodology, including the ways we have weighted and 'normalised' data to ensure that the findings are representative of UK residential broadband users as a whole, and that ISP package performance is presented in an accurate and robust way.

- **Annex 4** provides details on significant differences between the performance of access technologies, and the performance of ISP packages, to a 95% confidence level and a 99% confidence level.

Section 3

Objectives and methodology

Research objectives

3.1 The overall objective of our research was to gain an understanding of residential fixed-line broadband performance across the UK. Specific objectives were:

- To measure average download speeds across the UK and assess how they relate to maximum line speeds and advertised 'headline' speeds.
- To identify how speeds vary by a number of factors including time of day, geographic location (including distance from the exchange for ADSL broadband), access technology and ISP.
- To measure a number of other factors that determine overall broadband performance: upload speeds, loading web pages, latency, packet loss, DNS and jitter.

How we explore variations in broadband speeds

3.2 Sections 5, 6 ,7 and 8 of this report examine why download speeds are typically below headline speeds and look in particular at the influence of the following factors:

- Geographic location.
- Time of day.
- Access technology.
- ISP.

3.3 Our technical approach to speed measurement did not allow us to report on other factors which influence actual download speeds, such as wiring into the home and internal wiring within the house.

3.4 It is also important to note that the download speeds which we measure are not always the speeds experienced by the end user, which may be degraded by:

- Bandwidth being shared by more than one PC using the same broadband connection simultaneously.
- The quality of the connection from the modem to the PC, for example the WiFi connection.
- The speed of the particular websites visited or applications used by the consumer.

3.5 In addition, the measures on which we focus on in this report – actual upload and download 'throughput' speeds – are not the only driver of broadband performance. Other indicators which can determine the overall broadband experience include web browsing, latency, upstream and downstream jitter, DNS look-up times and DNS failure rates. We examine these further in section 9.

3.6 Nevertheless, we believe that focusing on download and upload speeds is useful because, other than price, they are the principal metric by which broadband is advertised and is the single most important metric in determining the overall quality of the user experience (we found that the lower range of performance for all the other metrics was sufficient for most internet applications – see section 9 for details). In addition, there is a reasonable correlation between download speed and most other performance metrics, so the drivers of variation in download throughput speed are likely to be similar to the drivers of variation in the other indicators.

Methodology

Consumer panel

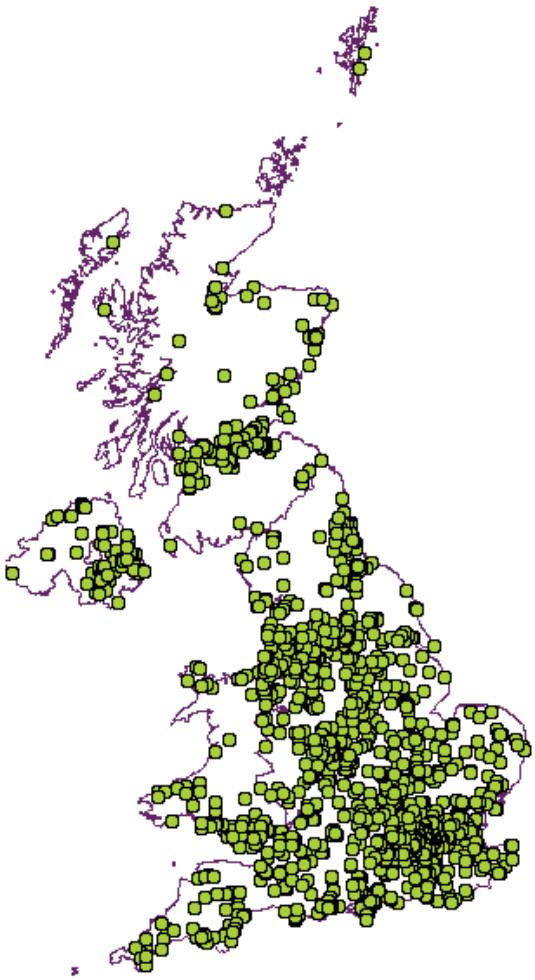
3.7 The technical methodology chosen is the same as that used in Ofcom's first round of research into broadband performance in 2008/9 and was based on that created by broadband performance company SamKnows. As Ofcom's partner in the project, SamKnows recruited a panel of UK residential broadband users 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.

3.8 All panellists were sent a hardware monitoring unit which they were instructed to connect to their router. Software within this unit 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).

3.9 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.

3.10 The performance data in this report are taken from a base of 1,710 panellists who had a broadband monitoring unit connected to their router in November/December 2010. Figure 3.1 details the geographical spread of the panellists, which is broadly in line with the geographic distribution of UK residential broadband subscribers.

Figure 3.1 Geographic distribution of panellists



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

3.11 The technical methodology is described in Annex 2.

3.12 Figure 3.2 details Ofcom's definitions of geographic broadband markets. 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 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.

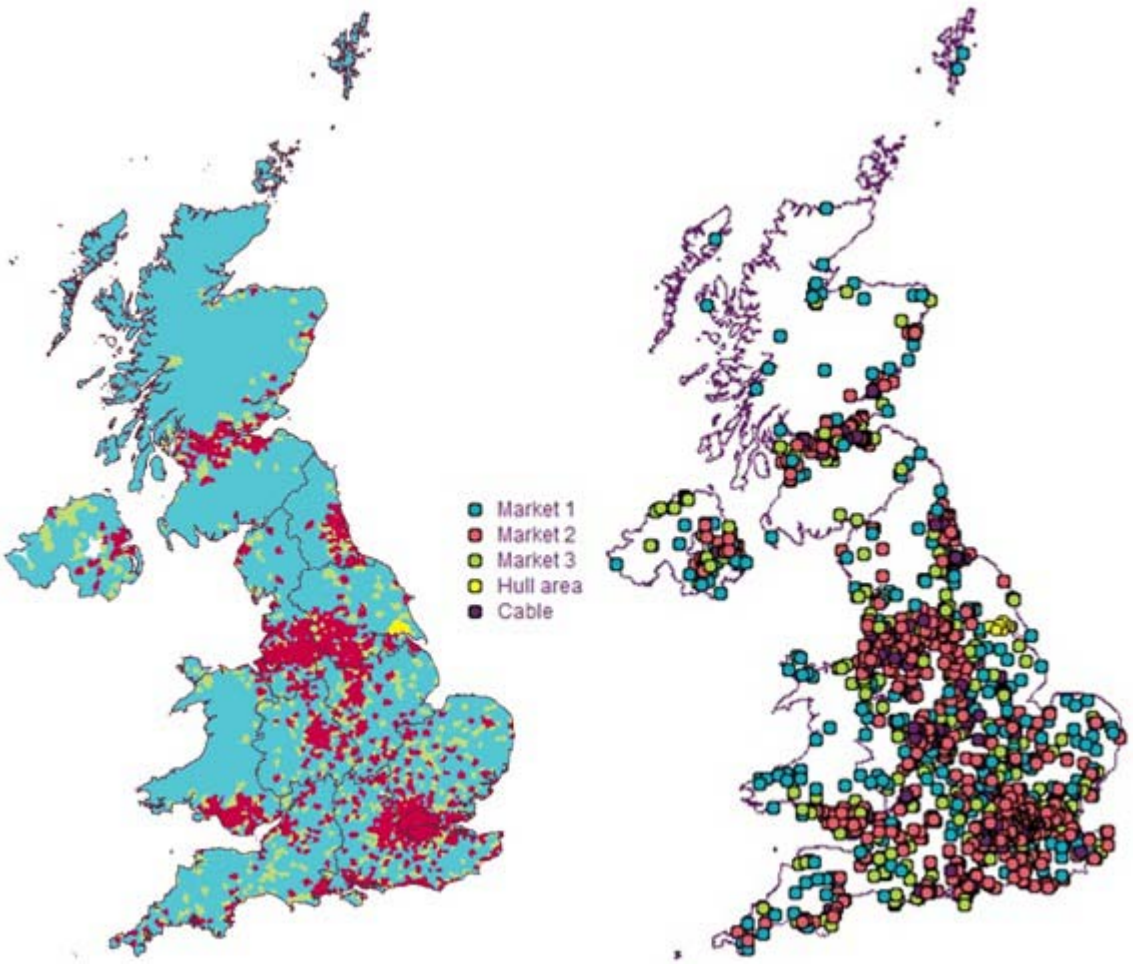
Figure 3.2 Ofcom definitions of geographic broadband markets

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

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

3.13 Figure 3.3 shows a map of the UK colour coded by geographic broadband market designation and the location of our panellists.

Figure 3.3 Distribution of exchange areas and panellists by geographic market definition



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

3.14 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.

3.15 All weightings applied have been developed by market research company Saville Rossiter-Base and reviewed by Ofcom before use. David Savlle of Savile Rossiter-Base also made an assessment the research methodology and panel and helped ensure it's 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 had

expert review and endorsement by econometrician Professor Andrew Chesher of University College London[24].

Operator data

3.16 In November 2010 we issued a formal request to the six largest ISPs in the UK (BT, Virgin Media, TalkTalk, Sky, Everything Everywhere and O2) to provide technical data on each of the broadband connections they operate. This included modem synchronisation speeds, attenuation data and line length.

3.17 This data were analysed in order to explore the relationship between speeds, attenuation and line length and to gain insight into how broadband performance varies by technology, line characteristics and local geography. The results of this analysis can be found in section 10 of this report.

[24] http://stakeholders.ofcom.org.uk/binaries/research/telecoms-research/broadbandspeeds.pdf p20

Section 4

Overview of UK broadband speeds

Why broadband speeds matter

4.1 The user experience of virtually all types of internet use is affected to some extent by connection speed, and this has become even more important as the use of bandwidth-hungry applications such as downloading video and audio has grown. Indeed, some services are only possible at faster speeds; the BBC, for example, recommends a minimum speed of 500kbit/s to use its iPlayer, and 3.2Mbit/s for the high-definition iPlayer service. Details of the theoretical time taken to perform some of the most common online activities at downstream speeds are given in Figure 4.1 below.

Figure 4.1 Theoretical time taken to perform various online activities

	Download throughput speed			
Provider	2Mbit/s	8Mbit/s	24Mbit/s	50Mbit/s
Download 250kB webpage	1 second	0.3 seconds	0.1 seconds	<0.1 seconds
Download 5MB music track	21 seconds	5 seconds	2 seconds	1 second
Download 25MB video clip	1 minute 45 seconds	26 seconds	9 seconds	4 seconds
Download low quality film (750MB)	52 minutes	13 minutes 6 seconds	4 minutes 22 seconds	2 minutes
Download DVD quality film (4GB)	4 hours 48 minutes	1 hour 11 minutes	24 minutes	11 minutes

Source: Ofcom

4.2 Moreover, consumers are increasingly sharing their broadband connection simultaneously between a number of different devices. For example, some households have a number of PCs/laptops, smartphones and/or tablet devices, and online gaming consoles connected to the internet at the same time. This demand for bandwidth is only likely to increase further as take-up of devices such as internet-enabled TVs increases and as consumers make greater use of web-based video and audio services.

4.3 The demand for broadband services varies: some households will require much greater bandwidth than others. For example, households with multiple devices connected to the internet simultaneously will require much faster speeds than those with only one. Hence it becomes even more important for consumers to have clear information on the speeds they can expect from different broadband services, otherwise they may not be able to choose the service which best meets their needs

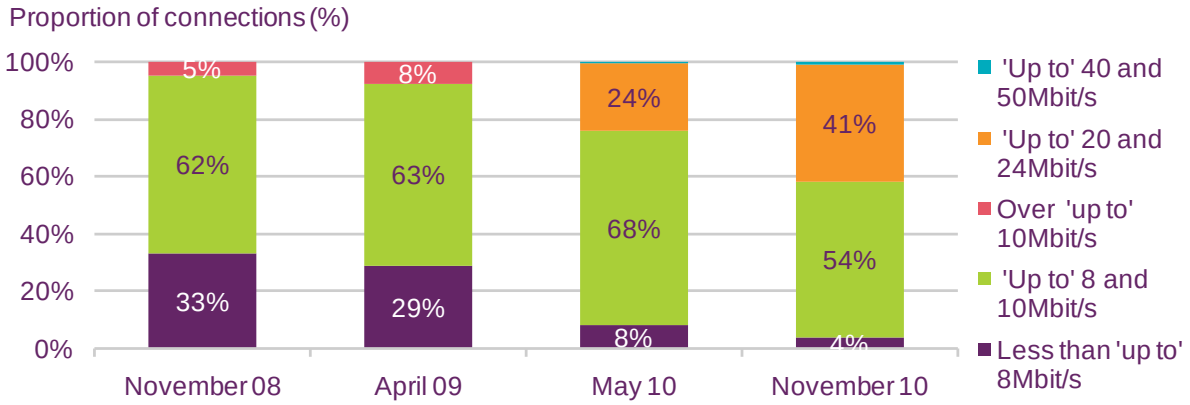
4.4 Headline speeds have been central to the way in which broadband is marketed, with UK residential services advertised according to their theoretical maximum download speed (for example, ‘up to’ 2Mbit/s, ‘up to’ 8Mbit/s or ‘up to’ 20Mbit/s). But there is some evidence that ISPs are changing the way in which they market their broadband services – in part, because they recognise that in many cases, consumers will not be able to achieve the headline speeds of the package. For example, TalkTalk does not typically advertise its services on the basis of speeds but instead simply promotes them on the basis that they will provide the fastest speed that a customer’s line is able to support.

4.5 Nevertheless, we have used the labels used by ISPs to describe their package to illustrate how consumers have been increasingly taking up higher-speed broadband services. Over the last year, most ISPs offering ADSL-based services have been migrating their ‘up to’ 8Mbit/s and 10Mbit/s customer bases to ‘up to’ 20Mbit/s or 24Mbit/s services. In addition, BT has continued to roll out fibre services, including its fibre-to-the-cabinet (FTTC) product which offers download speeds of ‘up to’ 40Mbit/s and upload speeds of ‘up to’ 10Mbit/s. BT has committed to making fibre-based services available to 40% of UK households by summer 2012 and 66% by 2015.

4.6 Figure 4.2 details the distribution of packages by headline speed based on data provided by the six largest ISPs in the UK by retail market share (they have a combined market share of over 90%). It indicates a significant shift in the market towards higher headline speeds during 2010. The average headline speed in November 2010 was 13.8Mbit/s, up from 11.5Mbit/s in May 2010.

4.7 We have presented the data in bands rather than detailing specific ISP packages in order to preserve the confidentiality of these data. All of the analysis in this report uses this weighting (in addition to weighting by ISP package market share and region) in order to ensure that it is representative of UK residential broadband consumers as a whole.

Figure 4.2 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)

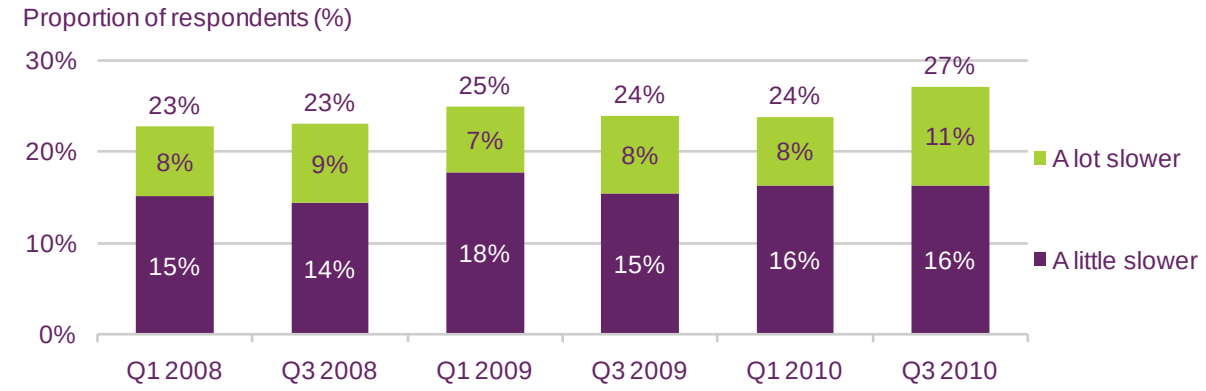
Over a quarter of UK consumers receive broadband speeds slower than they expected when they signed up for their service

4.8 Ofcom research shows that broadband speeds are a concern for a significant minority of consumers. Ofcom research conducted in July to September 2010 showed that 27% of adults with a home broadband connection received slower connection speeds than they had expected when they first took their service. (Figure 4.3).

4.9 In July to September 2010 the proportion of people who said that their connection was 'a lot slower' than they expected when taking the service (11%) was three percentage points higher than when the same question was asked six months previously. This increase may be related to consumers being migrated to services with higher 'up to' headline speeds but the actual speeds which they obtain being significantly lower than these.

Figure 4.3 Perception of actual speeds compared to expected speeds

How does the speed of your fixed broadband internet compare to how you expected it to be when you first got it?



Source: Ofcom research
Base: All adults aged 15+ with a fixed broadband connection
Note: Includes only those who expressed an opinion

Actual download speeds are significantly below advertised 'up to' speeds

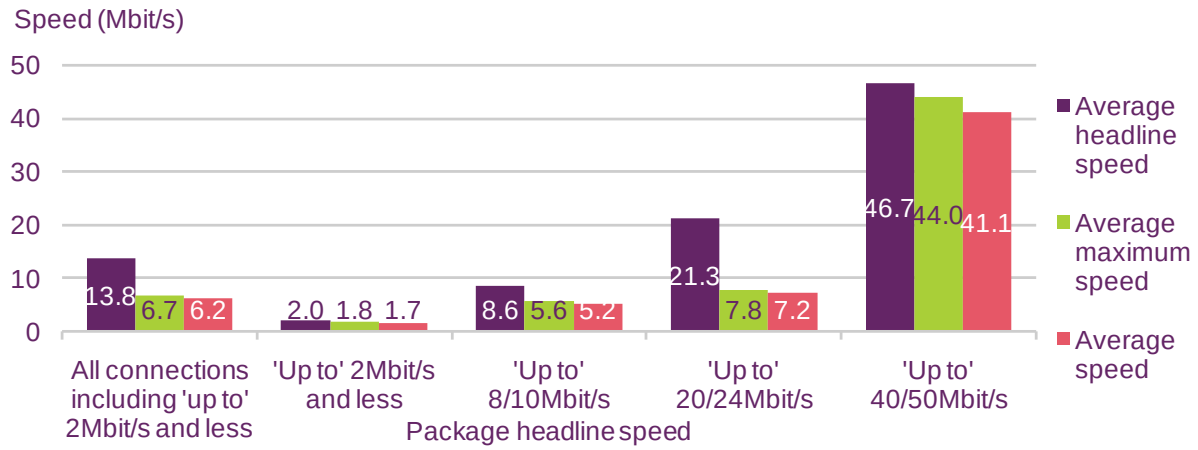
4.10 As stated previously, in this report, we use three key terms to describe download speeds:

- The 'headline speed' or 'advertised speed' is the download speed at which broadband services are typically marketed, usually expressed as 'up to' xMbit/s.
- The 'maximum line speed', or 'access line speed', is the maximum download speed that a specific line is capable of supporting.
- The 'average actual download throughput' speed, or 'average actual download' speed, represents the average actual speeds that a consumer receives, which drives the speed at which web pages and files can be downloaded. The average actual download throughput speed is referred to throughout this document as "average download speed", unless specified otherwise.

4.11 In practice, advertised headline 'up to' speeds are rarely delivered: our present research found that the overall average download speed delivered to UK residential consumers in November/December 2010 was 6.2Mbit/s (from the results of multi-thread speed tests), only 45% of the average headline speed of 'up to' 13.8Mbit/s (Figure 4.4).

4.12 Maximum line speeds are a better indicator than headline speeds of the actual speeds that consumers can expect, and we found that average download speeds attained using multi-thread tests were 93% of maximum speeds in November/December 2010. It is in this context that Ofcom introduced the Voluntary Code of Practice on Broadband Speeds, implemented by ISP signatories in 2008, through which all signatories commit to notifying consumers at the point of sale of the maximum speed their line is capable of supporting.

Figure 4.4 Average UK broadband speeds, November/December 2010 (multi-thread tests)



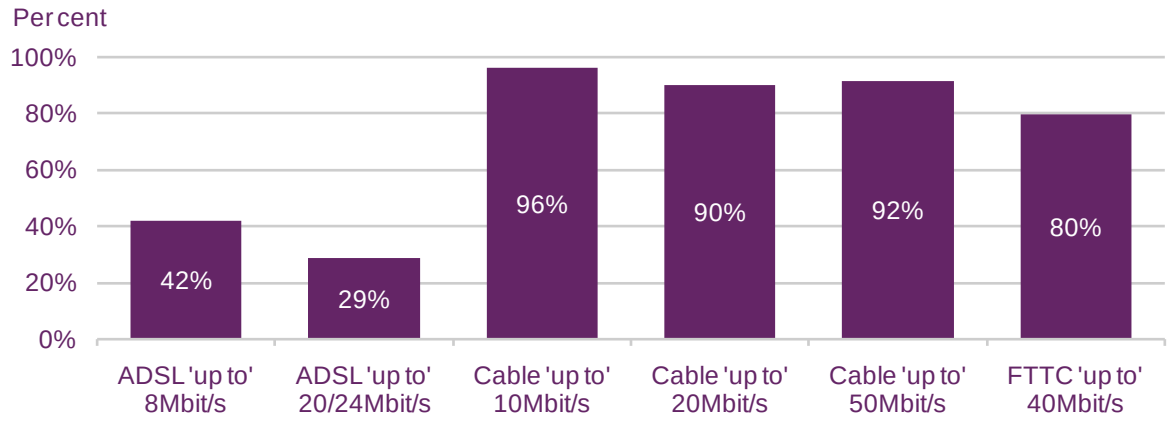
Source: SamKnows measurement data for all panel members with a connection in November/December 2010
Panel Base: 999
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative 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/December 2010; (3) Data collected from multi-thread download speed tests

4.13 Cable services generally delivered average download speeds that were much closer than ADSL services to the advertised 'up to' speeds (Figure 4.5). On average, the actual speeds delivered to consumers on 'up to' 8Mbit/s ADSL packages were 42% of the advertised speed, while those on 'up to' 20 or 'up to' 24Mbit/s were 29% of the advertised 'up to' speed in November/December 2010. Cable services, on average, delivered between 90% and 96% of the advertised speeds. BT's 'up to' 40Mbit/s FTTC service also performed better than ADSL services, on average delivering 80% of the headline download speed during the period[25].

4.14 It should be noted that these results relate to actual speeds measured using multi-thread tests (which involve measuring speeds when multiple files are downloaded simultaneously) which delivered higher speeds than those from single-thread tests for all services, and in particular for the higher-speed packages. We found that, on average across our 45-day testing period, multi-thread tests were around 59% faster than single-thread tests for Virgin Media's 'up to' 50Mbit/s package and around 28% faster than single-thread tests for BT's 'up to' 40Mbit/s FTTC product[26].

[25] BT's 'up to' 40Mbit/s service experienced a fault during three days in December when all customers on our panel had their speeds capped at 2Mbit/s during the evening hours of 6pm to 12am as a result of an incorrect traffic management profile being applied. We have excluded test results from these days from our analysis in this report. However, including these results would have had the impact of reducing average speeds by around 0.7Mbit/s and reducing speeds during the peak period by around 2.7Mbit/s.
[26] It should be noted that these figures differ from those in paragraph 8.35, which are calculated from test results taken across the two weeks when both single- and multi-thread tests ran concurrently, rather than the whole 45-day testing period.

Figure 4.5 Average download speeds (24 hours) as a proportion of headline speeds by connection headline speed and technology, November/December 2010 (multi-thread tests)



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
Panel Base: 999
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

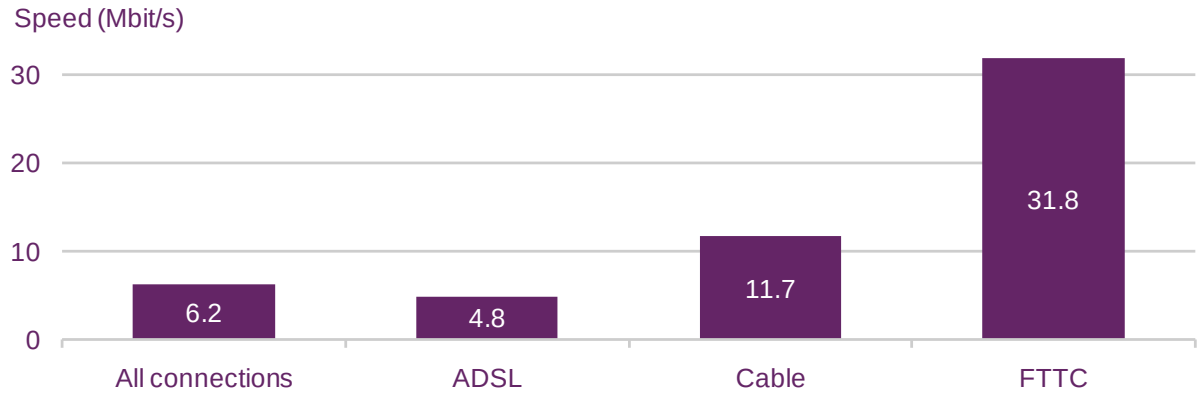
Average UK broadband speeds increased by 5% between May and November/December 2010

4.15 Our research found that overall average UK download speeds, measured using multi-thread speed tests, were 6.2Mbit/s in November/December 2010 (Figure 4.6). The average actual download speed for ADSL connections was 4.8Mbit/s, compared to 11.7Mbit/s for cable broadband services and 31.8Mbit/s for BT's 'up to' 40Mbit/s FTTC service[27].

4.16 It should be noted that these figures will to a large extent be defined by the mix of connections by headline speeds for each technology – for example the large majority of Virgin Media's cable customers currently take its lowest-price 'up to' 10Mbit/s service, meaning that the cable average is much closer to the average speed delivered for this package than for its 'up to' 20Mbit/s or 'up to' 50Mbit/s packages.

[27] BT's 'up to' 40Mbit/s service experienced a fault during three days in December when all customers on our panel had their speeds capped at 2Mbit/s during the evening hours of 6pm to 12am as a result of an incorrect traffic management profile being applied. We have excluded test results from these days from our analysis in this report. However, including these results would have had the impact of reducing average speeds by around 0.7Mbit/s and reducing speeds during the peak period by around 2.7Mbit/s.

Figure 4.6 Average download speeds for fixed broadband connections, all connections including 'up to' 2Mbit/s and less, by technology , November/December 2010 (multi-thread tests)

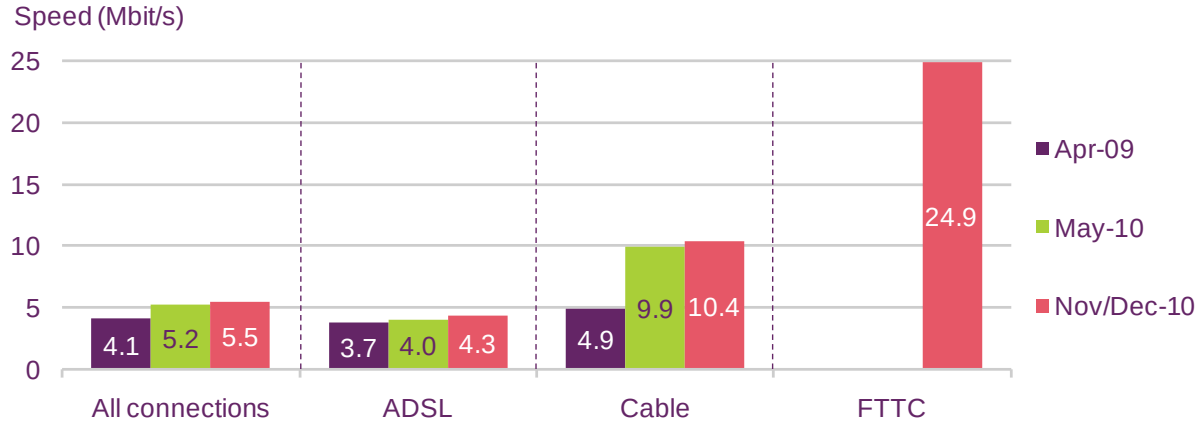


Source: SamKnows measurement data for all panel members with a connection in November/December 2010
Panel Base: 999
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

4.17 Single thread test results (which typically record lower speeds than those from multi-thread tests) showed average download speeds to be 5.5Mbit/s in November/December 2010, a 5% increase on the 5.2Mbit/s delivered in May 2010.

4.18 The increasing take-up of ADSL2+ services offering theoretical maximum speeds of 24Mbit/s (and advertised as 'up to' 20Mbit/s or 24Mbit/s), compared to the theoretical maximum of 8Mbit/s offered by first-generation ADSL services contributed to this increase; as Figure 4.7 indicates, overall average ADSL speeds (measured using single-thread tests and including all ADSL packages at all headline speeds) increased by 0.3Mbit/s during the period (8%). Meanwhile, the overall average speeds delivered to Virgin Media's cable customers grew by 0.4Mbit/s (4%) to 10.4Mbit/s, partly due to a greater proportion of customers taking its 'up to' 20Mbit/s and 'up to' 50Mbit/s packages. BT's 'up to' 40Mbit/s FTTC package, on average, delivered actual download speeds of 24.9Mbit/s measured using single-thread tests.

Figure 4.7 Average download speeds for fixed broadband connections, all connections including 'up to' 2Mbit/s and less, by technology (single-thread tests)

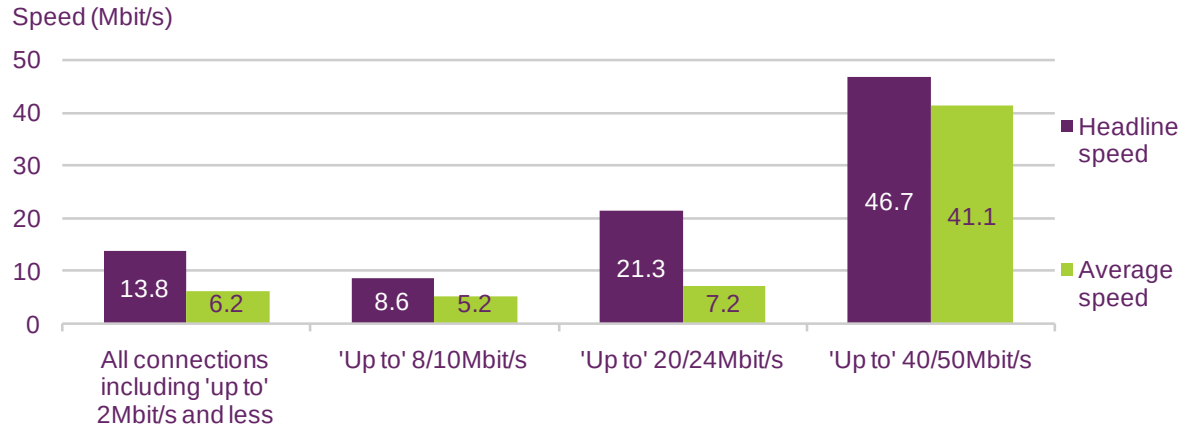


Source: SamKnows measurement data for all panel members with a connection in November/December 2010
Panel Base: 999
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative 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/December 2010; (3) Data collected from single-thread download speed tests

4.19 On average, in November/December 2010 'up to' 8Mbit/s or 10Mbit/s broadband connections delivered average actual download speeds of 5.2Mbit/s (measured using multi-thread tests), while 'up to' 20Mbit/s or 24Mbit/s services delivered average speeds of 7.2Mbit/s and connections with a headline speed of 'up to' 40Mbit/s or 50Mbit/s delivered average speeds of 41.1Mbit/s[28] (Figure 4.8).

[28] BT's 'up to' 40Mbit/s service experienced a fault during three days in December when all customers on our panel had their speeds capped at 2Mbit/s during the evening hours of 6pm to 12am as a result of an incorrect traffic management profile being applied. We have excluded test results from these days from our analysis in this report; however, including these results would have the impact of reducing average speeds by around 0.7Mbit/s and reducing speeds during the peak period by around 2.7Mbit/s.

Figure 4.8 Average headline and actual broadband speeds, November/December 2010 (multi-thread tests)



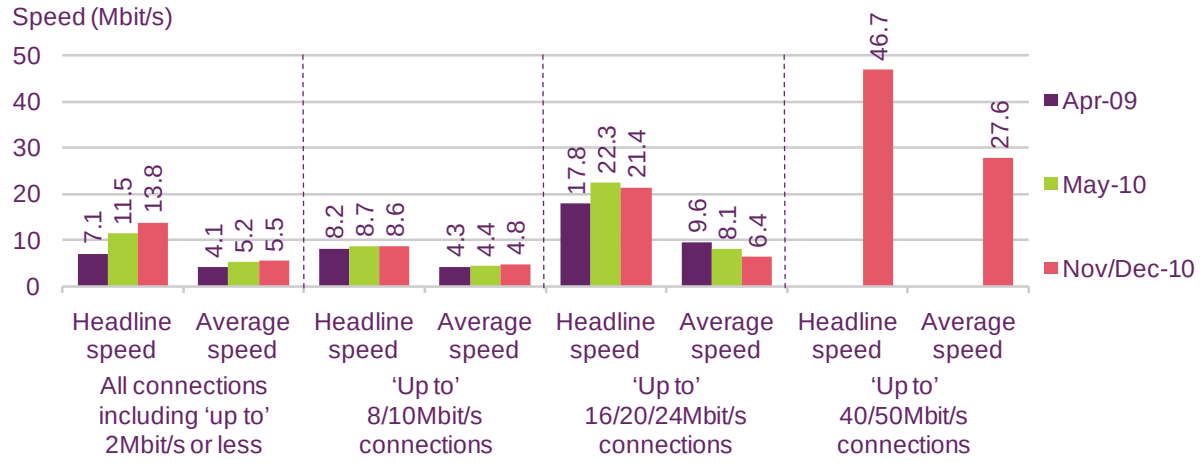
Source: SamKnows measurement data for all panel members with a connection in November/December 2010
Panel Base: 999
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

4.20 The average download speed for 'up to' 8Mbit/s and 10Mbit/s connections (measured using single-thread tests) increased by 0.3Mbit/s to 4.8Mbit/s between May and November/December 2010, while average download speeds on packages with advertised speeds of 'up to' 20Mbit/s and 24Mbit/s packages fell from 8.1Mbit/s to 6.4Mbit/s (Figure 4.9).

4.21 This fall in speeds is likely to be the consequence of wider selling of these higher-speed services; by the end of 2010 many of the largest ADSL operators only offered 'up to' 20Mbit/s (e.g. BT Retail and Orange) or 'up to' 24Mbit/s (e.g. TalkTalk) packages to new customers. Therefore, customers with long line lengths who might previously have signed up for a lower-speed package now by default are on packages with an advertised speed of 'up to' 20Mbit/s or 24Mbit/s.

4.22 Connections with a headline speed of 'up to' 40Mbit/s or 50Mbit/s in November/December 2010 provided average download speeds of 27.6Mbit/s measured using single-thread tests.

Figure 4.9 Average headline and actual broadband speeds (single-thread tests)



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
Panel Base: 999
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/December 2010; (3) Data collected from single-thread download speed tests

Why actual broadband speeds vary from headline speeds

4.23 Typically, a number of constraints combine to make actual broadband speeds significantly lower than headline speeds:

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

- The amount of 'electrical noise' on an individual line also affects speeds. Noise can arise from 'cross talk' from other ADSL connections between the home and the exchange. Within the home it can arise from many different electrical sources including TVs, lighting, heating, pumps, etc.

- Poor wiring and interference within the home can severely affect performance. In 2009, BT launched an initiative to address this by offering the *BT Broadband Accelerator* or *iPlate* (a filter which consumers install into their phone socket in order to reduce electrical interference from telephone-extension wiring) free of charge (save postage and packing) to all customers where BT believes performance can be improved. Although not all customers have suitable telephone junction boxes for an *iPlate*, those that do and have fitted one report increases in the download speed achieved.

- For all broadband connections, speeds are constrained by contention in the ISP's own network; this is a particular problem during peak periods as multiple users put demand on backhaul capacity.

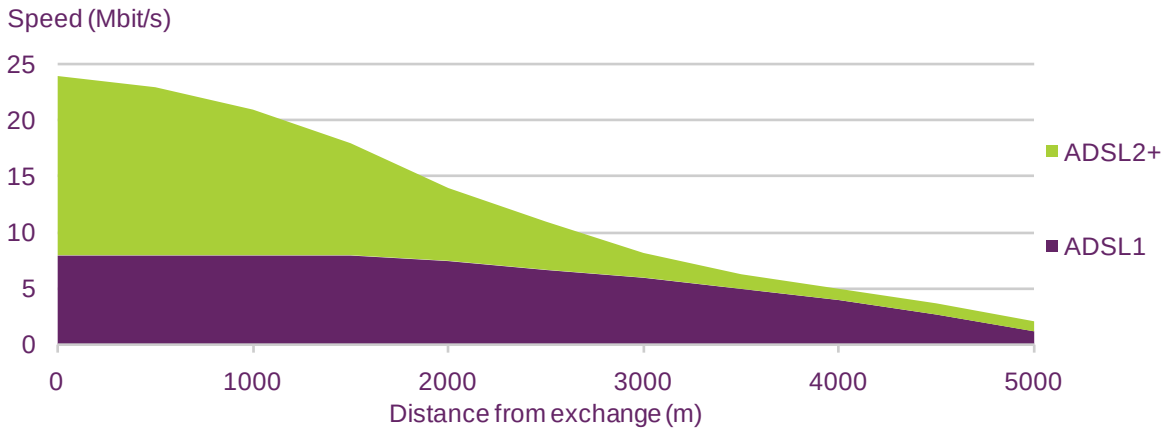
- Congestion on the wider internet causes individual web sites and applications to slow down. (Our research runs tests to multiple web sites and locations across the day in order to minimise the impact this has on our results).

- Consumer equipment performance, in particular computers and routers, can affect speeds received. (Again our hardware-based technical solution, in which the monitoring unit is plugged directly into the router, minimises the impact that this has).

4.24 As ADSL broadband is currently the only broadband technology that is available nationwide, the maximum speeds available to many consumers are defined by the length and quality of the copper wire between their home and the local telephone exchange.

4.25 Figure 4.10 depicts the theoretical degradation of the maximum speeds achievable by ADSL broadband as the length of line from the local telephone exchange to premises increases. It shows that although second-generation ADSL services (ADSL2+) offer significantly faster speeds than first-generation ADSL speeds to customers with a short line length, beyond a distance of 3km from the exchange there is little difference between the two technologies. The relationship between technology, line length and speeds is discussed in more detail in section 10 below.

Figure 4.10 Theoretical maximum ADSL speeds by length of line from exchange to premises



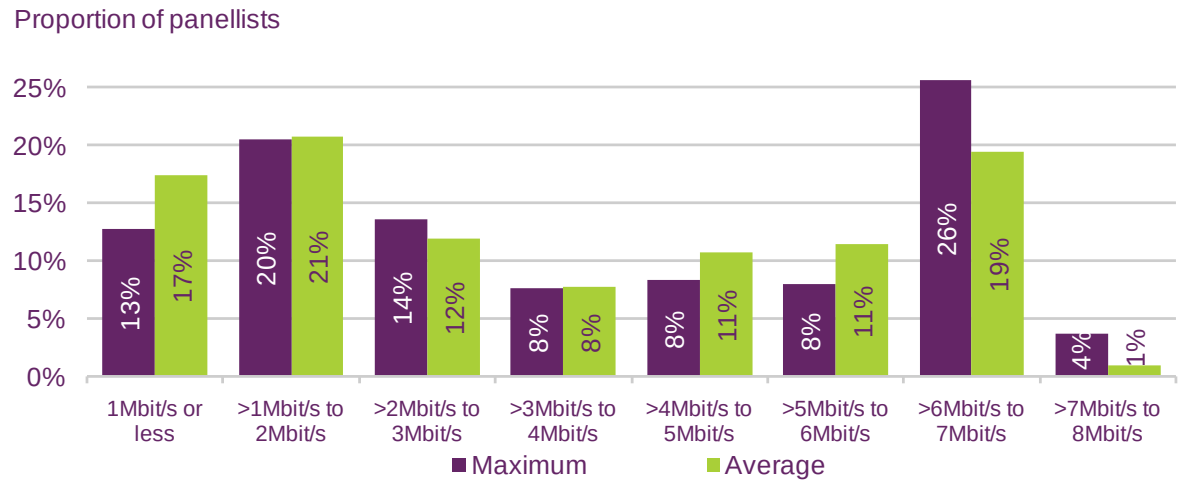
Source: http://www.tpg.com.au/dslam/faq.php

The distribution of actual broadband speeds

4.26 Given the number of factors on which download speeds depend, it is not surprising that, for ADSL broadband, there is wide variation in the average download speeds received among consumers on packages with the same 'up to' headline speed. Figures 4.11 and 4.12 show the distribution of average download speeds received by panellists on 'up to' 8Mbit/s ADSL packages and 'up to' 20Mbit/s or 24Mbit/s ADSL packages.

4.27 In addition to the wide variation in performance, it is striking how few consumers on ADSL services received average download speeds which were close to headline speeds. For example, only 20% of our sample on 'up to' 8Mbit/s ADSL headline speed packages received average download speeds of over 6Mbit/s and 50% received 3Mbit/s or less (Figure 4.11). Similarly, 29% of our sample on 'up to' 8Mbit/s ADSL headline speed packages received maximum download speeds of over 6Mbit/s and 47% received maximum speeds of 3Mbit/s or less.

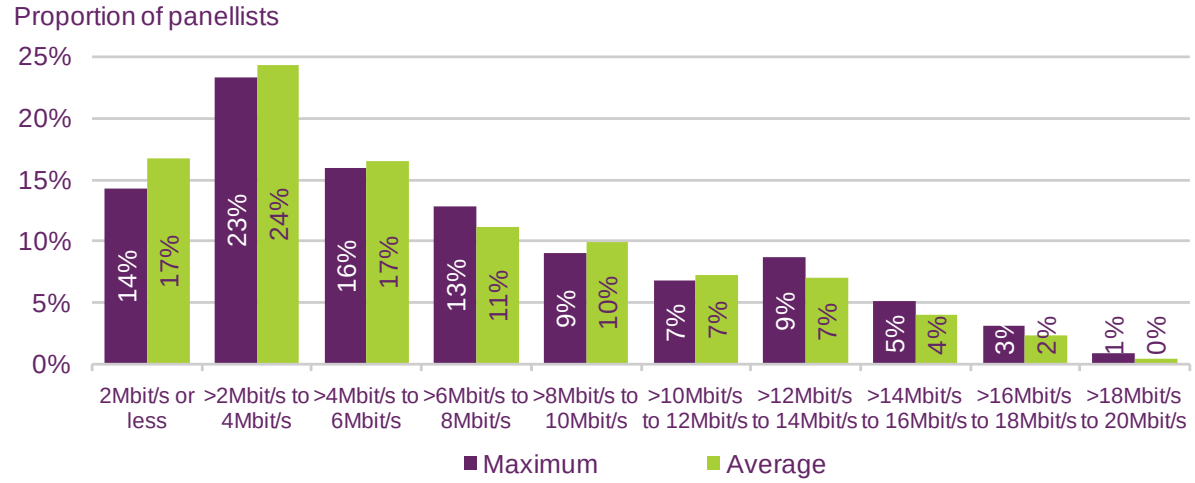
Figure 4.11 Distribution of maximum and average download speeds for consumers on 'up to' 8Mbit/s ADSL packages, November/December 2010 (multi-thread tests)



Source: SamKnows measurement data for panel members with a connection in November/December 2010,
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

4.28 Similarly, very few customers on 'up to' 20Mbit/s or 24Mbit/s ADSL packages received speeds close to headline speeds, with just 14% receiving average download speeds in excess of 12Mbit/s, and 18% receiving average maximum speeds greater than 12Mbit/s (Figure 4.12). Meanwhile, 58% received average download speeds of 6Mbit/s or less and 54% average maximum speeds of 6Mbit/s or less.

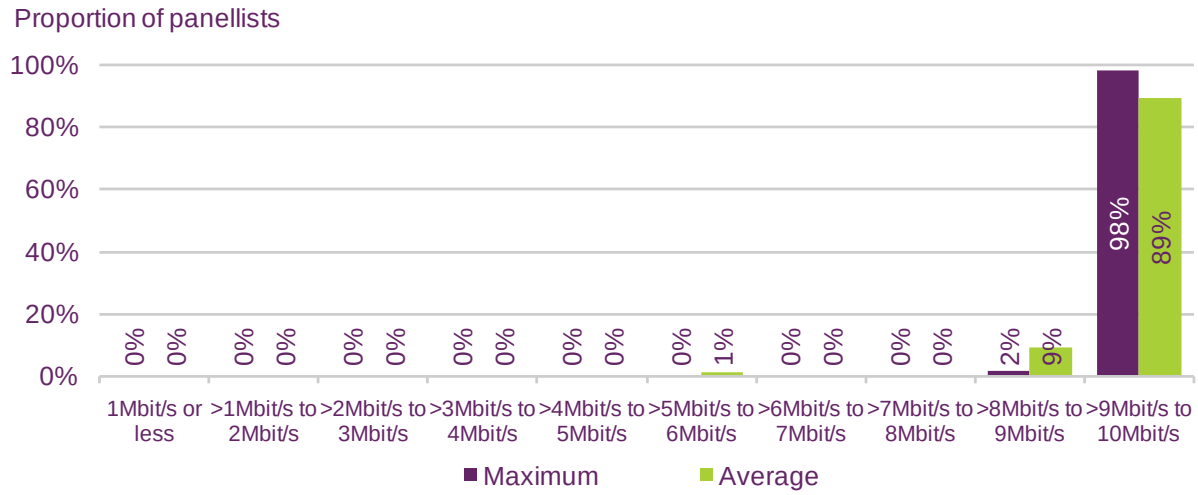
Figure 4.12 Distribution of maximum and average download speeds for consumers on 'up to' 20Mbit/s and 24Mbit/s ADSL packages, November/December 2010 (multi-thread tests)



Source: SamKnows measurement data for panel members with a connection in November/December 2010,
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

4.29 There was significantly less variation in the average download speeds delivered to cable panellists, with 98% of panellists on ‘up to’ 10Mbit/s cable packages receiving maximum speeds in excess of 9Mbit/s, and 89% having average speeds of over 9Mbit/s (Figure 4.13).

Figure 4.13 Distribution of maximum and average download speeds for consumers on 'up to‘ 10Mbit/s cable packages, November/December 2010 (multi thread tests)

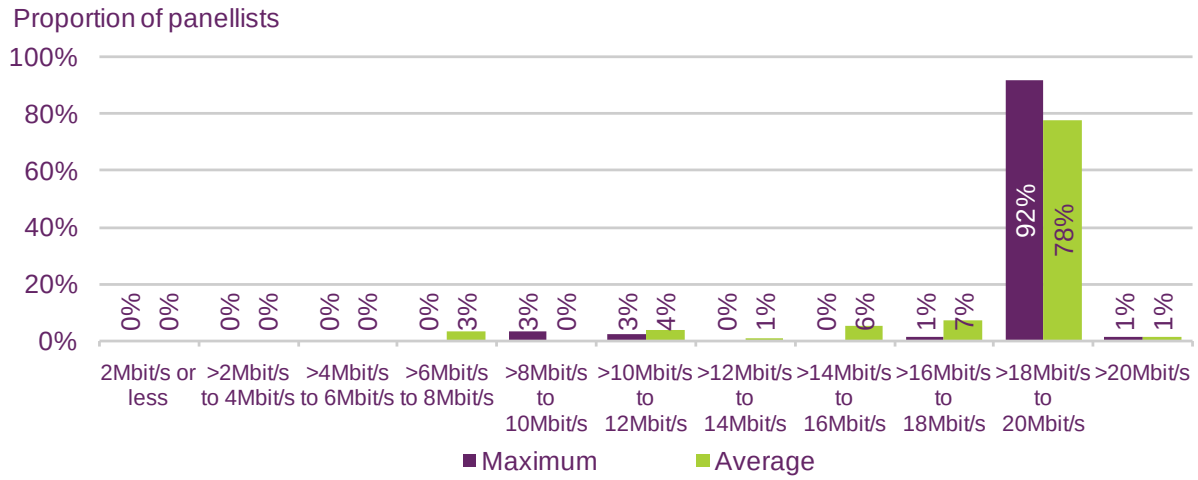


Source: SamKnows measurement data for panel members with a connection in November/December 2010,
Notes: (1) Data have been weighted to regional coverage to ensure that they are representative of UK cable ‘up to’ 20Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests

4.30 Similarly, 93% of panellists on an ‘up to’ 20Mbit/s cable package received maximum speeds in excess of 18Mbit/s, and 79% had average speeds of over 18Mbit/s (Figure 4.14). It is also notable that a small proportion received maximum and/or average speeds in excess of the service’s headline speed. With both Virgin Media’s ‘up to’ 20Mbit/s and 50Mbit/s services, it is notable that some connections get average speeds which are significantly lower than the headline speed. This may be because some lines are set to a legacy profile, or due to misconfigured customer equipment.

4.31 In February 2011, Virgin Media announced that it is to stop offering a 20Mbit/s service to new customers, and in place launched a new ‘up to’ 30Mbit/s cable service; if we are able to recruit sufficient panellists we will include this in our next Broadband Speeds report.

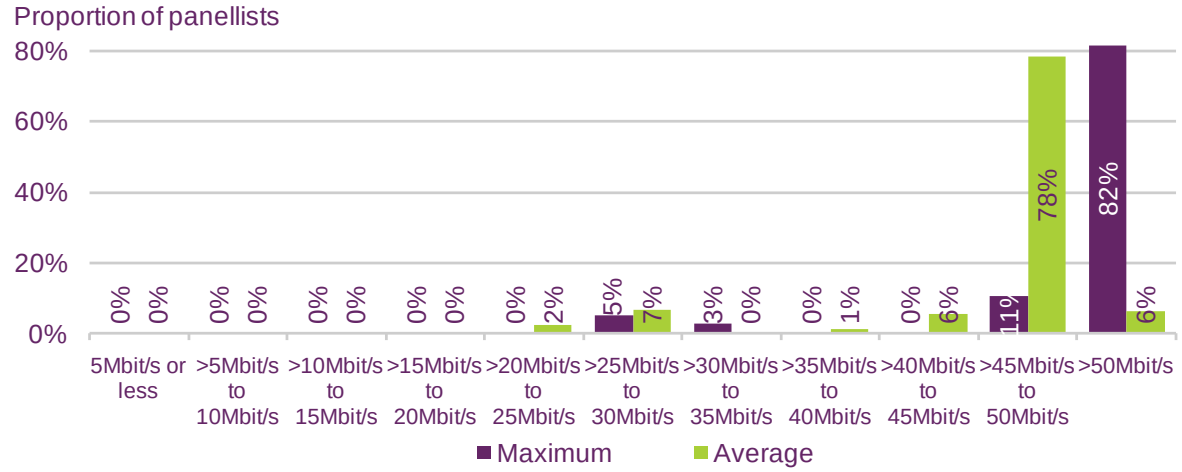
Figure 4.14 Distribution of maximum and average download speeds for consumers on 'up to' 20Mbit/s cable packages, November/December 2010 (multi-thread tests)



Source: SamKnows measurement data for panel members with a connection in November/December 2010,
Notes: (1) Data have been weighted to regional coverage to ensure that they are representative of UK cable 'up to' 20Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests

4.32 Ninety-two per cent of panellists with an 'up to' 50Mbit/s cable package received maximum speeds in excess of 45Mbit/s, and 84% had average speeds of over 45Mbit/s (Figure 4.15). Again, some panellists received maximum and/or average speeds in excess of 50Mbit/s, and 82% of panellists with an 'up to' 50Mbit/s cable package received average maximum download speeds greater than the connection headline speed. In December 2010 Virgin Media began offering an 'up to' 100Mbit/s cable service in some areas; again, we will include this package within future research if we are able to recruit sufficient panellists.

Figure 4.15 Distribution of maximum and average download speeds for consumers on 'up to' 50Mbit/s cable packages, November/December 2010 (multi-thread tests)

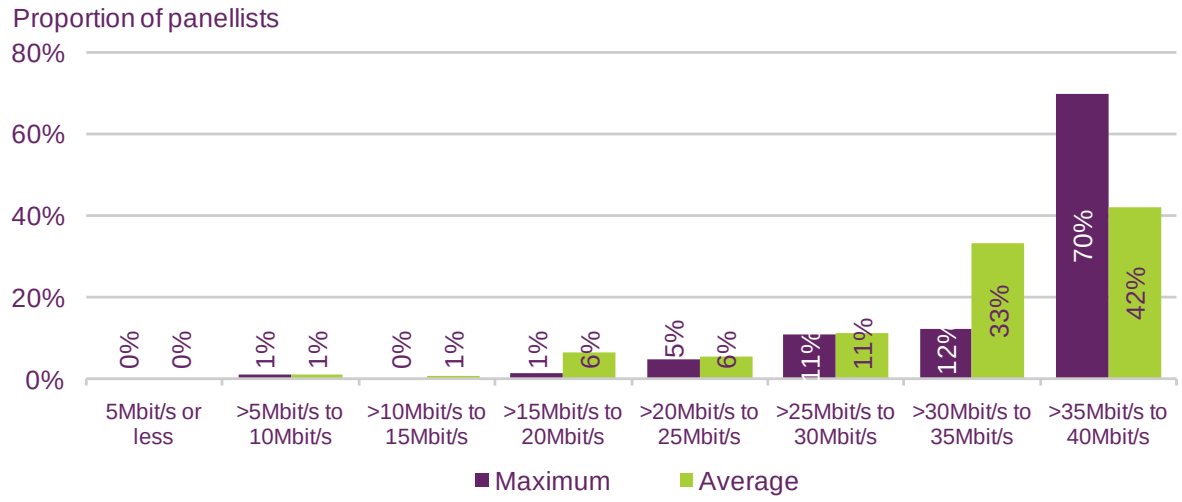


Source: SamKnows measurement data for panel members with a connection in November/December 2010,

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

4.33 While 70% of panellists with a BT 'up to' 40Mbit/s FTTC connection had a maximum connection speed greater than 35Mbit/s, only 42% had an average download speed of greater than 35Mbit/s, although 75% received average download speeds greater than 30Mbit/s (Figure 4.16)[29].

Figure 4.16 Distribution of maximum and average download speeds for consumers on 'up to' 40Mbit/s FTTC packages, November/December 2010 (multi-thread tests)



Source: SamKnows measurement data for panel members with a connection in November/December 2010,
Notes: (1) Data collected from multi-thread download speed tests

[29] BT's 'up to' 40Mbit/s service experienced a fault during three days in December when all customers on our panel had their speeds capped at 2Mbit/s during the evening hours of 6pm to 12am as a result of an incorrect traffic management profile being applied. We have excluded test results from these days from our analysis in this report. However, including these results would have had the impact of reducing average speeds by around 0.7Mbit/s and reducing speeds during the peak period by around 2.7Mbit/s.

Section 5

Variation of speeds by geographic location

Overview

5.1 There are two key drivers of variations of speeds by geographic location:

- For ADSL customers, the length of the line between the local telephone exchange and premises is a key factor which determines the speed of the broadband connection.

- The availability of services varies by geography. Around 88% of UK homes have access to ADSL2+ services, offering speeds of 'up to' 20Mbit/s or 24Mbit/s, meaning that around 12% of UK homes only have access to ADSL1-based DSL services, offering a maximum speed of 'up to' 8Mbit/s, and actual speeds typically much lower than this. Currently around 48% of UK households have access to Virgin Media's cable services, which offer speeds of 'up to' 50Mbit/s (and 'up to' 100Mbit/s in some locations) and we estimate that approximately 15% of homes are connected to BT local exchanges that have been upgraded to offer FTTC services. BT has committed to making fibre services available to 40% of UK homes by the end of 2012, and 66% by the end of 2012.

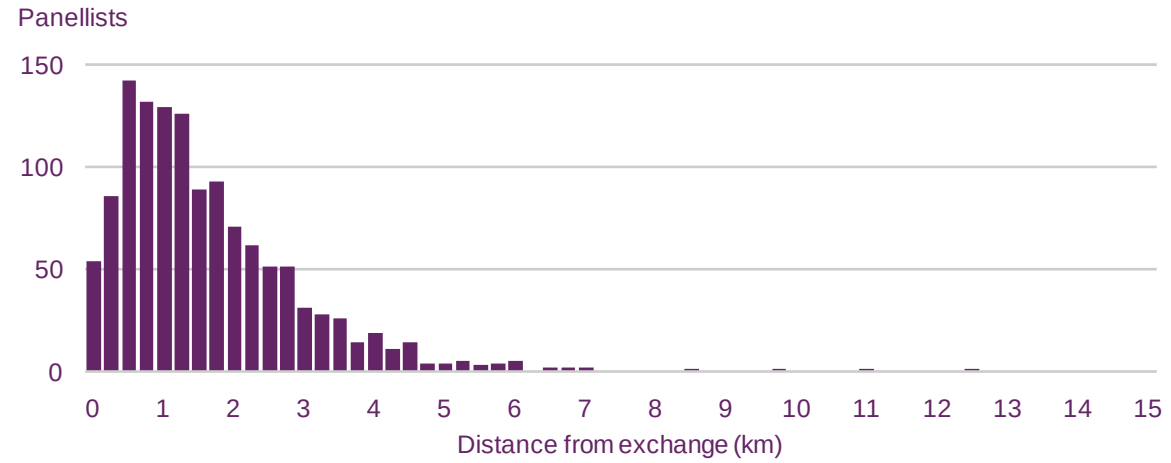
ADSL broadband speeds decline as distance from exchange increases

5.2 As detailed above, it is a characteristic of ADSL broadband that speeds degrade with the length of the copper wire between the exchange and the consumer's premises. We would therefore expect to see some relationship between the distance between a broadband connection and its local exchange and the speeds that are delivered through the connection. (See paragraph 4.23 onwards for a discussion of access line speeds and how they vary by length of line from exchange to premises).

5.3 Our research was not able to ascertain the length of the line between an individual panellist's address and their local exchange; we were only able to calculate the straight-line distance (i.e. 'as the crow flies') from the full postcode of the panellist to the local exchange. As Figure 5.1 illustrates, there was a wide range of distances from premises to exchange among our panellists, with an average of around 1.75km.

5.4 It should be noted that straight-line distances can differ significantly from line lengths; it is the latter which have an impact on the speed of ADSL broadband. In urban areas in particular, line lengths are often considerably longer than the straight-line distance as a consequence of the route taken; for example, in the Isle of Dogs in London's Docklands, it is not uncommon for line lengths to exceed 7km, despite being only 3km from the exchange.

Figure 5.1 Distribution of panellists, by distance from exchange

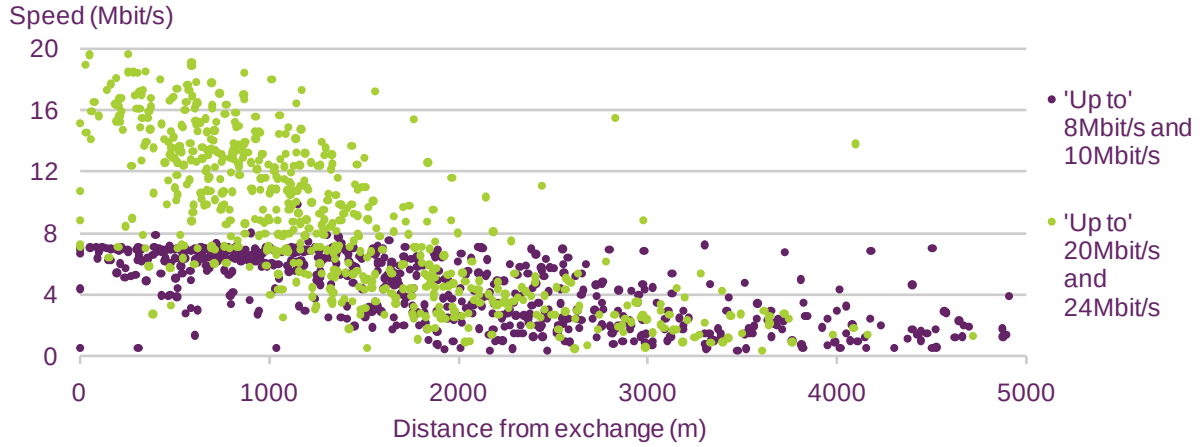


Source: Ofcom using data supplied by SamKnows

5.5 Figure 5.2 shows a plot of line length against maximum download speed compiled from the results of multi-thread tests. These show that none of our panellists on 'up to' 20 or 'up to' 24Mbit/s ADSL packages ever received average download speeds of more than 20Mbit/s, and few ever received average maximum speeds of more than 18Mbit/s. It also shows that there was a cluster of 'up to' 8Mbit/s customers who received maximum speeds of around 7Mbit/s. This indicates consumers whose line is likely to support a faster speed, but who are being constrained by the limitations of ADSL1 technology (compared to ADSL2+ which support theoretical speeds of up to 24Mbit/s), or are being throttled at around 7Mbit/s as they have signed up for an 'up to' 8Mbit/s package.

5.6 It is also clear that there is a relationship between the maximum download speed delivered and the length of the line (as illustrated in Figure 4.10 previously), although it is also evident that there is a big variation between the speeds delivered to consumers with similar line lengths. This may be explained by a number of factors, including the fact that line length is not an exact proxy of signal loss, the varying quality of in-house wiring, microfilters not being connected, as well as differences between the 'as the crow flies' distance and the actual length of the wire connection.

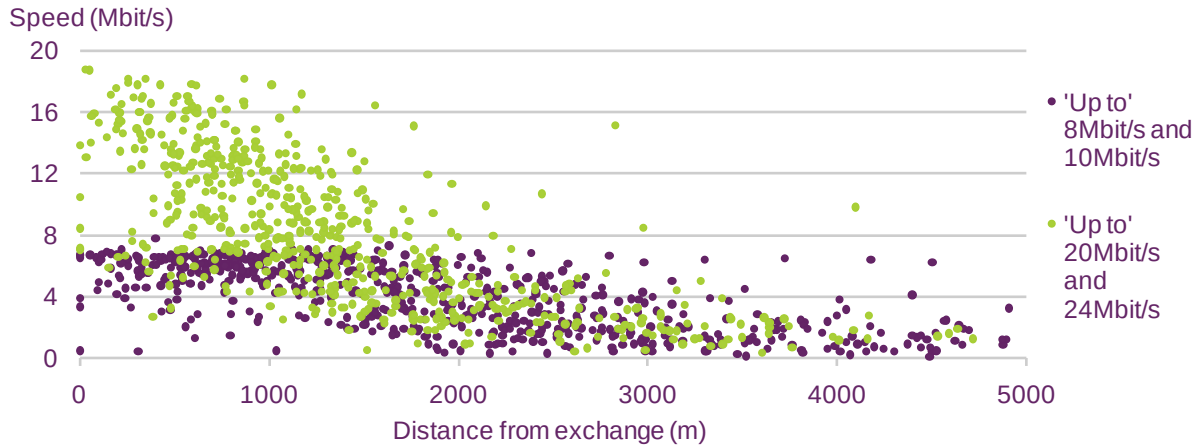
Figure 5.2 Distance from exchange and maximum download speeds achieved by panellists on 'up to' 8Mbit/s and 'up to' 20Mbit/s and 24Mbit/s ADSL packages, November/December 2010 (multi-thread tests)



Source: SamKnows measurement data for all panellists with a ADSL connection in November/December 2010
Note: Data are unadjusted so are not directly comparable with data elsewhere in this report, which have been weighted for line length

5.7 As might be expected, there is also a relationship between distance from exchange and the average download speeds delivered (Figure 5.3). The pattern is similar to that of maximum download speeds, but average speeds are lower, with only five panellists receiving average speeds of more than 18Mbit/s. This is primarily due to download speeds being constrained by contention within ISPs' networks.

Figure 5.3 Distance from exchange and average download speeds achieved by panellists on 'up to' 8Mbit/s and 'up to' 20Mbit/s and 24Mbit/s ADSL packages, November/December 2010 (multi-thread tests)



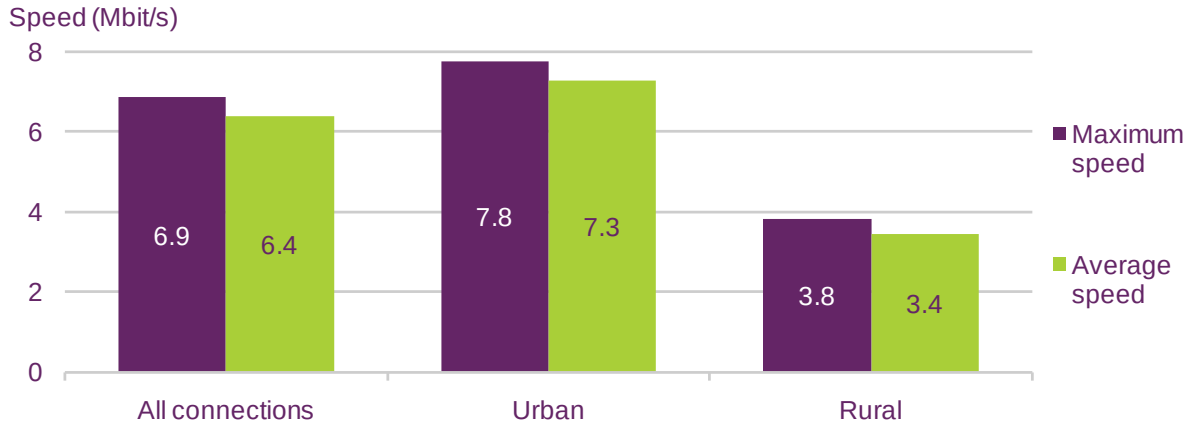
Source: SamKnows measurement data for all panellists with a ADSL connection in November/December 2010
Note: Data are unadjusted so are not directly comparable with data elsewhere in this report, which have been weighted for line length

Rural versus urban location

5.8 Urban consumers typically have a wider choice of broadband provider than their rural counterparts, and are more likely to have a choice of higher-speed services.

5.9 This greater availability of higher-speed services means that average download speeds delivered to urban consumers are significantly higher than the average speeds delivered to rural consumers. We estimate that, overall, including cable and DSL connections, the average maximum speed delivered to residential fixed-line broadband consumers in rural areas (3.8Mbit/s) was less than half the average 7.8Mbit/s delivered to urban consumers (Figure 5.4). Similarly, average download speeds in rural areas averaged 3.4Mbit/s, less than half the 7.3Mbit/s average in urban areas.

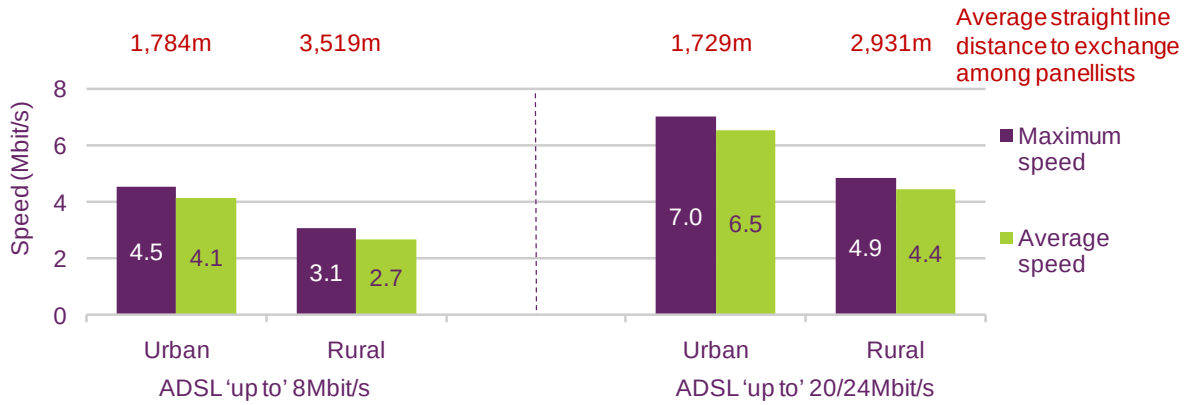
Figure 5.4 Estimated average and maximum download speeds for broadband connections in rural & urban areas, November/December 2010 (multi-thread tests)



Source: SamKnows measurement data for all panel members with a connection in November/December 2010,
Panel Base: 999
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/December 2010 and an estimated split between rural and urban areas; (3) Data collected from multi-thread download speed tests

5.10 Among our ADSL panellists, the average line length for rural consumers was 3,390m, compared to an average of 1,758m for urban consumers, meaning that on average rural ADSL consumers received much slower speeds than those living in urban areas. Figure 5.5 indicates that both maximum and average download speeds were significantly slower for ADSL consumers in rural areas on 'up to' 8Mbit/s packages, and on 'up to' 20Mbit/s or 24Mbit/s packages. In addition to having typically shorter line lengths, the greater availability of ADSL2+ services in urban areas is also likely to be a factor.

Figure 5.5 Average and maximum download speeds for ADSL broadband connections in rural & urban areas, November/December 2010 (multi-thread tests)



Source: SamKnows measurement data for all panel members with a connection in November/December 2010,
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

5.11 Different areas of the country have different ranges of providers. In some locations it is only possible to obtain broadband services using lines operated by BT Wholesale. In other parts of the country, there is a wider range of providers, both via cable and operators which have taken over BT lines using local-loop unbundling. We wanted to see how download speeds varied between these different areas[30].

5.12 Ofcom considers three separate geographic markets for wholesale broadband provision (see paragraph 3.12 onwards)[31]:

- Market 1 – Those geographic areas covered by exchanges where BT is the only operator (i.e. there has been no LLU)
- Market 2 – Those geographic areas covered exchanges where two Principal Operators[32] 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

[30] It should be noted that the Market definitions and local exchange designations used in the analysis contained in this report were updated in December 2010, and therefore differ to those used in previous Broadband Speeds reports.
[31] A fourth area is the Hull area, consisting of those geographic areas covered by exchanges where KCom is the only operator (representing 14 exchanges and covering 0.7% of the population). Ofcom, *Review of the wholesale broadband access markets: Statement on market definition, market power determinations and remedies*, December 2010 available at http://stakeholders.ofcom.org.uk/binaries/consultations/wba/statement/wbastatement.pdf
[32] The operators classed as Principal Operators are BT, Cable & Wireless Worldwide, O2, Orange, Sky, TalkTalk and, in local exchange areas where cable coverage exceeded 65 per cent of premises, Virgin Media.

- Market 3 – Those geographic areas covered by exchanges where four or more Principal Operators are present or forecast AND exchanges where three Principal Operators are present or forecast but where BT's share is less than 50%.

5.13 In general, exchanges in Market 1 tend to serve rural areas, and those in Market 3 tend to service the most densely populated areas. Therefore, comparing performance by these markets provides an indication of how broadband performance varies with demography.

5.14 Consumers living in areas designated as Market 1 on average received download speeds significantly slower than those in areas designated as Markets 2 or 3. (Figure 5.6). Average broadband download speeds in Market 1 areas were just 3.1Mbit/s compared to 4.9Mbit/s in Market 2 areas and 7.1Mbit/s in Market 3 areas[33].

5.15 The lower speeds recorded in Market 1 areas can be attributed to three factors:

- as Market 1 areas tend to be rural they will on average have a longer line length than those in Markets 2 and 3; consequently ADSL services will tend to be slower than those in Markets 2 and 3;
- consumers living in Market 2 and 3 areas have greater access to ADSL2+ services, both via LLU operators and BT; and
- there is higher availability of cable broadband services (which tend to be faster than those provided using ADSL and are available to 48% of the UK population) in Market 3 areas than in Market 2 areas, and very low availability in Market 1 areas.

Figure 5.6 Average and maximum download speeds by geographic market, November/December 2010 (multi-thread tests)

Source: SamKnows measurement data for all panel members with a connection in October/December 2010,
Panel Base: 999
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/December 2010 and an

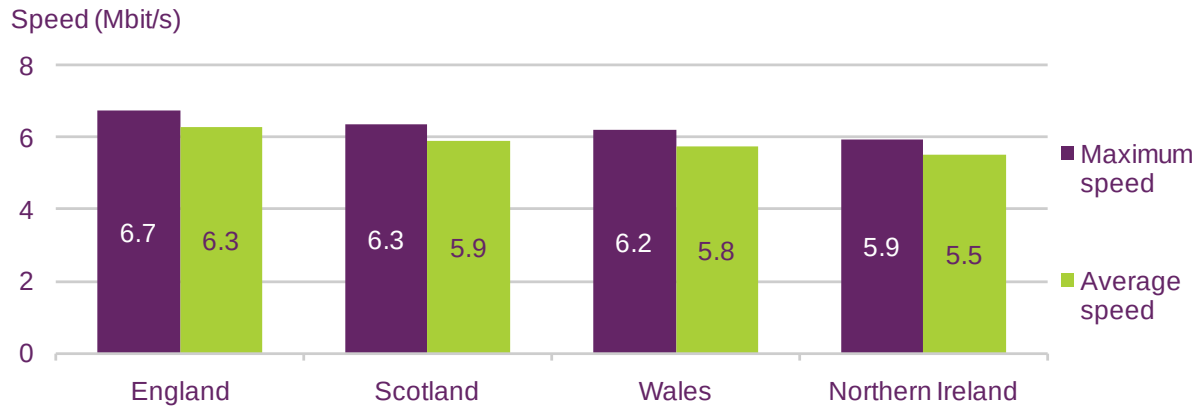
[33] Note that we while these results enable comparison between Markets, they will not match the overall national results due to sampling methodology.

estimated split between rural and urban areas; (3) Data collected from multi-thread download speed tests

5.16 Figure 5.7 below shows our estimates of average speeds by UK nation, which were derived from applying the average speeds of connections in each of the three markets to the split of connections in each of the nations (and hence the same caveats apply).

5.17 This analysis suggests that among the UK nations maximum and average speeds were highest in England (at 6.7Mbit/s and 6.3Mbit/s respectively) - around 15% higher than in Northern Ireland, where both maximum and average speeds were lowest. It must be noted that these are estimated figures and that the method of calculation means that these figures are not comparable with the UK averages published elsewhere in this report.

Figure 5.7 Estimated average and maximum download speeds by UK nation, November/December 2010 (multi-thread tests)



Source: SamKnows measurement data for all panel members with a connection in November/December 2010,
Panel Base: 999
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/December 2010 and an estimated split between nations; (3) Data collected from multi-thread download speed tests

Section 6

Variation of speeds by time of day

Download speeds typically slow down during peak periods

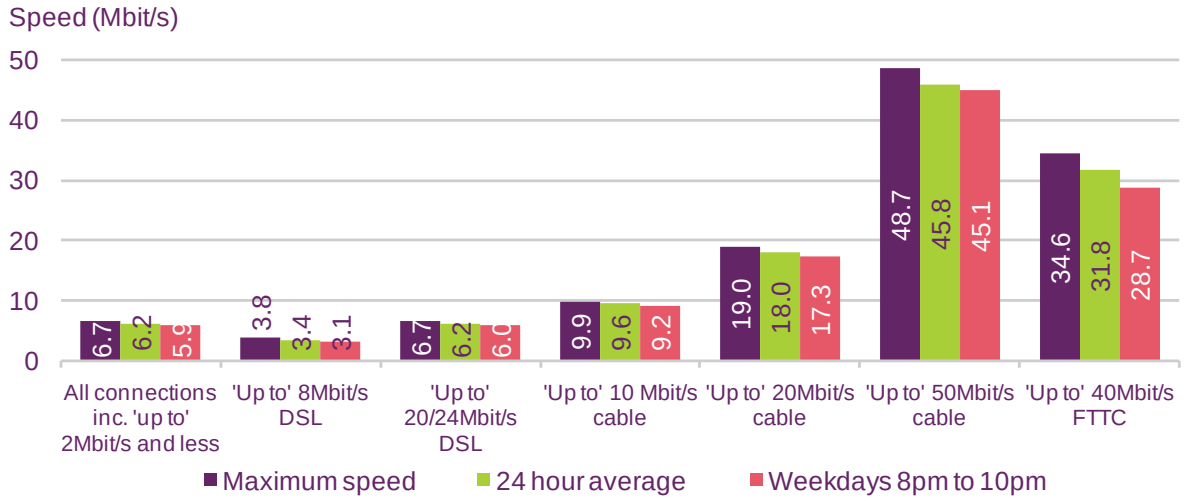
6.1 In addition to geographic factors, another major driver of variation in broadband performance is contention in the ISP's network, meaning that speeds are degraded as multiple users share the same bandwidth. It is primarily for this reason that average download speeds in November/December 2010, measured using multi-thread tests during the peak evening period of 8 to 10pm, were on average across all panellists around 89% of the maximum download speed ever recorded (which was typically during an off-peak hour when there was very little contention in the network). Similarly, average download speeds in this peak evening period of between 8pm and 10pm on weekdays were around 95% of the average download speeds recorded throughout the day.

6.2 Figure 6.1 indicates that there was similar pattern across all types of ADSL and cable services. It should be noted, however, that there is some variation between ADSL providers in terms of peak-time performance (see section 8).

6.3 These data relate only to normal web traffic such a web pages and simple file transfers, thereby excluding most peer-to-peer (also known as 'file sharing') traffic. If peer-to-peer traffic were included, it is likely that there would be a greater difference between average download speeds at peak and off-peak times; it is peer-to-peer traffic which some ISPs 'throttle' during peak times as a way of managing their network capacity (although some ISPs 'throttle' a small proportion of all of the traffic of their heaviest users during peak times as an alternative).

6.4 It should also be noted that our tests have been designed to measure the performance delivered by ISPs. Speeds experienced by consumers are likely to slow down further in peak periods due to contention on the wider internet (for example, as processor loading on servers delivering content is shared by multiple simultaneous requests).

Figure 6.1 Variations in download speed by time of day, November/December 2010 (multi-thread tests)[34]



Source: SamKnows measurement data for all panel members with a connection in November/December 2010,
Panel Base: 999
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/December 2010; (3) Data collected from multi-thread download speed tests

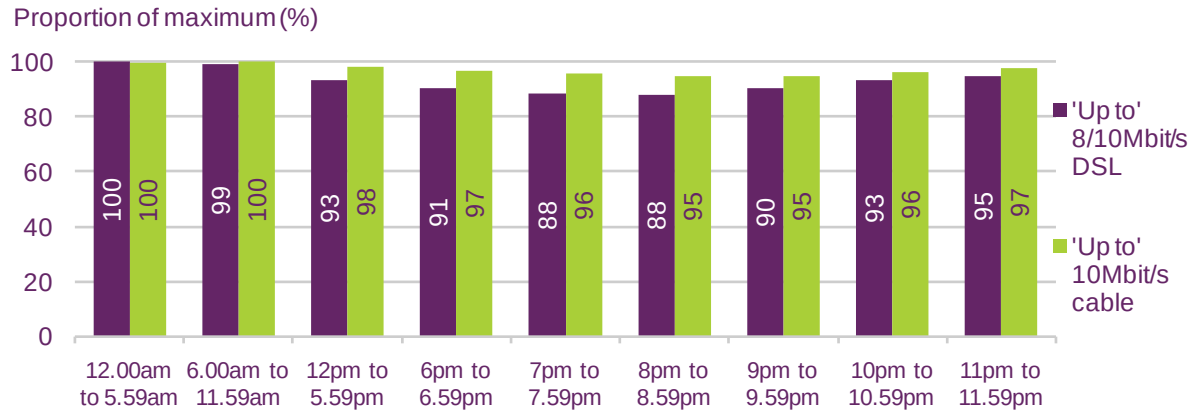
On average, ADSL services showed greater slowdown during peak hours than cable among 'up to' 8Mbit/s and 10Mbit/s packages

6.5 Figure 6.2 shows the average download speeds delivered to panellists on 'up to' 8Mbit/s ADSL packages and 'up to' 10Mbit/s cable packages as a proportion of the average maximum for each type of connection by time of day. It indicates that speeds were fastest in the early morning for each connection type, and slowed down during the 'peak' evening period.

6.6 For 'up to' 8Mbit/s ADSL packages, average download speeds in the slowest period of 8 to 9pm (3.2Mbit/s) were 12% slower than the 3.6Mbit/s average maximum recorded between 12 and 6am. For 'up to' 10Mbit/s cable services the difference between the slowest speed recorded (9.2Mbit/s at 9 to 10pm) and the highest (9.7Mbit/s at 6am to 12pm) was lower, with the slowest speed being 5% lower than the highest one. (It should be noted, however, that there is variation between ADSL providers in terms of peak-time performance, see paragraph 8.19 onwards).

[34] BT's 'up to' 40Mbit/s service experienced a fault during three days in December when all customers on our panel had their speeds capped at 2Mbit/s during the evening hours of 6pm to 12am as a result of an incorrect traffic management profile being applied. We have excluded test results from these days from our analysis in this report. However, including these results would have had the impact of reducing average speeds by around 0.7Mbit/s and reducing speeds during the peak period by around 2.7Mbit/s.

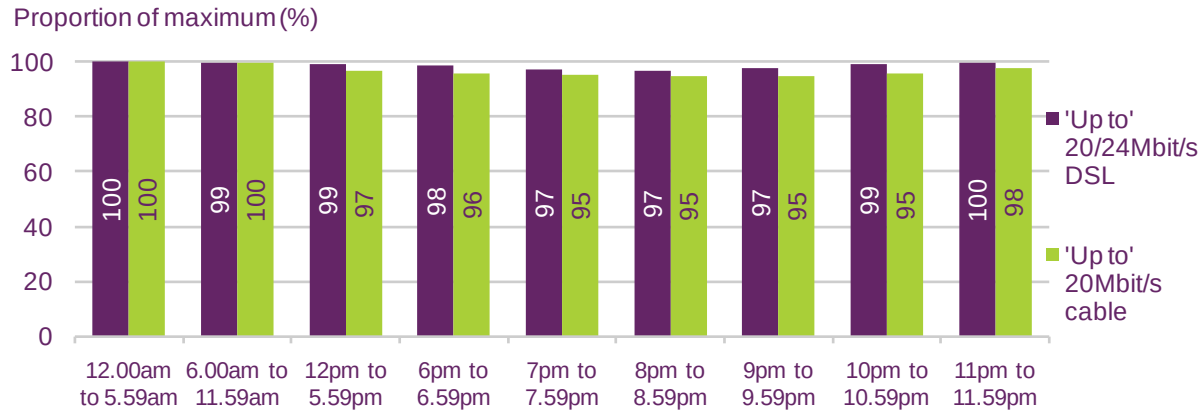
Figure 6.2 Average download speed as a proportion of maximum speed by time of day for panellists 'up to' to 8Mbit/s and 10Mbit/s packages, November/December 2010 (multi-thread tests)



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
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

6.7 The difference was less marked when comparing the highest and lowest recorded hourly average download speeds for 'up to' 20Mbit/s or 24Mbit/s ADSL packages and 'up to' 20bit/s cable connections (Figure 6.3). Although cable customers on 'up to' 20Mbit/s packages receive significantly higher speeds than customers on 'up to' 20Mbit/s and 24Mbit/s ADSL services, the decrease in speeds in peak periods was greater for cable connections, with speeds in the slowest hour of 8 to 9pm (17.3Mbit/s) being 5% lower than those in the fastest hour of 12 to 6am (18.3Mbit/s), compared to a 3% difference between the lowest (6.1Mbit/s at 8 to 9pm) and highest (6.3Mbit/s at 12 to 6am) values for 'up to' 20Mbit/s or 24Mbit/s ADSL packages.

Figure 6.3 Average download speed as a proportion of maximum speed by time of day for panellists 'up to' to 20Mbit/s and 24Mbit/s packages, November/December 2010 (multi-thread tests)

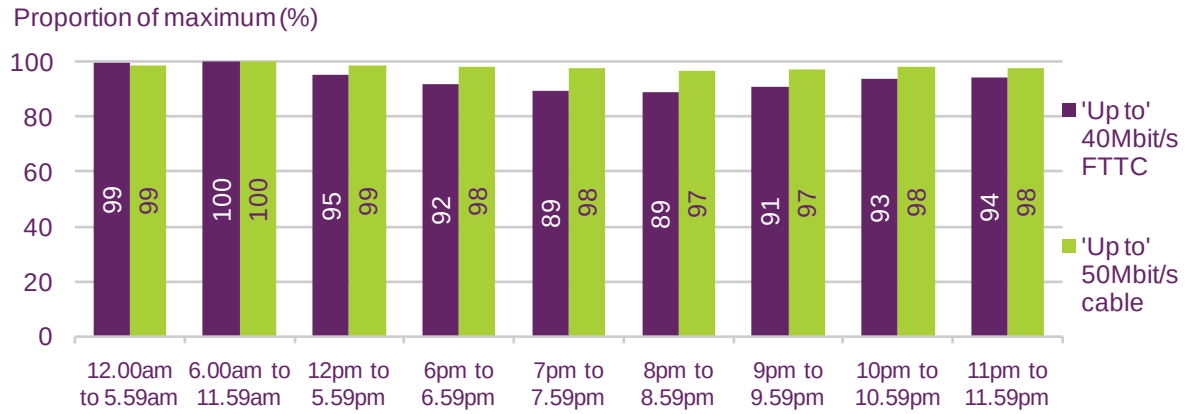


Source: SamKnows measurement data for all panel members with a connection in November/December 2010
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK 'up to' 20Mbit/s and 24Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests

6.8 For super-fast connections (those with a headline speed higher than 24Mbit/s), BT's 'up to' 40Mbit/s FTTC service suffered a greater slowdown in average speed in peak times than Virgin Media's 'up to' 50Mbit/s cable package (Figure 6.4). Average download speeds for BT's 'up to' 40Mbit/s service in the slowest period of 8 to 9pm (29.0Mbit/s) were 11% slower than the 32.7Mbit/s average maximum recorded between 6am and 12pm[35]. In comparison, for 'up to' 50Mbit/s Virgin Media customers, average speeds in the peak hour of 8 to 9pm were just 3% lower than those recorded in off-peak hours.

[35] BT's 'up to' 40Mbit/s service experienced a fault during three days in December when all customers on our panel had their speeds capped at 2Mbit/s during the evening hours of 6pm to 12am as a result of an incorrect traffic management profile being applied. We have excluded test results from these days from our analysis in this report; however, including these results would have the impact of reducing average speeds by around 0.7Mbit/s and reducing speeds during the peak period by around 2.7Mbit/s.

Figure 6.4 Average download speeds as a proportion of maximum speed by time of day for panellists 'up to' to 40Mbit/s and 50Mbit/s packages, November/December 2010 (multi-thread tests)



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
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' 40 and 50Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests

Section 7

Variation of speeds by access technology

A range of different broadband technologies are available in the UK

7.1 Broadband services in the UK are delivered using a number of different technologies. Our research examined ADSL broadband (that is, broadband delivered over the copper wires that form the public switched telephone network or fixed voice network), cable broadband (Virgin Media has over 99% of all cable customers in the UK, and all of our cable panellists were customers of Virgin Media) and BT's recently-launched 'up to' 40Mbit/s FTTC service.

7.2 Outside the scope for our research was broadband accessed by dedicated fibre networks (this currently accounts for less than 0.5% of all broadband customers in the UK) and satellite broadband (which also has very low take-up).

7.3 In addition, 'mobile broadband', that is broadband delivered 'over the air' by cellular mobile network operators typically via a USB modem or 'dongle', was excluded. We have recently commissioned research into mobile broadband performance and expect to publish a report in spring 2011. We have commissioned separate research into mobile broadband performance which we also expect to publish in the spring

7.4 Over 75% of fixed-line broadband connections in the UK are delivered by ADSL broadband, via two different technology standards:

- **ADSL** (sometimes referred to as ADSL1) was the first generation of DSL technology and can currently deliver broadband speeds up to a theoretical maximum of 8Mbit/s. However, speeds of 8Mbit/s are not achieved by most customers because ADSL broadband degrades as the length of the line from the exchange gets longer. Indeed, ISPs typically cap speeds at less than 8Mbit/s in order to ensure connections are stable. (For example, BT Wholesale's Broadband Remote Access Server (BRAS) system sets a maximum speed of 7.2Mbit/s for ADSL1 broadband – its ADSL Max product). BT Wholesale is currently upgrading its exchanges to enable it to offer the higher speed (ADSL2+) *Wholesale Broadband Connect* (WBC) product in addition to ADSL Max. As a consequence, BT Retail ,and other ISPs who purchase services from BT Wholesale, have customers on both ADSL1 and ADSL2+ services,

- **ADSL2+** is an upgrade to ADSL1 and requires the installation of different equipment within the local telephone exchange and at the customer premises, where a modem compatible with ADSL2+ must be used. It enables the delivery of broadband to a theoretical maximum of 24Mbit/s, although many ISPs (including BT Retail, O2, Orange and Sky) market it as an 'up to' 20Mbit/s service. As illustrated in Figure 4.10 previously, the speed of ADSL2+ broadband degrades more quickly than ADSL1 over the length of the copper wire from exchange to premises, meaning that at a distance of more than 3km there is little difference between the two technologies. ADSL2+ has been widely rolled out in the UK since 2006 by LLU providers such as Sky, Orange and O2/Be. BT Wholesale has launched its WBC ADLS2+ service, and is currently upgrading its exchanges to this standard, while LLU-based ADSL2+ services are already available to over 85% of UK homes. By January 2011, BT had upgraded over 900 exchanges, serving around 60% of the UK population, to ADSL2+, and it has announced

plans to extend this to exchanges serving around 75% of the population by spring 2011[36].

7.5 Over 20% of broadband connections in the UK are made via cable, and Virgin Media's cable services are available to just under half of UK homes, delivering broadband via its hybrid fibre and co-axial cable network. Unlike ADSL, cable broadband does not degrade with distance from the exchange, although it is subject to the same constraints of limited network capacity (contention). In 2008 and 2009 Virgin Media upgraded its network to the DOCSIS 3.0 standard which has allowed it to offer services of 'up to' 100Mbit/s in some parts of the UK.

Cable broadband services were significantly faster than ADSL services

7.6 Our results demonstrated significant differences in performance between different broadband technologies. Figure 7.1 below compares the average download speeds delivered to panellists in November/December 2010 by access technology and by headline speed. It details both the average download speeds delivered across every hour of every day, and the average download speeds in the peak evening hours of 8pm to 10pm. They 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 consumers 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 – they do not indicate the range of performance delivered.

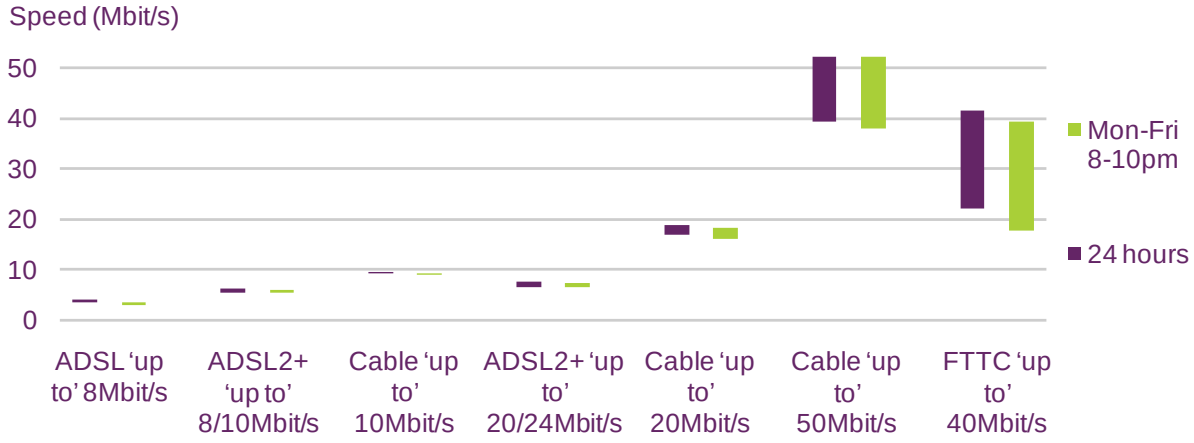
7.7 The average download speeds received by cable customers are significantly higher than those available to ADSL customers; on average, cable customers on 'up to' 10Mbit/s packages received speeds more than twice as high as ADSL customers on 'up to' 8Mbit/s services. In fact, the average download speeds of 'up to' 10Mbit/s cable services were in line with the average download speeds of ADSL2+ services offered at 'up to' 20Mbit/s or 24Mbit/s.

7.8 The difference between cable and ADSL was also repeated for higher-speed packages. Cable customers on a headline speed of 20Mbit/s on average received speeds more than twice as fast as ADSL2+ packages at 'up to' 20Mbit/s or 24Mbit/s, while 'up to' 50Mbit/s cable connections also delivered average speeds closer to the headline speeds than BT's 'up to' 40Mbit/s FTTC service[37].

[36] http://www.btplc.com/today/art98419.html

[37] BT's 'up to' 40Mbit/s service experienced a fault during three days in December when all customers on our panel had their speeds capped at 2Mbit/s during the evening hours of 6pm to 12am as a result of an incorrect traffic management profile being applied. We have excluded test results from these days from our analysis in this report. However, including these results would have had the impact of reducing average speeds by around 0.7Mbit/s and reducing speeds during the peak period by around 2.7Mbit/s.

Figure 7.1 Average download speeds by technology and headline package, November/December 2010[38]



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
Panel Base: 999
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/December 2010; (3) Data collected from multi-thread download speed tests; (4)The range shown represents a 95% confidence interval around the mean

The services and speeds available depend on a consumer's location

7.9 As detailed previously in section 4, the performance of ADSL services is highly dependent on distance from the exchange. Consumers living more than 3km from an exchange will typically experience little difference between ADSL1 and ADSL2+; the actual speeds they receive will typically be lower than the average download speeds detailed above and are unlikely to change significantly if they 'upgrade' from an 'up to' 8Mbit/s or 10Mbit/s package to an 'up to' 20Mbit/s or 24Mbit/s package. Conversely, consumers living within 1km of the exchange can expect a much faster performance than the average download speeds detailed above.

7.10 A consumer's location not only determines the length of their connection to the local exchange, it also determines what services are available since, as described earlier, ADSL2+ service offering speeds of 'up to' 20Mbit/s or 24Mbit/s and cable broadband services are only available in some parts of the country. Also, it may not always be clear to consumers whether they will receive ADSL1 (with a maximum speed of 'up to' 8Mbit/s) or ADSL2+ services, since some operators market a single package but offer ADSL1 services from some exchanges and ADSL2+ services from others. Consumers should ask operators to provide them with their access line speed in

[38] BT's 'up to' 40Mbit/s service experienced a fault during three days in December when all customers on our panel had their speeds capped at 2Mbit/s during the evening hours of 6pm to 12am as a result of an incorrect traffic management profile being applied. We have excluded test results from these days from our analysis in this report. However, including these results would have had the impact of reducing average speeds by around 0.7Mbit/s and reducing speeds during the peak period by around 2.7Mbit/s.

order to understand the maximum speed that may be available to them[39]. A more detailed set of factors on what should be considered when purchasing broadband is available in Ofcom's consumer guide to buying broadband[40].

[39] All operators who have signed up to Ofcom's Voluntary Code of Practice on Broadband Speeds are required to give consumers an estimate of their individual maximum line speed at the point of sale.
[40] http://stakeholders.ofcom.org.uk/market-data-research/telecoms-research/broadband-speeds/main/

Section 8

Variation of speeds by internet service provider (ISP) package

8.1 The results described in the previous sections indicate that in addition to the geographic location of the consumers (particularly in terms of line length for ADSL consumers), there are two main reasons why broadband performance may vary: the technology used by the ISP serving the consumer and the capacity per user of their network (often described as level of contention). In this section we examine the effects of these factors on individual ISP packages' performance, firstly on download speeds and then on upload speeds. ISP performance on other metrics (web browsing, latency, DSN, packet loss and jitter) are included in section 9.

ISP packages for which we had a representative sample

8.2 Our ability to robustly compare the performance of specific ISP packages was dependent on achieving sufficient sample sizes necessary to allow meaningful statistical analysis. We were able to achieve this for the following packages (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);
- O2/Be's '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' 8Mbit/s ADSL service;
- Plusnet's 'up to' 8Mbit/s ADSL service (note that although Plusnet is owned by BT, it was considered separately as parts of the network are different);
- Sky's 'up to' 20Mbit/s ADSL service;
- TalkTalk's 'up to' 24Mbit/s ADSL service; and
- Virgin Media's 'up to' 10Mbit/s, 'up to' 20Mbit/s and 'up to' 50Mbit/s cable services.

8.3 We were able to generate statistically reliable results only for ISP packages for which we were able to recruit sufficient test recruits; these accounted for over 90% of broadband connections in November/December 2010. However, there are many other smaller ISPs available, many of which may match or better the performance of some of the ISPs included in the report. See paragraph 2.11 onwards.

8.4 As in the July 2010 report, for comparisons of ISP package performance in the present research we only used panellists who live within geographic Markets 2 and 3 (see paragraph 3.12). 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 caused by

the inclusion of panellists who live in (typically less densely populated) Market 1 areas and for whom LLU services are not available.

8.5 For those ADSL operators who offer services using LLU and for whom a clear distinction is made between 'on-net and 'off-net' customers, we only included 'on-net' customers, i.e. those customers who are served from an exchange which their ISP has unbundled; these operators are O2/Be, Sky and TalkTalk..

8.6 It should be noted that for some LLU operators it is not always clear to consumers whether the service available to them is delivered using the ISP's access network (i.e. 'on-net' from an unbundled exchange), or is delivered via another operator's access network (i.e. 'off-net' utilising a wholesale agreement that the ISP has with BT Wholesale or another wholesale provider). This is something which consumers are advised to check, as there are potentially differences in performance between on-net and off-net services.

Methodological considerations

8.7 As discussed in section 3 above, in a change to the methodology used in previous Ofcom Broadband Speeds reports, the analysis in this section shows the results from multi-thread tests, which test the speed when multiple files are downloaded simultaneously (previous reports have concentrated on the results from single-thread tests which test the speed of download of a single file). While a single-thread test replicates the consumer experience of downloading a small file such as an MP3 track, multi-thread testing replicates web page downloads, peer-to-peer configurations, or multiple PCs simultaneously downloading files using the same broadband connection.

8.8 In fact, we ran both single and multi-thread test schedules during November/December 2010 to allow us to make time-series comparisons with data in previous Broadband Speeds reports, and also to make more robust comparisons of results from the two types of tests (see section 8.32 below). Due to the more rigorous nature of the test schedule used it was necessary to extend the testing period from the usual one month used in these reports in order to reduce the risk of impacting on the data usage caps of our volunteer panellists.

8.9 In the last 12 months, most ISPs have changed their package offerings. Whereas previously they all offered 'up to' 8Mbit/s packages as standard, BT Retail, Sky and Orange now offer 'up to' 20Mbit/s as the standard on all packages, and TalkTalk offer 'up to' 24Mbit/s (marketed as the fastest speed the line can provide) as the standard on all its products. However, in November/December 2010 many providers still had customers on legacy products, where maximum speeds are still capped at 'up to' 8Mbit/s (or, for a small proportion of BT Retail and Orange customers, at 'up to' 2Mbit/s).

8.10 As such, it was a challenge to allocate panellists taking part in the research to the most appropriate package. It was necessary to do this in order to ensure that valid comparisons were made – we consider that it would not be appropriate to consider, for example, all BT Retail ADSL customers to be on an 'up to' 20Mbit/s package, when a large proportion of its subscription base had purchased and were still receiving an 'up to' 8Mbit/s ADSL1-based service.

8.11 The method we applied to allocate panellists to the most appropriate package are detailed in Annex 3; the basic logic was that panellists who stated that they were on the higher-speed package and lived in an area where such services were available

were allocated to that package. For those who stated that they were on lower-speed packages, we estimated the maximum speed they should receive, based on the distance between their home and the local exchange, and allocated them to the higher-speed package if they received maximum speeds higher than would be expected for an 'up to' 8Mbit/s service

8.12 In order to provide a like-for-like comparison, we have weighted the data for the ADSL operators to 'normalise' for distance from exchange. The following points should be noted about this normalisation process:

- This adjustment is necessary in order to ensure that an ISP with nationwide coverage is not represented as having poor performance compared to an ISP focused on more densely populated areas simply because it has customers with typically longer line lengths between premises and exchange. (A characteristic of ADSL broadband is that performance degrades over the length of the copper wire.)

- Data have been normalised using the straight-line distance from exchange to six-digit postcode. We detail the methodology we have used to do this in Annex 3. This Annex also sets out the checks we applied to ensure that straight-line distance is a suitable metric for normalisation. Specifically, we illustrate that straight-line distance is an appropriate substitute for normalising by an alternative method (using attenuation data), and that the 'un-normalised' results indicate that there is little variation in the distance-profile of the ISPs whose performance results we describe.

- In order to enable normalisation and like-for-like comparison between ISP packages we have excluded all panellists who live more than 5km from the local exchange. This only represents a small proportion of ADSL customers in geographic Markets 2 and 3 (around 5%); however it does have the impact of slightly increasing the average download speeds of all ADSL packages compared to what they would be if all line lengths were included, we estimate by around 2%. (Note that panellists on all line lengths are included where data representing the UK as a whole are presented).

- A characteristic of O2/Be's customer base on its 20/24Mbit/s package is that line lengths are typically shorter than for other ISPs. This is the result of a historic policy of only selling higher speed packages to customers whose lines can support speeds higher than the 'up to' 8Mbit/s offered by its lower speed package. Since May 2010 we have been able to recruit additional O2/Be panellists with longer lines enabling us to normalise the O2/Be data so that we can compare ISPs on a like-for-like basis. However, O2/Be results should be treated with some caution as normalisation may not be as effective for O2/Be due to the lower incidence of panellists with longer than average line lengths.

- Data for BT's 'up to' 40Mbit/s fibre-to-the-cabinet service have not been normalised by distance from exchange as the distance to exchange is not as relevant.

- Data for the cable operator, Virgin Media, have been weighted by its network footprint in order to enable direct comparison with ADSL services, which are available nationwide. It is not appropriate to weight by line length as the performance of cable is not affected to any significant extent by the length of the line.

8.13 We consider that the data set out below represent an accurate assessment of the comparative download speeds achieved by the ISP packages included in the research during November/December 2010. However, caution should be applied in drawing conclusions from this research given its limitations. In particular, we highlight the following constraints:

- The data represent a 'snapshot' of the market in November/December 2010. It should be noted that this is a dynamic market and that the performance levels we found may not be representative of current (i.e. February 2011) or future performance. For example, from Janauary 2011 Orange began migrating customers to a new network.

- The analysis below details findings at a nationwide level. However, the choice of broadband provider available to consumers and their performance are both to a large extent determined by geographical location. For ADSL broadband, the length of the line between local exchange and premises is a more significant driver of broadband speeds than choice of provider. In general, the longer the distance between premises and exchange the less variation there is likely to be between providers. Consumers are advised to enquire about the length of their line and the maximum speed it can support before purchasing broadband services.

- Traffic management policies are also relevant to the user experience and are not generally captured in the data below. These may include policies which limit peer-to-peer traffic and which slow down the download speeds available to heavy broadband users. Under Ofcom's Voluntary Code of Practice on Broadband Speeds, ISP signatories have committed to advise consumers of these policies if they use them[41].

- As explained above, we have only been able to include the largest ISP packages within our analysis (with the exception of Virgin Media's 'up to' 50Mbit/s and BT's 'up to' 40Mbit/s services, given ease of recruitment of panel members). We are keen to include additional ISP packages in future research. Relevant considerations include the ability to obtain a representative sample of consumers on a particular ISP package and the ease of recruitment of panel members.

Results over the 24-hour period

8.14 Figures 8.1 and 8.2 illustrate the differences among ISP packages of 'up to' 8Mbit/s or 10Mbit/s for the average of all the multi-thread download speed tests run 24 hours a day, during the November/December 2010 testing period. As with the results by technology, set out earlier, they 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 customers (i.e. not just customers within our sample) falls within the range shown.

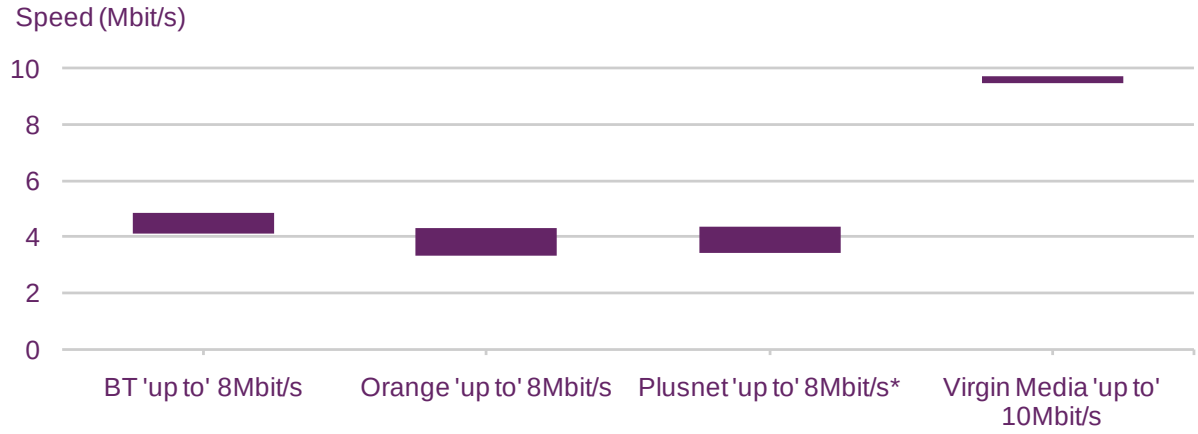
8.15 The sample size for each ISP package, and the variation of performance among panellists within each ISP package, combine to determine the size of the bars. We emphasise that these bars indicate the average (mean) performance – they do not indicate the range of performance delivered. We also set out a table which describes where differences between ISPs are statistically significant using a 5% test of

[41] Voluntary Code of Practice: Broadband Speeds, www.ofcom.org.uk/telecoms/ioi/copbb

significance (tables detailing differences at a 1% test of significance are provided in Annex 4).

8.16 Our research found that the average actual download speeds received by Virgin Media cable customers on 'up to' 10Mbit/s (9.5 to 9.7Mbit/s) were significantly higher than those delivered by any of the ADSL operators' 'up to' 8Mbit/s packages included in this research.

Figure 8.1 Average download speeds for 'up to' 8Mbit/s or 10Mbit/s ISP packages, 24 hours, November/December 2010 (multi-thread tests)



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
**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

Figure 8.2 Significant differences to a 95% level of confidence between average download speeds on 'up to' 8Mbit/s and 'up to' 10Mbit/s packages, 24 hours, November/December 2010 (multi-thread tests)

ISP package	Is slower than...	Is faster than...
BT 'up to' 8Mbit/s	Virgin Media	
Orange 'up to' 8Mbit/s	Virgin Media	
Plusnet 'up to' 8Mbit/s*	Virgin Media	
Virgin Media 'up to' 10Mbit/s		BT, Orange and Plusnet

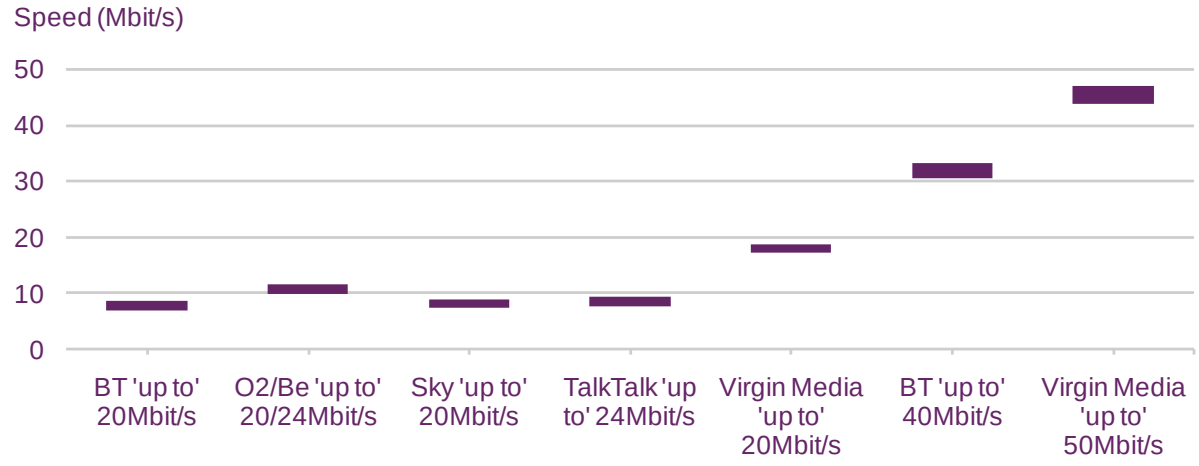
Source: Ofcom
**Caution: small sample size (<50)*
Note: Significant differences to a 99% level of confidence are provided in Annex 4

8.17 Figures 8.3 and 8.4 apply the same analysis to 'up to' 20Mbit/s and 24Mbit/s ISP packages. Again, it finds that Virgin Media's cable service delivered significantly faster download speeds than ADSL equivalents, with average download speeds of 17.4 to 18.6Mbit/s on its 'up to' 20Mbit/s service compared to average download speeds of 6.9 to 11.6Mbit/s delivered by ADSL providers' 'up to' 20Mbit/s or 24Mbit/s packages. Virgin Media's 'up to' 50Mbit/s service delivered average speeds between

43.9Mbit/s and 47.2Mbit/s, while BT's 'up to' 40Mbit/s FTTC service delivered, on average, speeds between 30.5Mbit/s and 33.1Mbit/s[42].

8.18 In terms of statistical significance, among the ADSL operators, the average download speeds delivered by O2/Be were significantly faster than those delivered by BT Retail, Sky and TalkTalk over the 24-hour period. It should be noted, however, that O2/Be results should be treated with some caution as normalisation may not be as effective for O2/Be due to the lower incidence of panellists with longer than average line lengths (see Paragraph 8.12 above). Virgin Media's 'up to' 50Mbit/s cable service was on average faster that BT's 'up to' 40Mbit/s service.

Figure 8.3 Average download speeds for 'up to' 20Mbit/s and above ISP packages, 24 hours, November/December 2010 (multi-thread tests)



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
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

[42] BT's 'up to' 40Mbit/s service experienced a fault during three days in December when all customers on our panel had their speeds capped at 2Mbit/s during the evening hours of 6pm to 12am as a result of an incorrect traffic management profile being applied. We have excluded test results from these days from our analysis in this report. However, including these results would have had the impact of reducing average speeds by around 0.7Mbit/s and reducing speeds during the peak period by around 2.7Mbit/s.

Figure 8.4 Significant differences to a 95% level of confidence between average download speeds for 'up to' 20Mbit/s and above ISP packages, 24 hours, November/December 2010 (multi-thread tests)

ISP package	Is slower than...	Is faster than...
Comparison of 'up to' 20/24Mbit/s packages		
BT 'up to' 20Mbit/s	O2/Be and Virgin Media	
O2/Be 'up to' 20/24Mbit/s	Virgin Media	BT, Sky and TalkTalk
Sky 'up to' 20Mbit/s	O2/Be and Virgin Media	
TalkTalk 'up to' 24Mbit/s	O2/Be and Virgin Media	
Virgin Media 'up to' 20Mbit/s		BT, O2/Be, Sky and TalkTalk
Comparison of 'up to' 40/50Mbit/s packages		
BT 'up to' 40Mbit/s	Virgin Media	
Virgin Media 'up to' 50Mbit/s		BT

Source: Ofcom
Note: Significant differences to a 99% level of confidence are provided in Annex 4

Results during peak periods

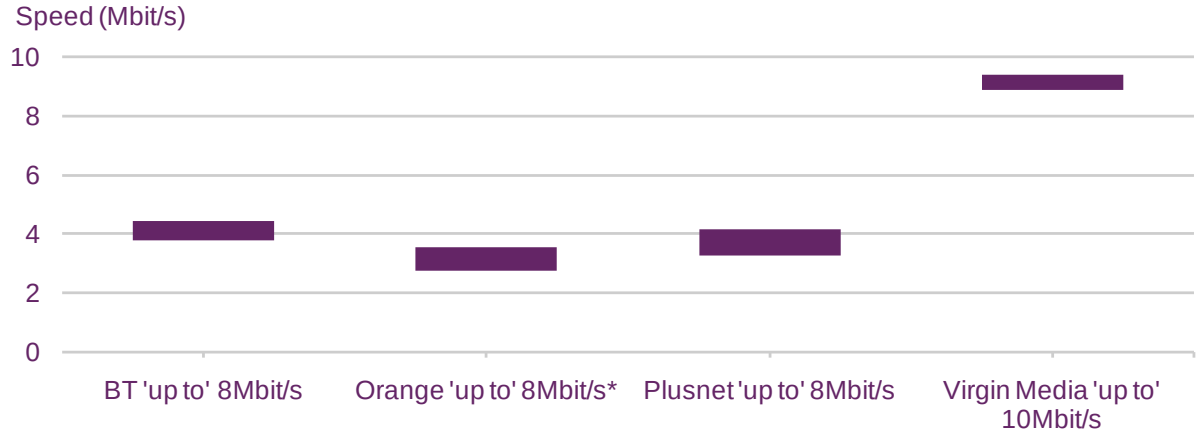
8.19 The effect of contention in ISPs' networks is shown in Figures 8.5 to 8.8 which look specifically at performance during the peak period between 8pm and 10pm on weekdays[43]. In aggregate, performance in this peak period is around 5% slower than over the 24-hour period.

8.20 Figure 8.5 indicates that during these peak hours, Virgin Media's 'up to' 10Mbit/s cable service remains significantly faster than any ADSL operator's 'up to' 8Mbit/s package, delivering average download speeds of 8.9 to 9.4Mbit/s, compared to the range of ADSL package performance from 2.7 to 4.4Mbit/s.

8.21 Among the ADSL operators, Orange had the biggest difference between average download speeds and peak-period download speeds, indicating that it suffers greater contention in its network than some other ISPs. Plusnet has the smallest difference between average download speeds and peak-period download speeds are experienced by panellists, suggesting that its network is less affected by contention than the ISPs for which we have data.

[43] Data from the London Internet Exchange indicate that data transfer levels in these peak evening hours are around four times as high as in the off-peak early hours of the morning, https://stats.linx.net/

Figure 8.5 Average download throughput speeds for 'up to' 8Mbit/s and 10Mbit/s packages, 8 to 10pm weekdays, November/December 2010 (multi-thread tests)



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
**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

Figure 8.6 Significant differences to a 95% level of confidence between average speeds on 'up to' 8Mbit/s and 10Mbit/s packages, 8 to 10pm weekdays, November/December 2010 (multi-thread tests)

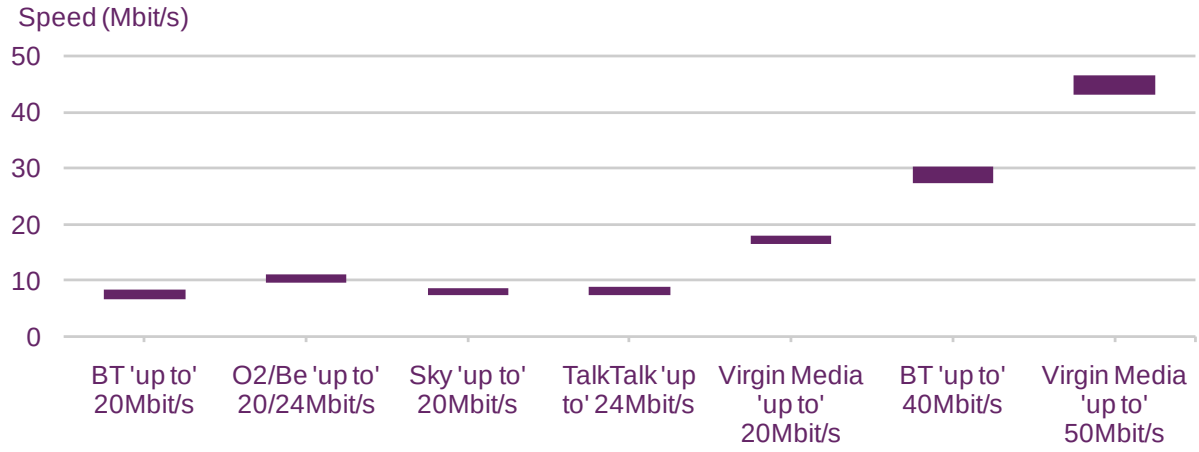
ISP package	Is slower than...	Is faster than...
BT 'up to' 8Mbit/s	Virgin Media	Orange
Orange 'up to' 8Mbit/s*	BT and Virgin Media	
Plusnet 'up to' 8Mbit/s	Virgin Media	
Virgin Media 'up to' 10Mbit/s		BT, Orange and Plusnet

Source: Ofcom
**Caution: small sample size (<50)*
Note: Significant differences to a 99% level of confidence are provided in Annex 4

8.22 Among the 'up to' 20Mbit/s and 24Mbit/s packages, Virgin Media's cable service delivered significantly faster peak-time download speeds than comparable ADSL packages (16.5 to 18.0Mbit/s compared to the range of ADSL package performance of 6.8 to 11.0Mbit/s) (Figure 8.7). O2/Be delivered significantly faster download speeds in the peak period than BT, Sky and TalkTalk (it should be noted, however, that O2/Be results should be treated with some caution as normalisation may not be as effective for O2/Be due to the lower incidence of panellists with longer than average line lengths - see Paragraph 8.12 above). Virgin Media's 'up to' 50Mbit/s service delivered average peak-time speeds between 43.1Mbit/s and 46.6Mbit/s,

significantly faster that the 27.4Mbit/s to 30.3Mbit/s44 average speeds delivered by BT's 'up to' 40Mbit/s FTTC service.

Figure 8.7 Average download throughput speeds for 'up to' 20Mbit/s and above packages, 8 to 10pm weekdays, November/December 2010 (multi-thread tests)



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
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

[44] BT's 'up to' 40Mbit/s service experienced a fault during three days in December when all customers on our panel had their speeds capped at 2Mbit/s during the evening hours of 6pm to 12am as a result of an incorrect traffic management profile being applied. We have excluded test results from these days from our analysis in this report. However, including these results would have had the impact of reducing average speeds by around 0.7Mbit/s and reducing speeds during the peak period by around 2.7Mbit/s.

Figure 8.8 Significant differences to a 95% level of confidence between average download throughput speeds for 'up to' 20Mbit/s and above packages, 8 to 10pm weekdays, November/December 2010 (multi-thread tests)

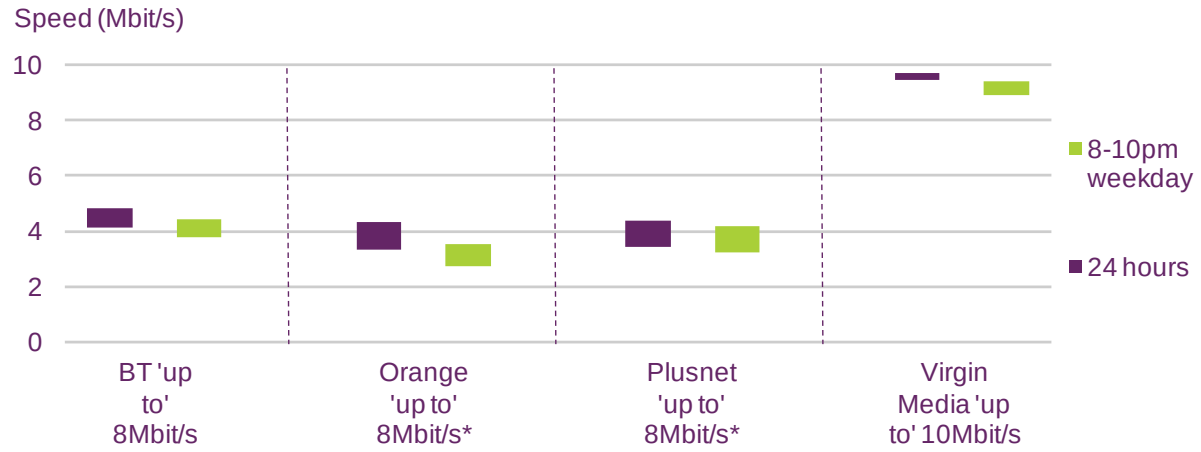
ISP package	Is slower than...	Is faster than...
Comparison of 'up to' 20/24Mbit/s packages		
BT 'up to' 20Mbit/s	O2/Be and Virgin Media	
O2/Be 'up to' 20/24Mbit/s	Virgin Media	BT, Sky and TalkTalk
Sky 'up to' 20Mbit/s	O2/Be and Virgin Media	
TalkTalk 'up to' 24Mbit/s	O2/Be and Virgin Media	
Virgin Media 'up to' 20Mbit/s		BT, O2/Be, Sky and TalkTalk
Comparison of 'up to' 40/50Mbit/s packages		
BT 'up to' 40Mbit/s	Virgin Media	
Virgin Media 'up to' 50Mbit/s		BT

Source: Ofcom
Note: Significant differences to a 99% level of confidence are provided in Annex 4

Summary of results

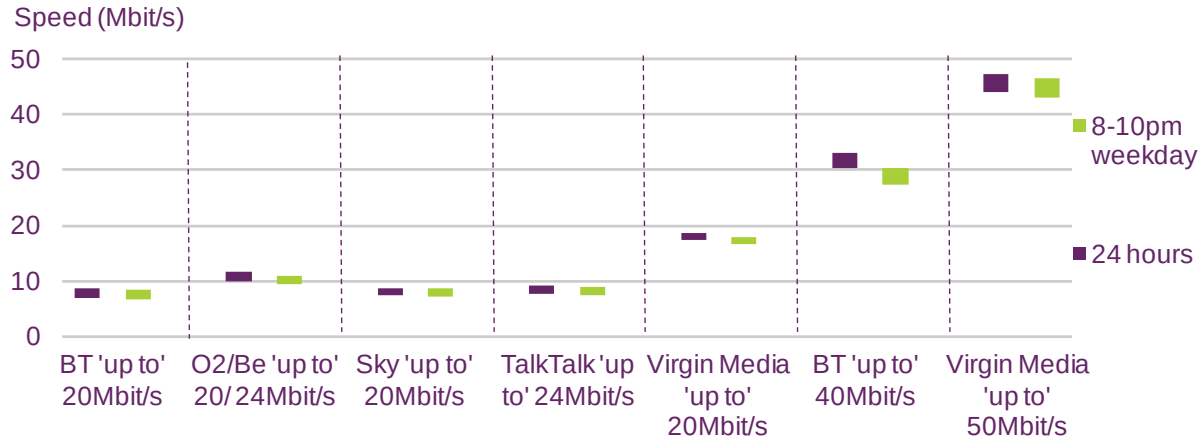
8.23 Figures 8.9 and 8.10 depict the average performance by ISP packages in November/December 2010 over a 24-hour period and in the peak period of 8pm to 10pm weekdays to a 95% confidence interval around the mean.

Figure 8.9 Average download speeds for 'up to' 8Mbit/s and 10Mbit/s connections by ISP, overall and in the peak period, November/December 2010 (multi-thread tests)



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
**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

Figure 8.10 Average download speeds for 'up to' 20Mbit/s and above connections by ISP, overall and in the peak period, November/December 2010 (multi-thread tests)[45]



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
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

8.24 Figure 8.11 summarises the speeds achieved by all ISPs in different time periods to a 95% confidence interval around the mean.

[45] BT's 'up to' 40Mbit/s service experienced a fault during three days in December when all customers on our panel had their speeds capped at 2Mbit/s during the evening hours of 6pm to 12am as a result of an incorrect traffic management profile being applied. We have excluded test results from these days from our analysis in this report. However, including these results would have had the impact of reducing average speeds by around 0.7Mbit/s and reducing speeds during the peak period by around 2.7Mbit/s.

Figure 8.11 Summary of average download speed by ISP package, November/December 2010 (multi-thread tests) [46]

	Average download throughput speed during period	
	24 hours	8 to 10pm weekdays
BT 'up to' 8Mbit/s	4.1 to 4.8Mbit/s	3.8 to 4.4Mbit/s
Orange 'up to' 8Mbit/s	3.3 to 4.3Mbit/s	2.7 to 3.5Mbit/s*
Plusnet 'up to' 8Mbit/s	3.4 to 4.4Mbit/s*	3.3 to 4.2Mbit/s
Virgin Media 'up to' 10Mbit/s	9.5 to 9.7Mbit/s	8.9 to 9.4Mbit/s
BT 'up to' 20Mbit/s	6.9 to 8.7Mbit/s	6.8 to 8.5Mbit/s
O2/Be 'up to' 20/24Mbit/s	9.9 to 11.6Mbit/s**	9.5 to 11.0Mbit/s**
Sky 'up to' 20Mbit/s	7.4 to 8.8Mbit/s	7.3 to 8.7Mbit/s
TalkTalk 'up to' 24Mbit/s	7.7 to 9.3Mbit/s	7.5 to 9.0Mbit/s
Virgin Media 'up to' 20Mbit/s	17.4 to 18.6Mbit/s	16.5 to 18.0Mbit/s
BT 'up to' 40Mbit/s	30.5 to 33.1Mbit/s	27.4 to 30.3Mbit/s
Virgin Media 'up to' 50Mbit/s	43.9 to 47.2Mbit/s	43.1 to 46.6Mbit/s

Source: SamKnows measurement data for all panel members with a connection in November/ December 2010
**Caution: Small sample size (<50)*
*** Results should be treated with some caution as normalisation may not be as effective for O2/Be due to the lower incidence of panellists with longer than average line lengths*
Panel Base:1081
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

Peak download speeds as a proportion of maximum line speeds

8.25 As discussed above, there are two key drivers of variation between ISP performance; (1) the backhaul capacity available (which determines the level of contention in the network); and (2) the access technology used (which is the main factor defining the maximum line speed available). Figures 8.12 and 8.13 below show the impact of contention in the network by examining the peak download speeds delivered against the maximum line speeds (defined as the maximum download speed a customer received in the month).

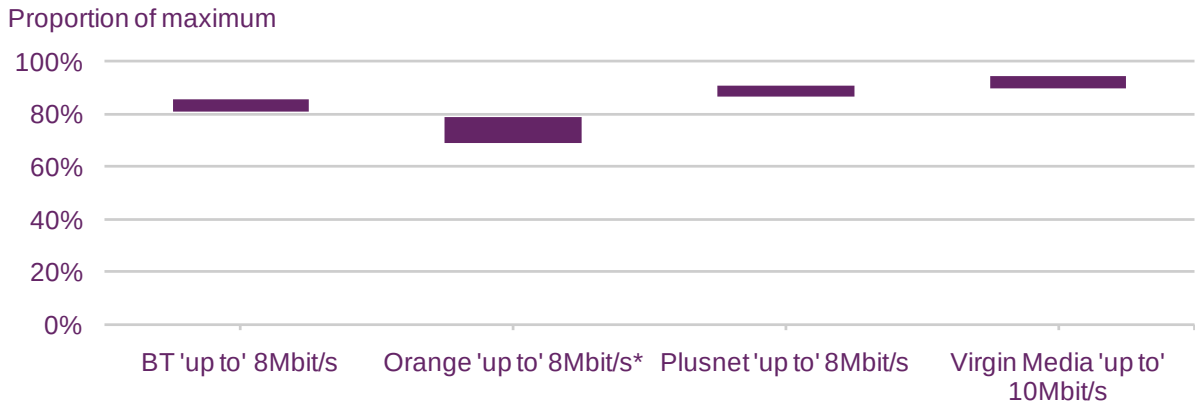
8.26 This is useful because it highlights the areas over which the ISP theoretically has control (as maximum download speed is defined by the physical constraints of the connection into a home, the average download speed as a proportion of the maximum speed reflects performance within these constraints). The maximum line

[46] BT's 'up to' 40Mbit/s service experienced a fault during three days in December when all customers on our panel had their speeds capped at 2Mbit/s during the evening hours of 6pm to 12am as a result of an incorrect traffic management profile being applied. We have excluded test results from these days from our analysis in this report; however, including these results would have the impact of reducing average speeds by around 0.7Mbit/s and reducing speeds during the peak period by around 2.7Mbit/s.

speed is also important to the way in which broadband is sold, since under Ofcom's Voluntary Code of Practice on Broadband Speeds, ISPs who have signed the Code have committed to advise customers of the maximum line speed (also known as the access line speed) at the point of sale.

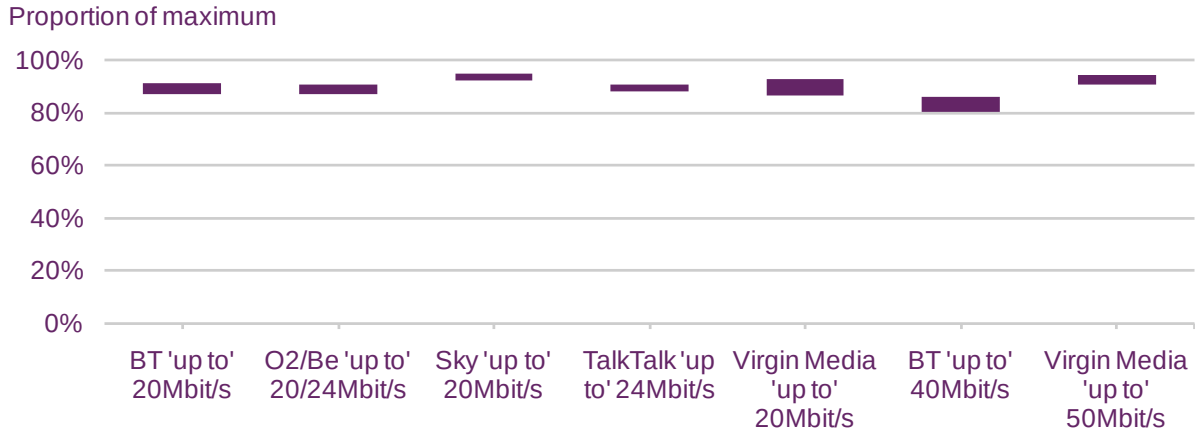
8.27 The analysis shows that there are some differences between operators, indicating that contention in the network is a bigger issue for some ISPs than for others. Sky's 'up to' 20Mbit/s ADSL service delivered the most consistent speeds, with average speeds in the peak period being 95% of maximum speeds. By contrast, average peak speeds for panellists on Orange's 'up to' 8Mbit/s package were less than 80% of maximum speeds, indicating comparatively high levels of network contention.

Figure 8.12 Peak (8 to 10pm weekday) speeds as a proportion of maximum speeds for 'up to' 8Mbit/s and 10Mbit/s connections by ISP package, November/December 2010 (multi-thread tests)



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
**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

Figure 8.13 Peak (8 to 10pm weekday) speeds as a proportion of maximum speeds for 'up to' 20Mbit/s and above connections by ISP package, November/December 2010 (multi-thread tests)[47]



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
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

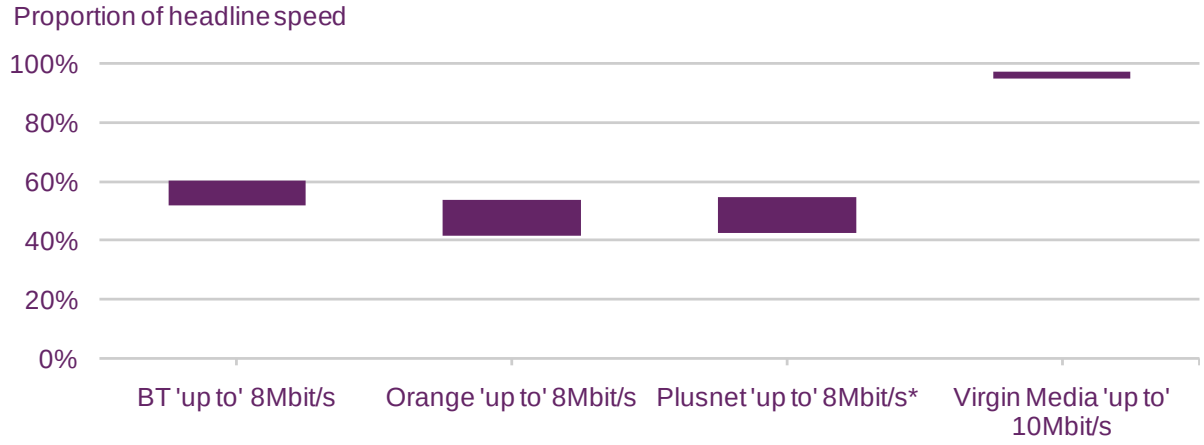
Average download speeds as a proportion of headline speeds

8.28 As broadband is marketed on the basis of an advertised (headline) 'up to' speed, another way of comparing ISP performance is by looking at average download speeds as a proportion of advertised speeds.

8.29 Among 'up to' 8Mbit/s ADSL packages, we found that average download speeds were typically around half of advertised speeds. The primary cause of this is, as discussed previously, ADSL broadband speeds degrade over the length of the copper wire from exchange to premises meaning that there is great variation in the speeds delivered to customers. Unaffected by such constraints, Virgin Media's cable service delivered download speeds which were on average much closer to the headline speed (Figure 8.14).

[47] BT's 'up to' 40Mbit/s service experienced a fault during three days in December when all customers on our panel had their speeds capped at 2Mbit/s during the evening hours of 6pm to 12am as a result of an incorrect traffic management profile being applied. We have excluded test results from these days from our analysis in this report; however, including these results would have the impact of reducing average speeds by around 0.7Mbit/s and reducing speeds during the peak period by around 2.7Mbit/s.

Figure 8.14 Average download speeds (24 hours) as a proportion of headline speeds for 'up to' 8Mbit/s and 10Mbit/s connections by ISP package, November/December 2010 (multi-thread tests)



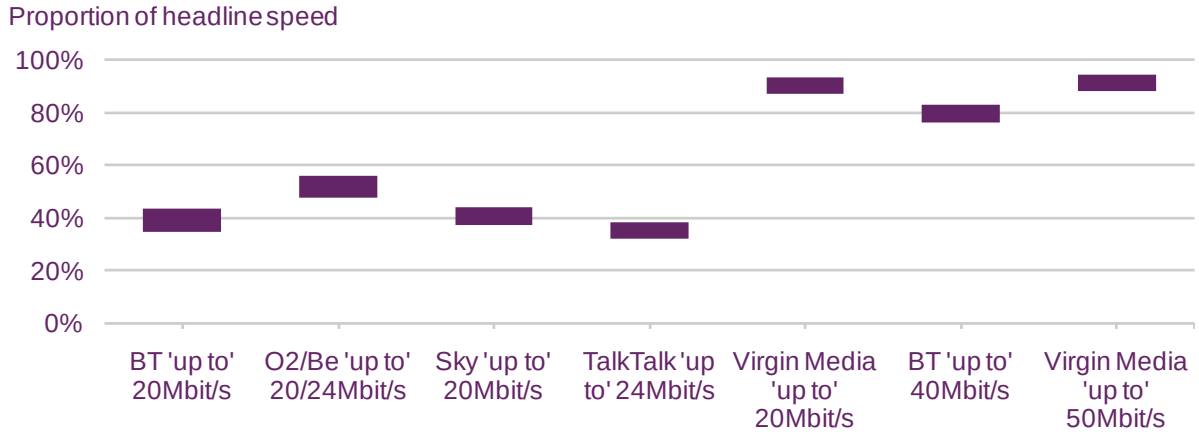
Source: SamKnows measurement data for all panel members with a connection in November/December 2010
**Caution: Small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for 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

8.30 Among the 'up to' 20Mbit/s or 24Mbit/s ADSL services, actual download speeds delivered are only around 40-50% of advertised speeds (Figure 8.15). This is to be expected as although the ADSL2+ technology associated with these packages can typically deliver faster speeds to consumers who live within 3km of the exchange than the ADSL1 technology associated with many 'up to' 8Mbit/s connections, speeds degrade more quickly with distance from the exchange. Therefore, while the upgrade of services to ADSL2+ and 'up to' speeds of 20Mbit/s and 24Mbit/s represents a step change in advertised speeds, the improvement in performance is less dramatic (and is likely to be negligible for consumers who live more than 3km from the exchange).

8.31 Virgin Media's three cable services and BT's 'up to' 40Mbit/s FTTC service[48] all delivered a much higher proportion of advertised 'up to' download speeds than did ADSL1 and ADSL2+-based connections.

[48] BT's 'up to' 40Mbit/s service experienced a fault during three days in December when all customers on our panel had their speeds capped at 2Mbit/s during the evening hours of 6pm to 12am as a result of an incorrect traffic management profile being applied. We have excluded test results from these days from our analysis in this report. However, including these results would have had the impact of reducing average speeds by around 0.7Mbit/s and reducing speeds during the peak period by around 2.7Mbit/s.

Figure 8.15 Average download speeds (24 hours) as a proportion of headline speeds for 'up to' 20Mbit/s and above connections by ISP, November/December 2010 (multi-thread tests)



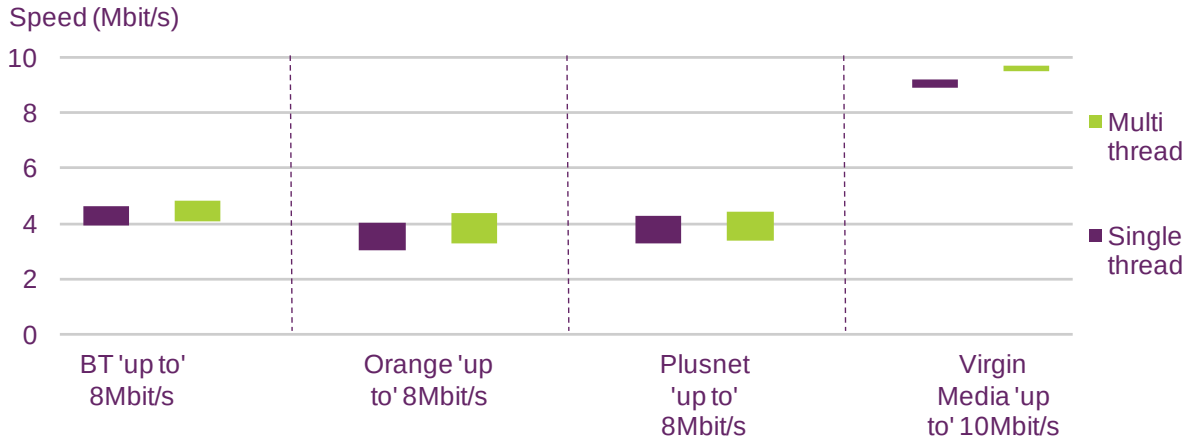
Source: SamKnows measurement data for all panel members with a connection in November/December 2010
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted 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

Comparison of download speed results from single and multi-thread tests

8.32 As detailed above (see paragraph 8.7), unlike in previous reports we have focused our analysis on multi-thread tests (which test the speed when multiple files are downloaded simultaneously), rather than single-thread tests (which test the speed of download of a single file). However, the two test types are relevant for different purposes; a single-thread test replicates the consumer experience of downloading a small file such as an MP3 track, multi-thread testing replicates web page downloads, peer-to-peer configurations, or multiple PCs simultaneously downloading files using the same broadband connection.

8.33 The differential between the results of single and multi-thread tests was greater among higher-speed connections than slower ones. Among the 'up to' 8Mbit/s and 10Mbit/s packages, multi-thread testing on average delivered speeds around 5% higher than single-thread tests for most ISP packages over the 24-hour period and the off-peak period in November/December 2010 (Figure 8.16).

Figure 8.16 Average download throughput speeds for 'up to' 8Mbit/s and 10Mbit/s ISP packages, single and multi-thread test results, 24 hours, November/December 2010



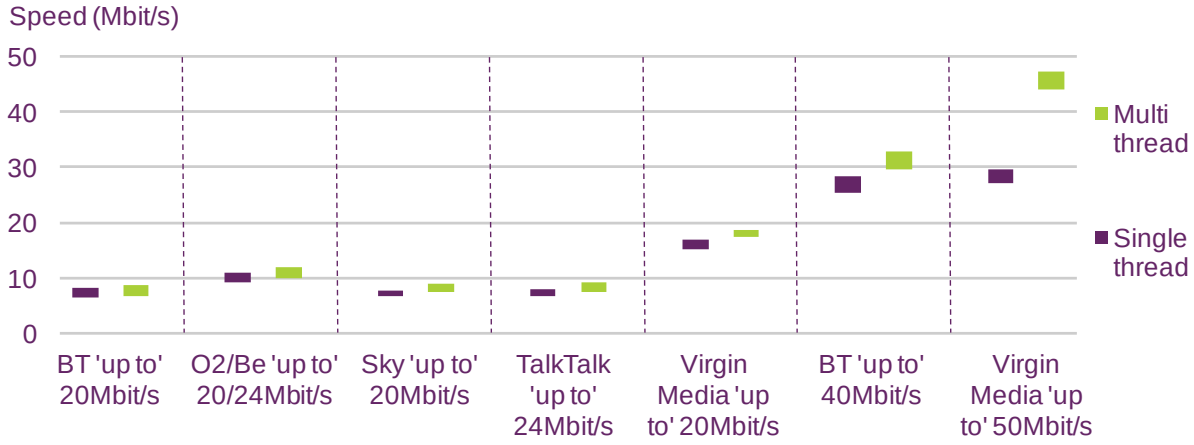
Source: SamKnows measurement data for all panel members with a connection in November/December 2010
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted 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 single and multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

8.34 However, multi-thread test results for 'up to' 20Mbit/s and 24Mbit/s connections were, on average, 11% higher than those from single-thread tests, while the differential for connections with a headline speed higher than ' up to' 24Mbit/s was even greater (Figure 8.17).

8.35 Particularly noticeable was the difference between single and multi-thread results for Virgin Media's 'up to' 50Mbit/s cable service, which recorded average download speeds using multi-thread tests that were 61% faster than those recorded by single-thread tests over the period when both sets of tests ran, while for BT's 'up to' 40Mbit/s the difference was much lower, at 16%[49].

[49] It should be noted that these figures differ from those in paragraph 4.14, which are calculated from test results taken across the whole 45-day testing period, rather than just the two weeks when both single- and multi-thread tests ran concurrently.

Figure 8.17 Average download throughput speeds for 'up to' 20Mbit/s and above ISP packages, single and multi-thread test results, 24 hours, November/December 2010



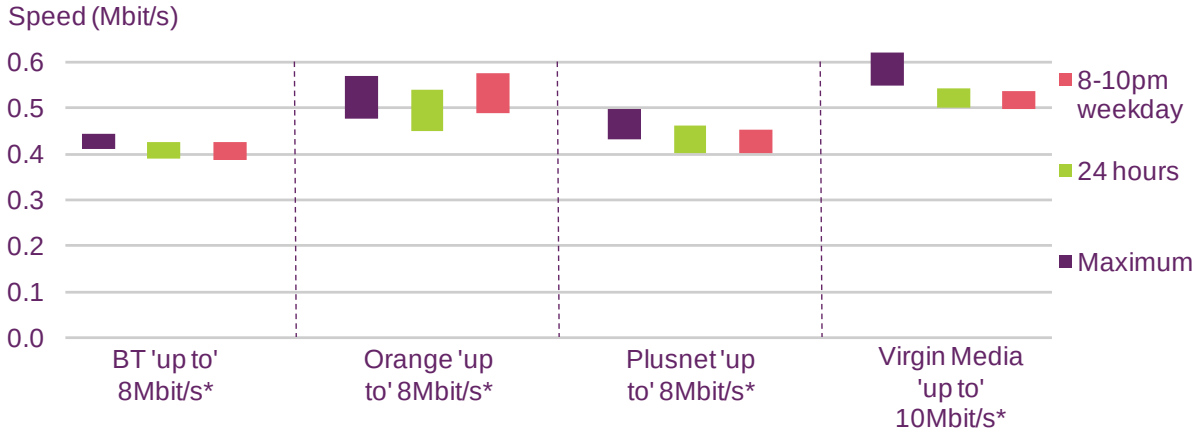
Source: SamKnows measurement data for all panel members with a connection in November/December 2010
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted 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 single and multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

Upload speeds

8.36 Broadband connections do, of course, work both ways – they have an upstream as well as a downstream. While the market tends to focus on download speeds, as these are most important for most consumer applications, upload speeds matter to those looking to share large files, use real-time video communications and for some online games.

8.37 For residential broadband services, ISPs configure their networks in such a way as to deliver upload speeds which are much lower than download speeds. Average actual upload speeds were around 0.5Mbit/s for all of the 'up to' 8Mbit/s and 10Mbit/s ISP packages considered in our research. In addition to delivering download speeds around twice as high as comparable ADSL services, Virgin Media's 'up to' 10Mbit/s cable package delivered average upload speeds faster than BT and Plusnet over the 24-hour period, while Orange was also faster than BT (Figure 8.18).

Figure 8.18 Maximum, average and peak time upload speeds for 'up to' 8Mbit/s and 10Mbit/s ISP packages, November/December 2010



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
**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

Figure 8.19 Significant differences to a 95% level of confidence between maximum, average and peak time upload speeds for 'up to' 8Mbit/s and 10Mbit/s ISP packages, November/December 2010

	24 hours		8-10pm weekday		Maximum	
ISP package	Is slower than...	Is faster than...	Is slower than...	Is faster than...	Is slower than...	Is faster than...
BT 'up to' 8Mbit/s*	Virgin Media and Orange		Virgin Media		Orange and Virgin Media	
Orange 'up to' 8Mbit/s*		BT				BT
Plusnet 'up to' 8Mbit/s*	Virgin Media				Virgin Media	
Virgin Media 'up to' 10Mbit/s*		BT and Plusnet		BT		Plusnet and BT

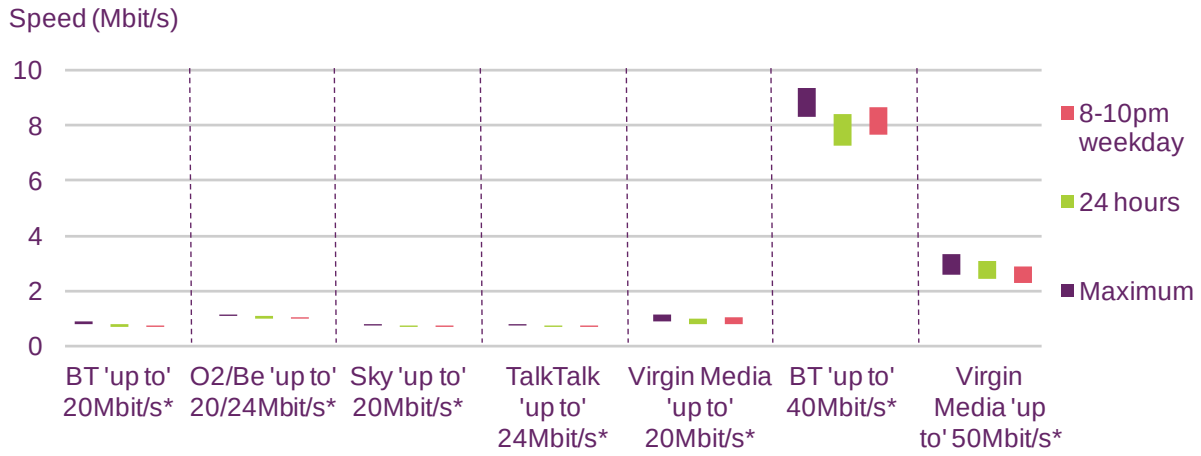
Source: Ofcom
**Caution: small sample size (<50)*
Note: Significant differences to a 99% level of confidence are provided in Annex 4

8.38 BT's 'up to' 40Mbit/s FTTC product delivered considerably faster upload speeds than any other ISP package within our research. Its average upload speeds were around 7.8Mbit/s (it has a headline upload speed of 'up to' 10Mbit/s). Virgin Media's 'up to' 50Mbit/s service delivered average upload speeds of around 2.8Mbit/s (Figure 8.20).[50]

[50] In September 2011, Virgin Media announced that it was increasing upload speeds across all of its packages, so that upload speeds would be 10% of download speeds (i.e. customers on its 'up to' 10Mbit/s package would get upload speeds of 1Mbit/s, customers on 'up to' 20Mbit/s packages would

8.39 Upload speeds for ISPs' 'up to' 20Mbit/s and 24Mbit/s ADSL packages were generally higher than for their 'up to' 8Mbit/s and 10Mbit/s services, averaging around 0.8Mbit/s. O2/Be's 'up to' 20/24Mbit/s ADSL services both delivered significantly higher upload speeds than other 'up to' 20Mbit/s and 24Mbit/s services, averaging around 1.0Mbit/s.

Figure 8.20 Maximum, average and peak time upload speeds for 'up to' 20Mbit/s and above ISP packages, November/December 2010



Source: SamKnows measurement data for all panel members with a connection in November/December 2010),
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

get 2Mbit/s and those on 'up to' 50Mbit/s would get upload speeds of 5Mbit/). This increase was to be rolled out from September and continue through 2011, http://shop.virginmedia.com/help/discover-broadband/broadband-speed/upload-speeds.html

Figure 8.21 Significant differences to a 95% level of confidence between maximum, average and peak time upload speeds for 'up to' 20Mbit/s and above ISP packages, November/December 2010

	24 hours		8-10pm weekday		Maximum	
ISP package	**Is slower than...**	**Is faster than...**	**Is slower than...**	**Is faster than...**	**Is slower than...**	**Is faster than...**
Comparison of 'up to' 20/24Mbit/s packages						
BT 'up to' 20Mbit/s*	O2/Be		O2/Be		O2/Be and Virgin Media	
O2/Be 'up to' 20/24Mbit/s*		BT, Sky and TalkTalk		BT, Sky and TalkTalk		BT, Sky and TalkTalk
Sky 'up to' 20Mbit/s*	O2/Be and Virgin Media		O2/Be		O2/Be and Virgin Media	
TalkTalk 'up to' 24Mbit/s*	O2/Be and Virgin Media		O2/Be		O2/Be and Virgin Media	
Virgin Media 'up to' 20Mbit/s*		Sky and TalkTalk				BT, Sky and TalkTalk
Comparison of 'up to' 40/50Mbit/s packages						
BT 'up to' 40Mbit/s*		Virgin Media		Virgin Media		Virgin Media
Virgin Media 'up to' 50Mbit/s*	BT		BT		BT	

Source: Ofcom
**Caution: small sample size (<50)*
Note: Significant differences to a 99% level of confidence are provided in Annex 4

Section 9

Other metrics affecting performance

9.1 Although download and upload throughput speeds may be the most significant determinants of the overall performance of a broadband connection, other factors also have an impact and may be more important for some applications. This section of the report discusses the impact of other key factors on the consumer experience and compares the performance of ISP packages included in the research on that basis. These are summarised in Figure 9.1 below.

Figure 9.1 Summary of additional metrics covered in the research

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

Source: Ofcom

Web browsing

9.2 Download speeds are of limited importance for web browsing, where file sizes are typically small (less than 100kb). A broadband connection's latency and DNS resolution time are equally important (both are discussed in more detail below), and combine with server-side factors (for example the bandwidth of the host site) to determine how quickly web pages are loaded.

9.3 In order to assess the basic web browsing performance of packages with different headline speeds, we measured the time in milliseconds to fetch the main HTML and assets (i.e. text, basic code and content files) from a test page hosted on the Ofcom website, a change from the methodology used in previous Broadband Speeds reports when only the main HTML was downloaded. Note that tests were designed to ensure that pages were not cached.

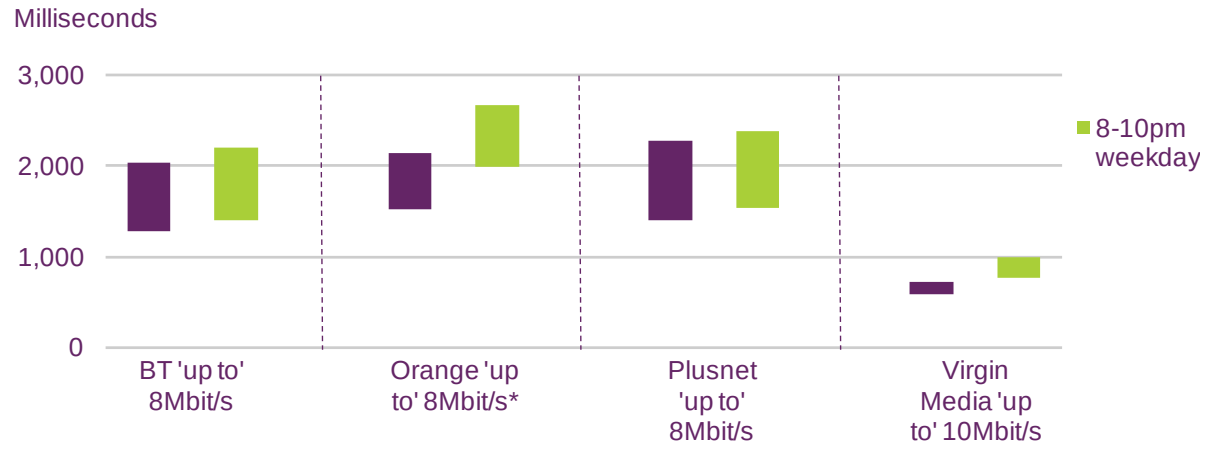
9.4 Due to the relatively small sizes of most web pages (often measured in tens of kilobytes), there comes a point when increasing the raw download speed of the connection yields no tangible increase in the browsing performance. Latency

becomes the limiting factor in determining webpage load times on very fast connections (see paragraph 9.7 onwards).

9.5 Among the 'up to' 8Mbit/s and 10Mbit/s ISP packages covered by our research, Virgin Media had the fastest web page loading time averaged across the whole day, while Virgin Media and O2/Be had the fastest web page loading times among the 'up to' 20Mbit/s and 24Mbit/s services covered in this report.

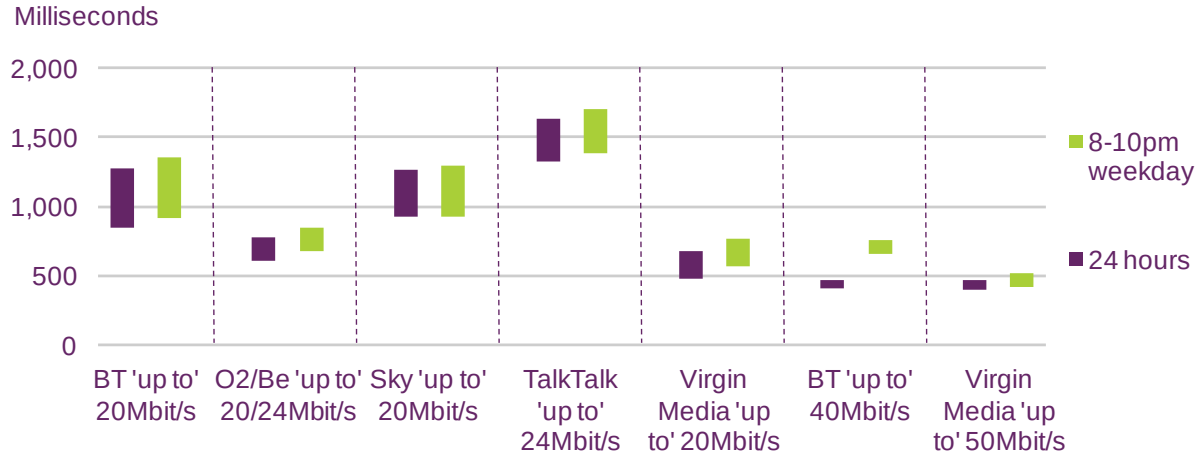
9.6 Among the highest speed packages, Virgin Media's 'up to' 50Mbit/s cable service, on average, had faster web page loading times than BT's 'up to' 40Mbit/s FTTC service across both the 24-hour period and the weekday peak evening period. (Note that in Figures 9.2 and 9.3 better performance is faster loading times, which are indicated by lower bars).

Figure 9.2 Average and peak time loading of web pages for 'up to' 8Mbit/s and 10Mbit/s ISP packages, November/December 2010



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
**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 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 9.3 Average and peak time loading of web pages for 'up to' 20Mbit/s and above ISP packages, November/December 2010



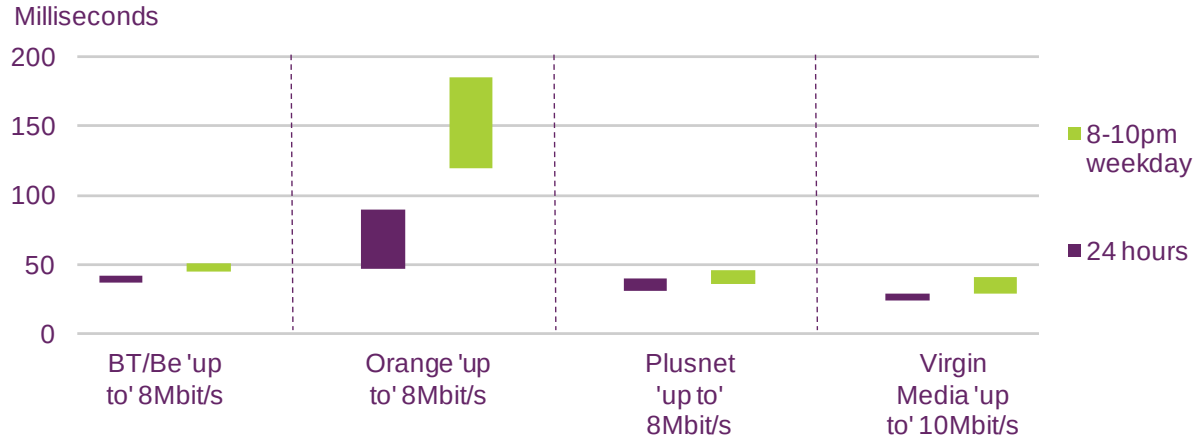
Source: SamKnows measurement data for all panel members with a connection in November/December 2010
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted 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) Better performance is indicated by a faster loading time, i.e. lower values

Latency

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

9.8 There was a wide range of performance among the lower-speed packages covered by our research. Virgin Media's 'up to' 10Mbit/s service was significantly better in terms of latency than BT, Orange and Plusnet's 'up to' 8Mbit/s services over the 24-hour period and in the peak period. (Note that in Figures 9.4 and 9.5 better performance is lower speeds, which are indicated by lower bars.)

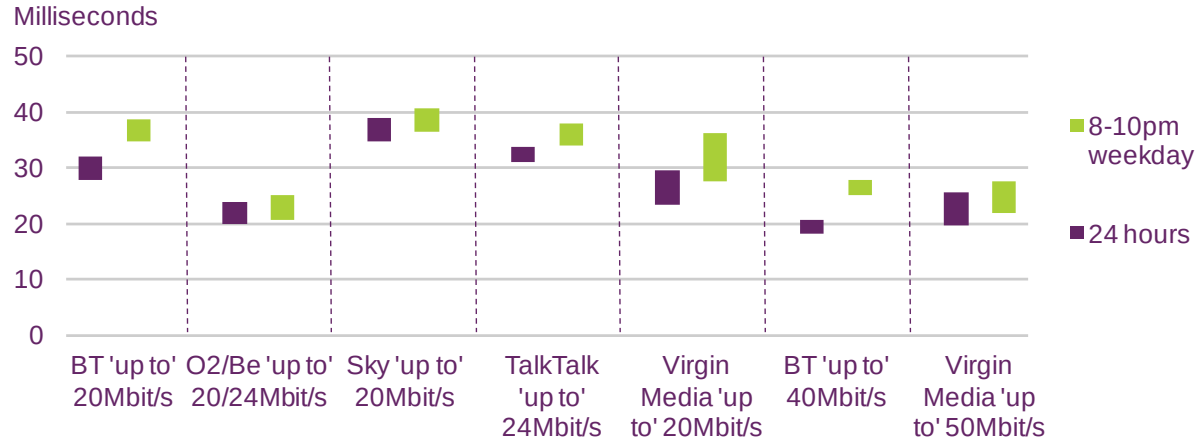
Figure 9.4 Latency for 'up to' 8Mbit/s and 10Mbit/s ISP packages, average and peak times, November/December 2010



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
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) Better performance is indicated by a low speed (i.e. lower values).

9.9 O2/Be had the lowest levels of latency among the 'up to' 20Mbit/s and 24Mbit/s ISP speed packages over the 24-hour period, while there was no difference in levels of latency between BT's 'up to' 40Mbit/s FTTC service and Virgin Media's 'up to' 50Mbit/s cable service on average across the whole day.

Figure 9.5 Latency for 'up to' 20Mbit/s and above ISP packages, average and peak times, November/December 2010



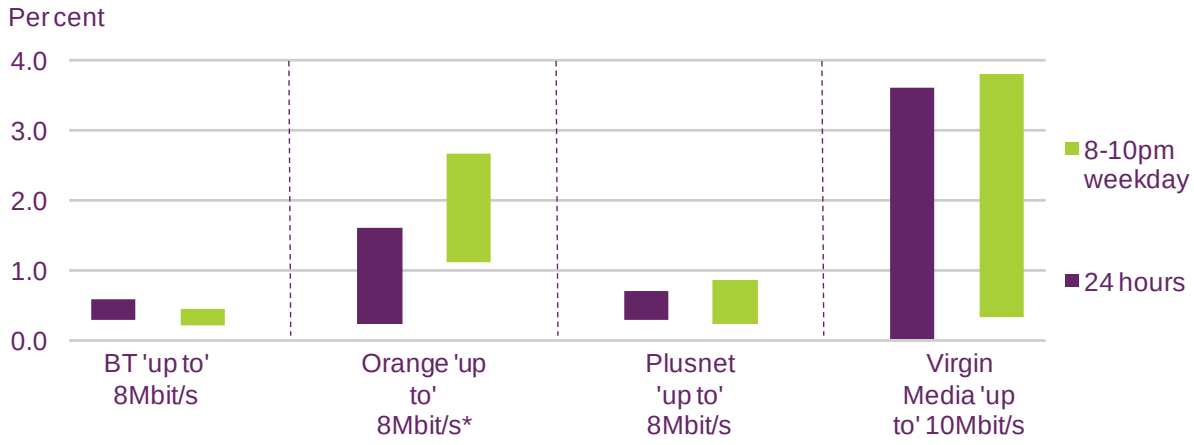
Source: SamKnows measurement data for all panel members with a connection in November/December 2010
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted 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) Better performance is indicated by a low speed (i.e. lower values).

Packet loss

9.10 Packets of data can be lost during transmission over an internet connection. Packet loss can considerably degrade the performance of real-time applications, and although network protocols such as Transmission Control Protocol (TCP) automatically deal with packet loss to minimise the impact on the end-user, there may still be a temporary slow-down. This can be a major concern for online gamers, and can also have a severe impact on voice over IP (VoIP) telephony or streaming audio or video (the odd dropped packet is generally acceptable as each packet in the test only accounts for 0.2 seconds, but extended periods of loss lead to choppy and broken-up video and audio).

9.11 Levels of packet loss were low among most of the ISP packages covered by our research, with few, if any, having loss of more than 2% (at which level it is unlikely that users would experience any noticeable degradation of service). There were no significant differences in packet loss over the 24-hour period among the 'up to' 8Mbit/s and 10Mbit/s ISP packages covered in the research, although BT and Plusnet performed better than Orange during the 8 to 10pm weekday peak period. (Note that in Figures 9.6 and 9.7 better performance is lower packet loss, which is indicated by lower bars.) The relatively large confidence interval ranges associated with Orange and Virgin Media are the result of greater variation in performance across these samples.

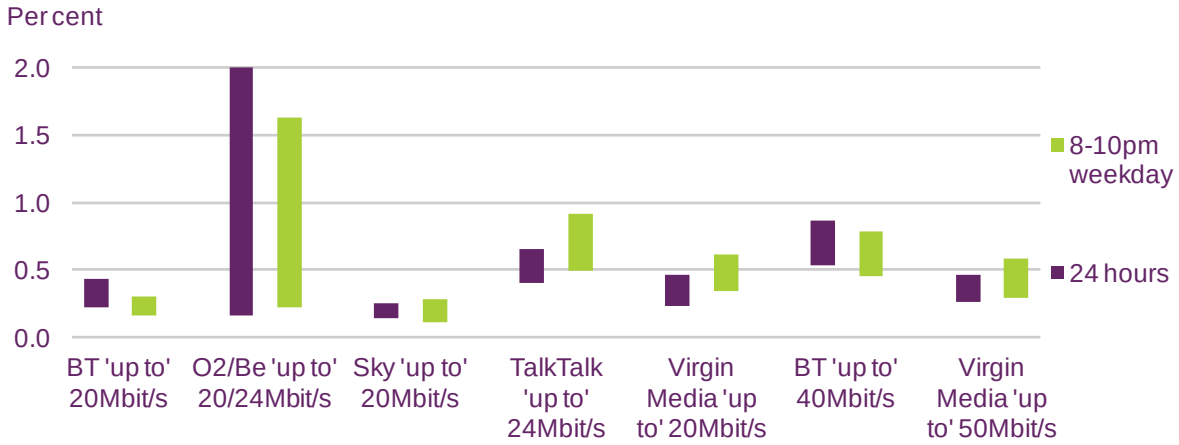
Figure 9.6 Average and peak time packet loss for 'up to' 8Mbit/s and 10Mbit/s ISP packages, November/December 2010



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
**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 lower packet loss (i.e. lower values).

9.12 Sky's 'up to' 20Mbit/s service had lower packet loss than TalkTalk's 'up to' 24Mbit/s service over the 24-hour period, while BT and Sky's 'up to' 20Mbit/s services both performed better than TalkTalk's 'up to' 24Mbit/s service and Virgin Media's 'up to' 20Mbit/s service at peak times. Virgin Media's 'up to' 50Mbit/s service had lower packet loss that BT's 'up to' 40Mbit/s service on average across the whole day, but there was no such difference at peak times. The relatively large confidence interval ranges associated with O2/Be is the result of greater variation in performance across this sample.

Figure 9.7 Average and peak time packet loss for 'up to' 20Mbit/s and above ISP packages, November/December 2010



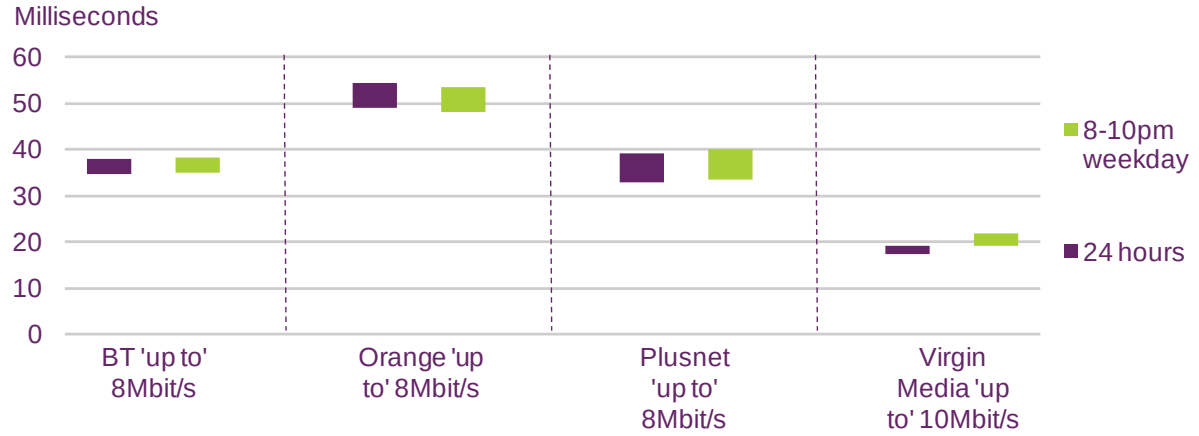
Source: SamKnows measurement data for all panel members with a connection in November/December 2010
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted 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 lower packet loss (i.e. lower values).

DNS resolution

9.13 DNS (the domain name service) plays a crucial role in the internet. This protocol translates domain names (such as ofcom.org.uk) into the IP addresses that are actually used to route traffic (e.g. 194.33.179.25). Every ISP maintains its own DNS servers through which customers' computers issue queries to translate names into IP addresses. When these servers fail or operate slowly, web browsing and other online activities suffer. A slow DNS time does not affect download speed, but can severely affect the responsiveness of the internet while browsing.

9.14 There was some variation in DNS resolution times across the packages covered by our research, although these were unlikely to have much impact on the user experience. Among the 'up to' 8Mbit/s and 10Mbit/s packages, most average resolution times fell within a range of 20 to 60ms, and Virgin Media's 'up to' 10Mbit/s cable service performed better than the other lower-speed connections on average across the whole day. (Note that in Figures 9.8 and 9.9 better performance is faster resolution times, which are indicated by lower bars.)

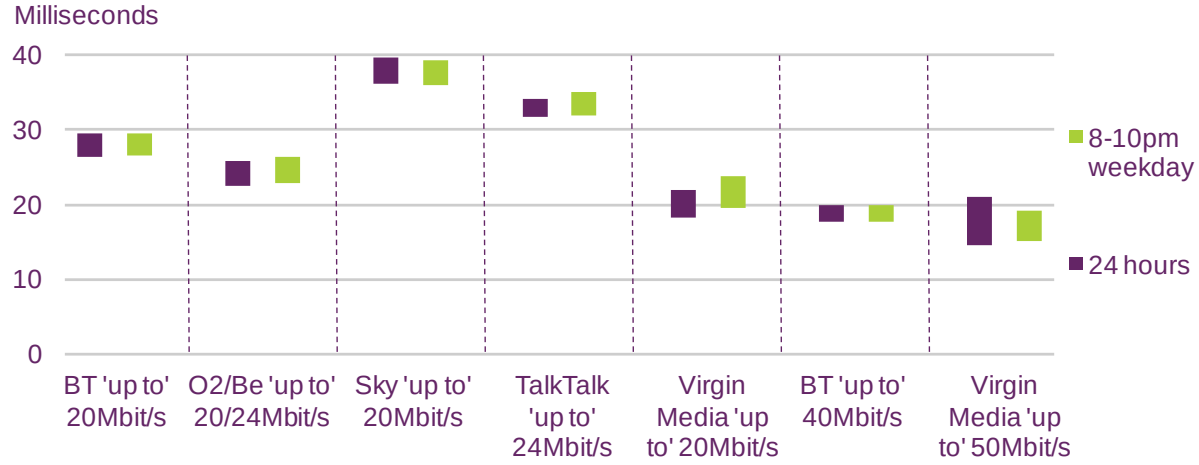
Figure 9.8 Average and peak time DNS resolution time by ISP package for 'up to' 8Mbit/s and 10Mbit/s packages, November/December 2010



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
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 faster resolution times (i.e. lower values).

9.15 Virgin Media's 'up to' 20Mbit/s service also performed best out of the 'up to' 20Mbit/s and 24Mbit/s services, although there was no difference between the performance of Virgin Media's 'up to' 50Mbit/s cable service and BT's 'up to' 40Mbit/s FTTC service.

Figure 9.9 Average and peak time DNS resolution time by ISP package for 'up to' 20Mbit/s and above packages, November/December 2010



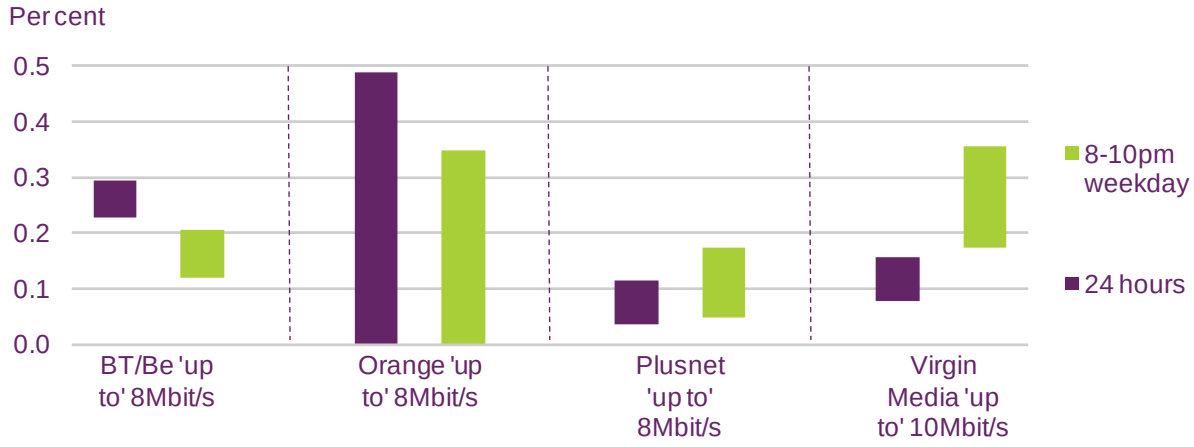
Source: SamKnows measurement data for all panel members with a connection in November/December 2010
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted 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 faster resolution times (i.e. lower values).

DNS failure

9.16 DNS failure occurs when an ISP's DNS server is unable to translate a domain name to an IP address in a TCP/IP network. When a DNS failure occurs the user is presented with an error message such as "*This server is unavailable*" or "*Host could not be found*", and is unable to access the requested page on that occasion.

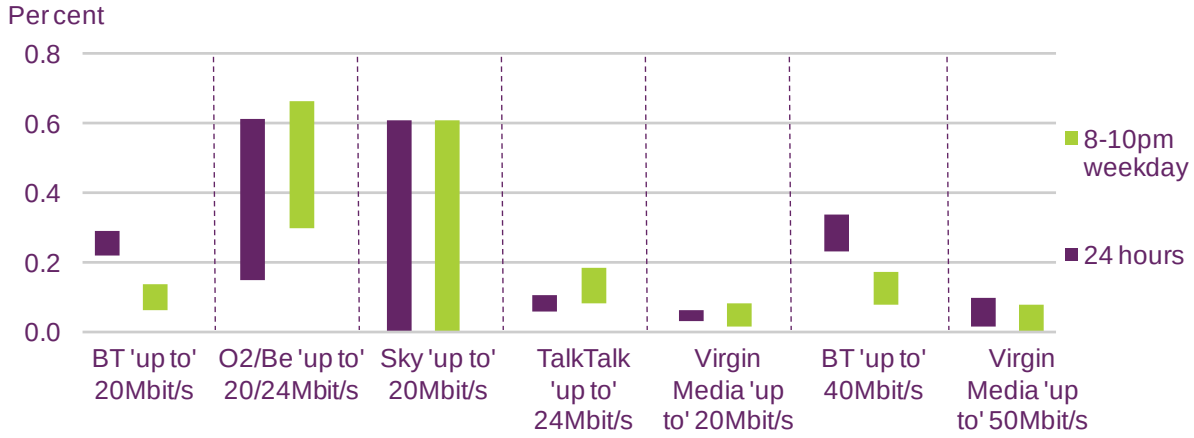
9.17 Figures 9.10 and 9.11 show the proportion of DNS requests which failed for each of the ISP packages. They show that, among the 'up to' 8Mbit/s and 10Mbit/s ISP packages, Plusnet's 'up to' 8Mbit/s service performed well over both the 24-hour and peak periods, while among the 'up to' 20Mbit/s and 24Mbit/s packages, TalkTalk and Virgin Media's services performed better than those of BT and O2/Be over the 24-hour period. On average, Virgin Media's 'up to' 50Mbit/s service performed better than BT's 'up to' 40Mbit/s service across the whole day. (Note that in these charts better performance is indicated by shorter times, which are indicated by lower bars). The relatively large confidence interval ranges associated with some packages is the result of greater variation in performance in these samples.

Figure 9.10 Average and peak time DNS failure rates by ISP package for 'up to' 8Mbit/s and 10Mbit/s packages, November/December 2010



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
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 faster resolution times (i.e. lower values).

Figure 9.11 Average and peak time DNS failure rates by ISP package for 'up to' 20Mbit/s and above packages, November/December 2010



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
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 faster resolution times (i.e. lower values).

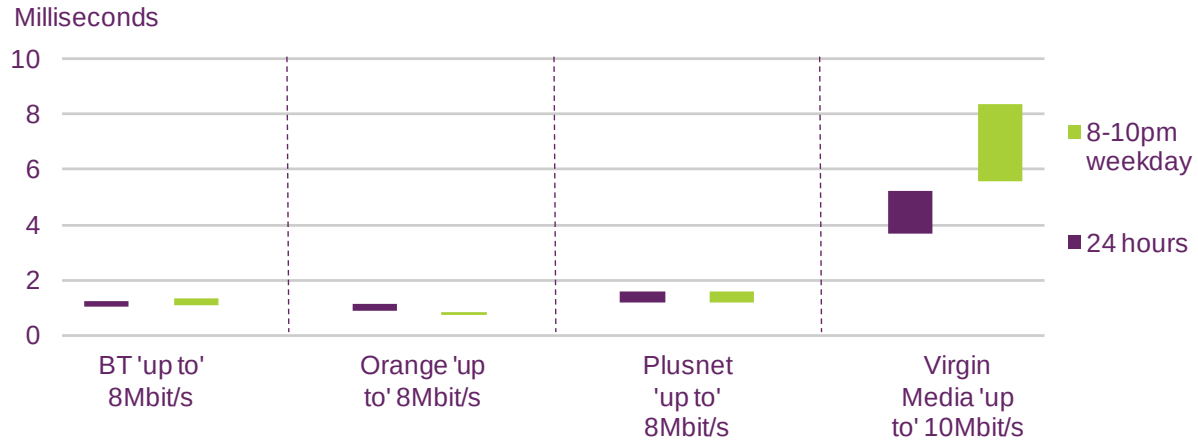
Jitter

9.18 'Jitter' is defined as the rate of change of latency. The lower the measure of jitter, the more stable a connection is. Jitter and packet loss are the two biggest contributors to the quality of a Voice over Internet Protocol (VoIP) phone call. Online gamers will also desire low jitter (low latency is useless if the connection has a high jitter rate).

9.19 It should be noted that modern specialist VoIP devices will often include a 'jitter buffer' of around 20 milliseconds. This effectively allows for up to 20 millisecond jitter with no noticeable effect for the end user. In a change to the test methodology used in previous Broadband Speeds reports, we conducted separate tests to determine levels of upstream and downstream jitter in November/December 2010.

9.20 Virgin Media's 'up to' 10Mbit/s and 'up to' 20Mbit/s services had higher rates of upstream jitter than the comparable ADSL packages covered in this report over both the 24-hour and weekday 8 to 10pm peak periods, while its 'up to' 50Mbit/s also had higher upstream jitter than BT's 'up to' 40Mbit/s service on average across the whole day and during peak times. (Note that in Figures 9.12 to 9.15 better performance is indicated by shorter times, which are indicated by lower bars.)

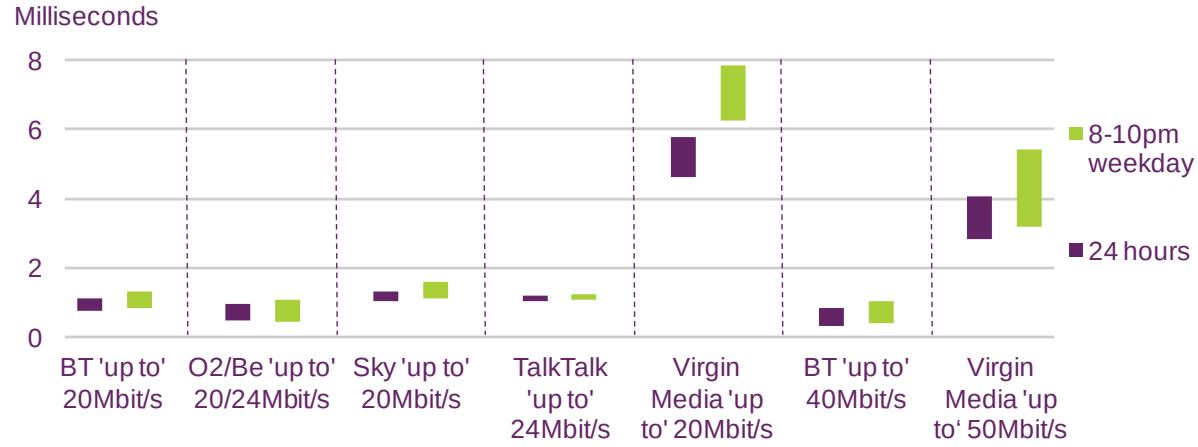
Figure 9.12 Average and peak time upstream jitter by ISP package for 'up to' 8Mbit/s and 10Mbit/s packages, November/December 2010



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
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).

9.21 Virgin Media's 'up to' 10Mbit/s and 'up to' 20Mbit/s services had higher rates of upstream jitter than the comparable ADSL packages covered in this report over both the 24-hour and weekday 8 to 10pm peak periods, while its 'up to' 50Mbit/s also had higher upstream jitter than BT's 'up to' 40Mbit/s service on average across the whole day and during peak times.

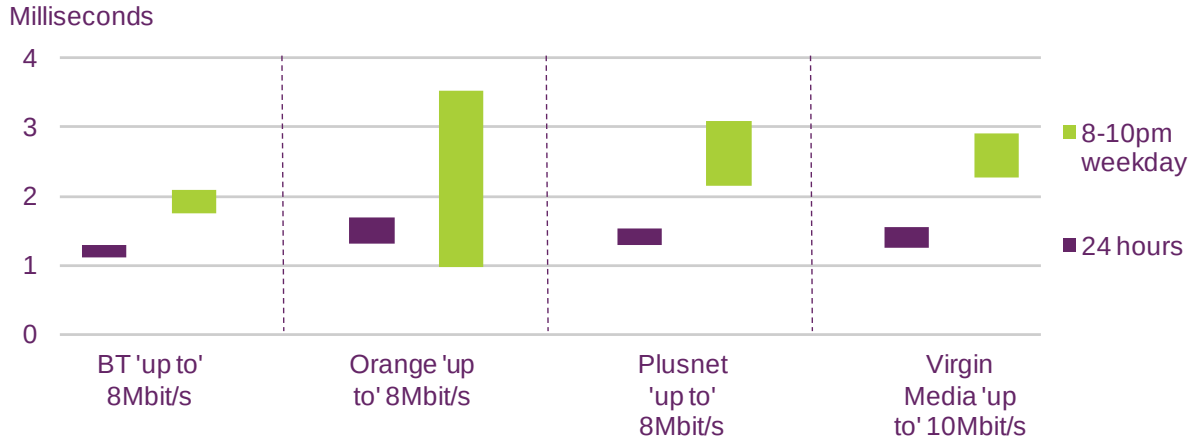
Figure 9.13 Average and peak time upstream jitter by ISP package for 'up to' 20Mbit/s and above packages, November/December 2010



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
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).

9.22 Among the ‘up to’ 8Mbit/s and 10Mbit/s ISP packages, BT’s ‘up to’ 8Mbit/s service had lower downstream jitter than Orange’s ‘up to’ 8Mbit/s service over the 24-hour period, and lower downstream jitter levels that Plusnet’s ‘up to’ 8Mbit/s service and Virgin Media’s ‘up to’ 10Mbit/s service during the peak weekday period.

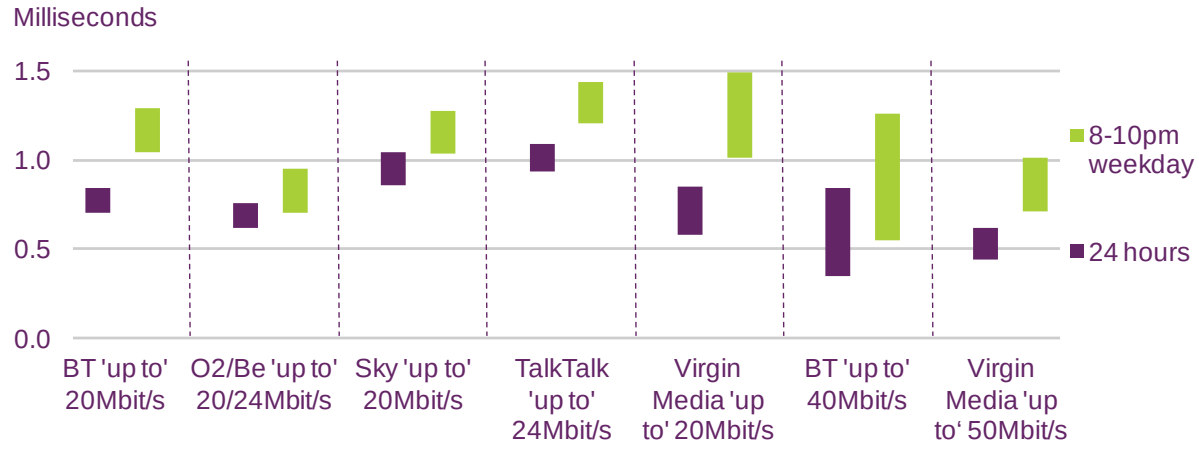
Figure 9.14 Average and peak time downstream jitter by ISP package for ‘up to’ 8Mbit/s and 10Mbit/s packages, November/December 2010



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
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).

9.23 BT and Virgin Media’s ‘up to’ 20Mbit/s services and O2/Be’s up to 20/24Mbit/s service all had lower downstream jitter levels that Sky’s ‘up to’ 20Mbit/s service and TalkTalk’s ‘up to’ 24Mbit/s, over the 24-hour period, while O2/Be’s up to 20/24Mbit/s and lower downstream jitter levels that all of the other ‘up to’ 20Mbit/s and 24Mbit/s ISP packages during the peak weekday period. There was no difference between the performance of BT’s ‘up to’ 40Mbit/s service and Virgin Media’s up to 50Mbit/s either across the whole day or at peak times.

Figure 9.15 Average and peak time downstream jitter by ISP package for 'up to' 20Mbit/s and above packages, November/December 2010



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
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).

Section 10

Analysis of operator data

Overview

10.1 The analysis set out elsewhere in this report is based on data collected from the consumer panel, which has been set up and managed on our behalf by SamKnows. In this section we set out our analysis of data supplied to us by the larger ISPs and Openreach.

10.2 We requested technical data from Openreach, BT Retail, Virgin Media, TalkTalk, Sky, Everything Everywhere and O2 on the broadband connections they operate. This data set has allowed us to gain a greater insight into how broadband performance varies by technology, line characteristics and geography.

10.3 This analysis should be read in conjunction with the rest of this report. As explained below, it focuses on broadband modem synchronisation speed (sync speeds). The sync speed is the 'raw' capacity available between the end-user's modem and the operator's equipment in the exchange or cabinet. The actual speeds available to the end users will always be lower than the sync speed because some of the raw capacity is required for communications protocol overheads.

10.4 In addition, the actual speeds achieved by an end-user may be affected by other factors such as contention on shared sections of the network, traffic management policies and the loading on the server the user is accessing. Nevertheless, analysis of sync speeds is of interest as it provides a useful indicator of the 'ceiling' of broadband speeds and a common benchmark to compare performance in different geographic areas.

10.5 Due to the differences in how the technologies work, the majority of the technical data requested from the ISPs was relevant to xDSL technologies, but not the DOCSIS technology used by cable broadband. Consequently the analysis below is focussed on xDSL performance.

xDSL technology overview

10.6 A family of digital subscriber line' technologies are used to deliver broadband over telephone lines. Collectively referred to as 'xDSL', early deployments used ADSL (referred to below as 'ADSL1') technology, deployed in telephone exchanges, which can provide downstream speeds of 'up to' 8Mbit/s. In the last few years a more advanced technology, ADSL2+, has been deployed, which offers 'up to' 24Mbit/s connections (often marketed as 'up to' 20Mbit/s), and in the past year Openreach (part of the BT Group) has deployed VDSL (FTTC) technology in street cabinets, which currently offers speed of 'up to' 40Mbit/s. While each variant of xDSL provides a different level of performance, the underlying technologies, and hence the drivers of performance, are the same.

10.7 Like many telecommunications channels, data are sent over telephone lines using a number of 'carrier frequencies' on which the data are loaded. The capacity of a channel (i.e. the speed at which data can be sent across it) is dependent on (i) how many carriers are used and (ii) how much data is loaded onto each carrier.

10.8 The principal difference between ADSL1, ADSL2+ and VDSL is the number of carriers used. ADSL1 uses carriers on the line operating at frequencies up to 1MHz, ADSL2+ makes use of additional carriers between 1MHz and 2MHz and the VDSL solution currently being deployed by Openreach uses frequencies up to 5MHz.

10.9 The amount of data that can be loaded onto each carrier is determined by the signal quality of each carrier as received at the user's modem. This in turn is dependent on the signal strength and level of electrical interference (or 'noise').

10.10 Given a fixed transmit power, signal strength at the end user's modem is determined by signal loss of the line (signal attenuation). As shown in figure 10.1, there is a close relationship between signal attenuation and line length, with longer lines suffering higher attenuation. It is also the case that higher frequency carriers are more quickly attenuated than lower frequencies; the higher frequencies used by ADSL2+ and VDSL have a limited ability to carry data on longer lines. This is one reason why there is only a marginal performance improvement when ADSL2+ technologies are used on longer lines, compared to ADSL1.

10.11 Electrical noise also affects signal quality and hence achievable speeds. 'Cross talk' of signals between lines in the same cable bundle is typically the dominant source of noise, although noise can enter the line from external sources, such as faulty fluorescent lighting, particularly if there is poor quality in-home telephone wiring or poor cable joints. The higher the difference between the received signal strength of each carrier and the received electrical noise (the 'noise margin'), the greater the amount of data that can be transmitted. Consumers can minimise the noise on their line by ensuring that they have correctly-fitted filters on all telephone extensions and, in some cases, by fitting a filter plate (sometimes known as an iPlate) to their master socket.

10.12 When an end user's xDSL modem first connects with an ISP's equipment in the local exchange or cabinet it goes through a process of 'negotiation'. The two devices exchange information to establish what technologies each supports (ADSL1, ADSL2+ or VDSL) and make measurements of the attenuation and noise on the line. Based on this information they agree which carrier frequencies to use and how much data to load on each one. This 'synchronisation' process determines the raw data capacity of the link, known as the 'sync speed'.

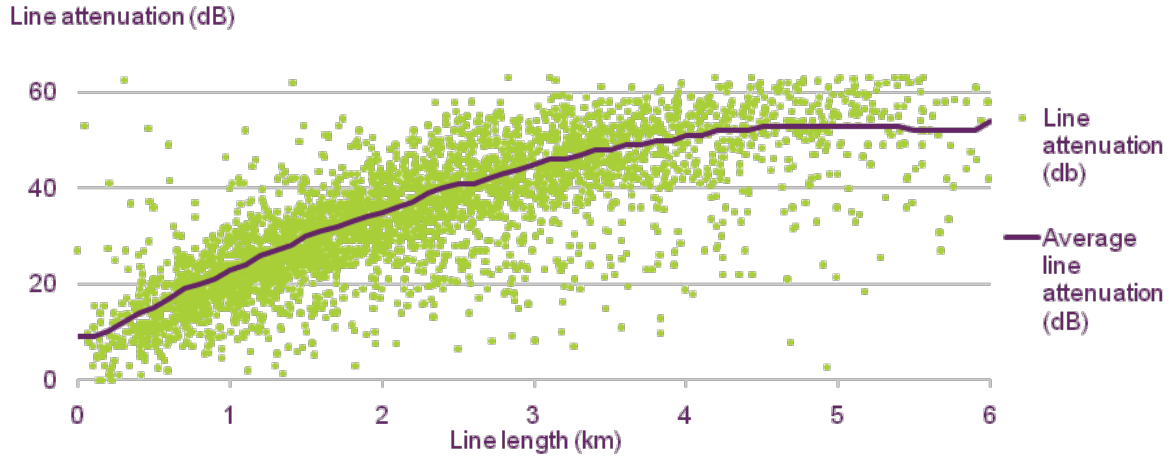
10.13 Sync speeds represent the upper ceiling of the speeds achievable on a line. Actual maximum speeds experienced by the end-user will be lower because some capacity is reserved for protocol overheads. However, sync speeds do provide a useful metric for comparing broadband speeds achievable under different conditions, such as geography, technology and line quality.

10.14 The remainder of this section summarises our initial analysis of operator data. We expect to undertake further analysis over the coming months on how sync speeds vary in different parts of the UK.

The relationship between line length, attenuation and sync speed

10.15 After technology choice (i.e. ADSL1, ADSL2+ or VDSL), signal attenuation is the key determinant of sync speeds. Whilse not a perfect correlation, line length is a good proxy for line attenuation. However, even for lines of the same length, there may be variations in attenuation due to other factors, such as variations in the gauge of the telephone wire, the material from which is it made and the quality of joints. Each point in Figure 10.1 shows the attenuation of a random sample of UK lines using ADSL2+ plotted against an estimate of the line length provided by Openreach. The solid line represents the average attenuation of lines of the same length. It can be seen that although the relationship between average attenuation and line length is relatively predictable, there are large variations in the attenuation of individual lines around the average, due to the other factors that affect attenuation.

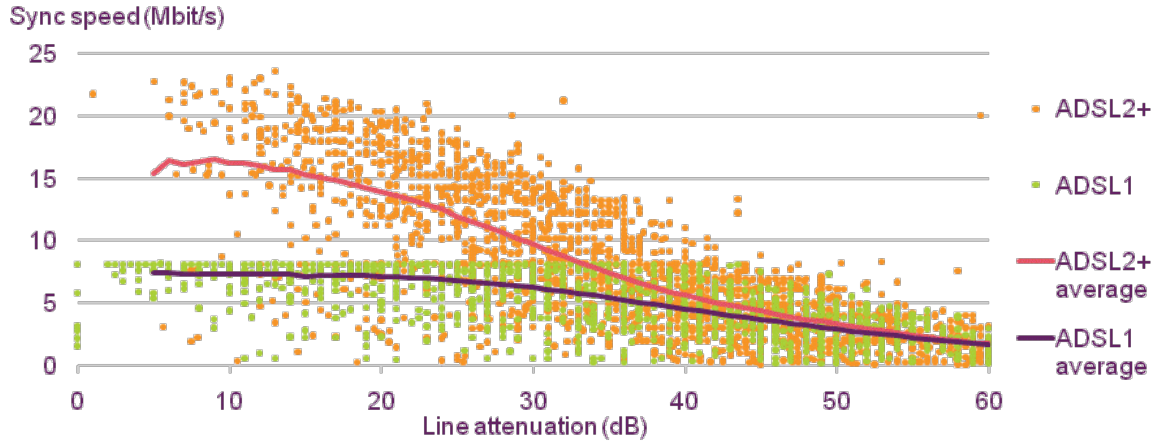
Figure 10.1 ADSL2+ line attenuation by line length



Source: Ofcom / operator data

10.16 Figure 10.2 shows how sync speeds vary with line attenuation for ADSL1 and ADSL2+ technologies. The solid line represents the average sync speed of lines with the same attenuation, while the individual points represent a random sample of individual lines. It can be seen that although there is a relatively close correlation between sync speed and line attenuation, there is a spread of individual lines around the average. In part this will be due to different levels of electrical noise.

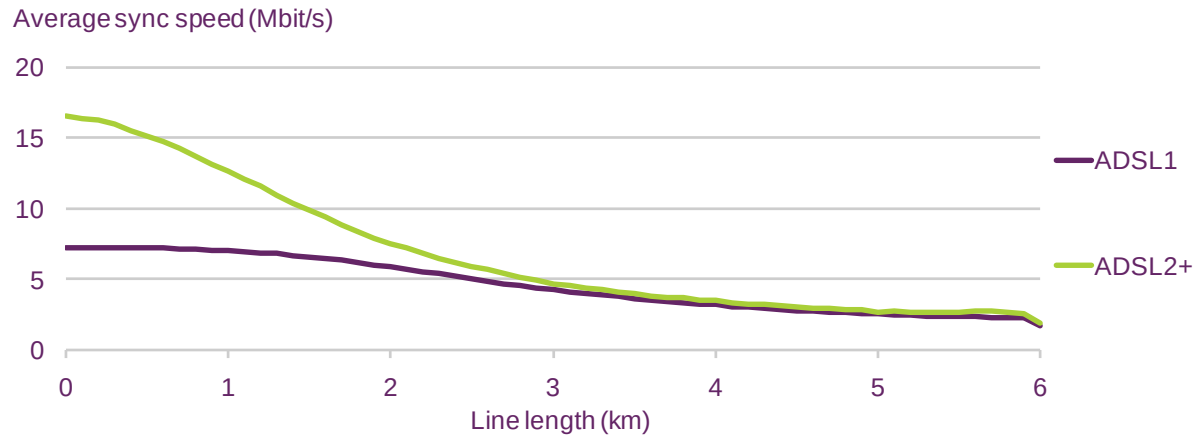
Figure 10.2 Sync speeds, by line attenuation



Source: Ofcom / operator data

10.17 Figure 10.3 represents an aggregation of the data shown in Figures 10.1 and 10.2 for ADSL1 and ADSL2+ technologies. It shows that for lines over 3km there is, on average, only a marginal benefit in using ADSL2+ technologies instead of ADSL1. As above, there will be a wide range of sync speeds for a given line length due to the various factors that affect the achievable speed.

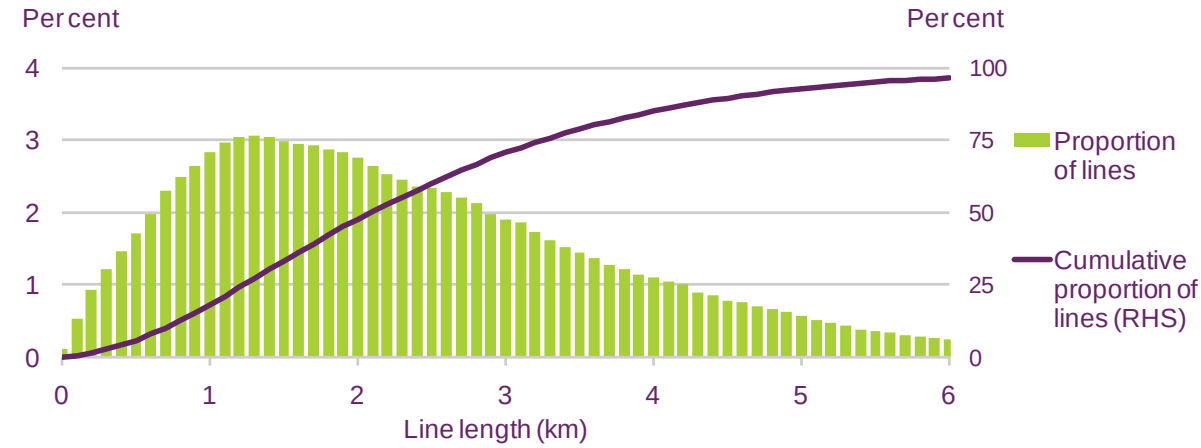
Figure 10.3 Average line sync speeds by length of line



Source: Ofcom / operator data

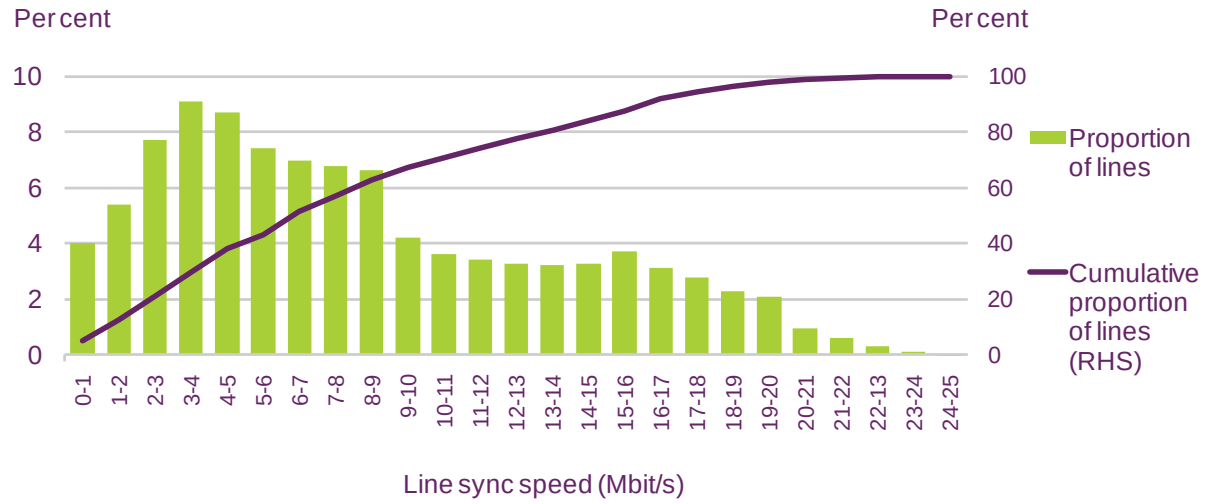
10.18 The distribution of sync speeds achieved across the UK is clearly dependent on the distribution of line lengths (and the technology in use).For example, Figure 10.4 shows the distribution of line lengths for existing 'up to' 20Mbit/s and 24Mbit/s connections and Figure 10.5 shows the resulting distribution of sync speeds.

Figure 10.4 Distribution of line lengths for active ADSL2+ connections



Source: Ofcom / operator data

Figure 10.5 Distribution of sync speeds for ADSL2+ connections



Source: Ofcom / operator data

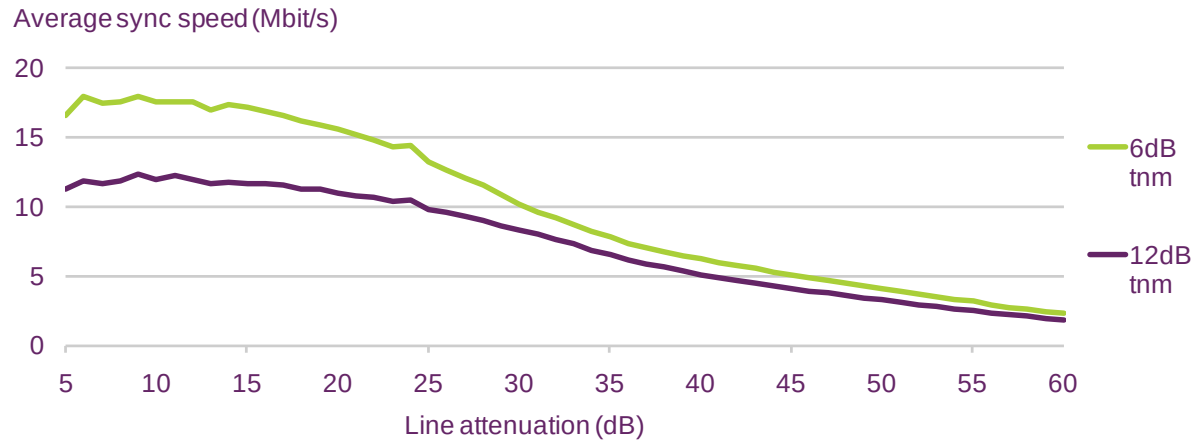
10.19 The average sync speed of these 20Mbit/s and 24Mbit/s packages was 7.9Mbit/s. This is 1.2Mbit/s more than the average maximum speeds measured during our consumer panel research for the same packages. This difference, in part, reflects the 'raw' capacity that sync speeds represent rather than the actual maximum speeds that consumers experience, after protocol overheads have been removed.

Electrical noise and sync speed

10.20 As outlined previously, the sync speeds of lines of the same attenuation may vary due to differing levels of electrical noise. During the synchronisation process the operator will set a 'target noise margin' and the equipment will adjust the sync speed to achieve this, potentially loading less data onto each carrier to improve the margin between the signal and the noise. Figure 10.6 below shows how sync speeds vary with target noise margin for an ISP which operates some lines with a target noise margin of 6dB and some at 12dB.

10.21 It can be seen that lower noise margins allow higher synchronisation speeds. However, these lines will be more susceptible to increases in electrical noise and, in some cases, may therefore be less stable. ISPs will typically monitor connections when they are first installed to assess how electrical noise varies over time and choose a target noise margin that strikes a balance between speed and stability.

Figure 10.6 Average sync speed and attenuation for different target noise margins



Source: Ofcom / operator data

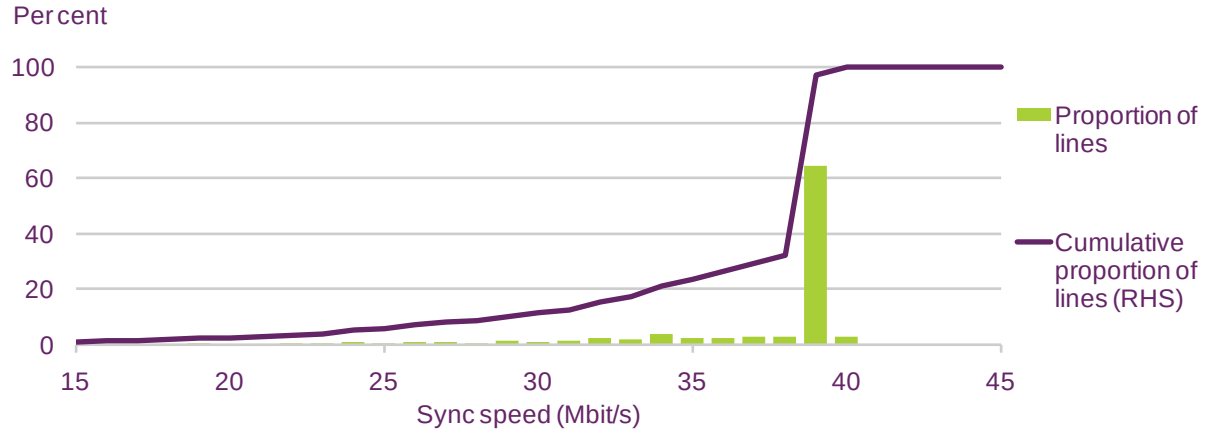
VDSL performance

10.22 Over the last year Openreach, the part of BT Group that operates the copper access network, has been deploying VDSL technology to cabinets across the UK. We estimate that around 15% of UK homes now have the option to buy a broadband package using VDSL technology.

10.23 When VDSL technology is deployed in street cabinets it is connected back to the local exchange using fibre optic cables. Known as fibre-to-the-cabinet (FTTC), this network architecture effectively reduces the length of copper to the home. The shorter line lengths, combined with the use of a greater number of data carriers, allows VDSL FTTC deployments to offer higher speeds than ADSL2+. For example, the current *Infinity* package from BT offers speeds of 'up to' 40Mbit/s downstream and 'up to' 10Mbit/s upstream.

10.24 We have analysed data associated with a large sample of FTTC lines operated by Openreach. Figure 10.7 shows the distribution of lines by downstream sync speed. It shows that approximately 80% had downstream sync speeds of over 35Mbit/s, with an average sync speed being 37Mbit/s.

Figure 10.7 Distribution of VDSL sync speeds

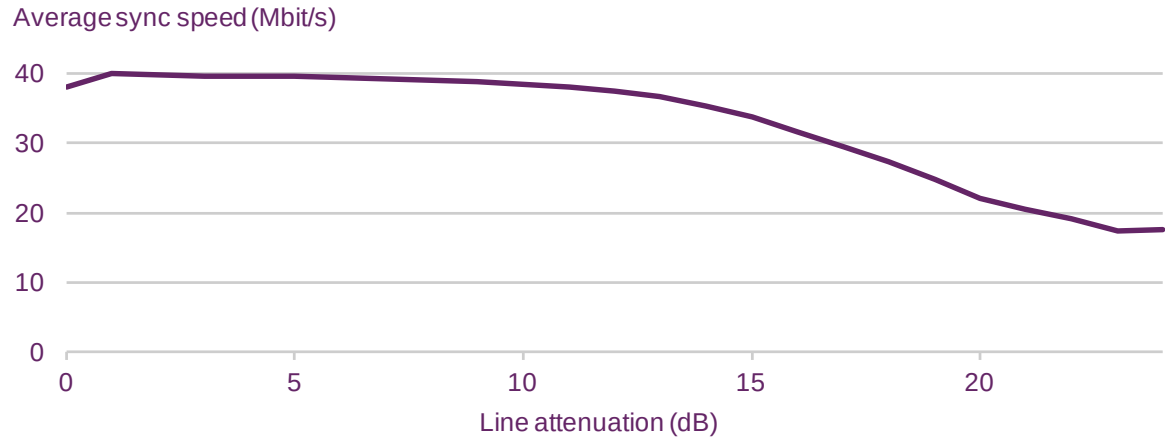


Source: Ofcom / operator data

10.25 The average maximum speed of BT's Infinity customers on our consumer panel was 34.6Mbit/s, 2.4Mbit/s lower than the average sync speed. The difference can, in part, be explained by the difference in the raw capacity that sync speeds represent and the actual maximum speeds available to the end-user once communications protocol overheads have been removed.

10.26 As with the other xDSL technologies, sync speeds for VDSL reduce with increased line length - i.e. the distance from the street cabinet to the home. To illustrate the point, Figure 10.8 shows how average sync speeds reduce with increasing line attenuation. As Openreach deploys FTTC to a larger number of cabinets across the UK it is possible that the average speeds achieved will change in line with the changing distribution of cabinet-to-home line lengths.

Figure 10.8 Average sync speed by line attenuation (cabinet to household)



Source: Ofcom / operator data

Variations by geography & rurality

10.27 Given the variation of sync speeds with technology and line length, it is clear that average speeds achieved in different parts of the UK will be influenced by line lengths and the mix of technologies in use.

10.28 We intend to undertake further analysis of operator data over the coming months to better understand regional variations in broadband performance. We expect to publish the results of this analysis in future reports.

Section 11

Conclusion and next steps

Implications for consumers

11.1 This research report is a representative snapshot of broadband performance of the ISP packages included in the research in November/December 2010. The broadband market is changing rapidly as operators are continuing to invest in their networks in order to make faster broadband available. Hence the results set out in this report will not necessarily reflect the future performance of networks and providers.

11.2 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 (sections 7 and 8). 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 require faster speeds.

11.3 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.

11.4 The research data, and the evidence we have considered on access line speeds (see paragraphs 4.19 to 4.22), show that consumers are currently getting a very wide variety of access line and 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.[51]

Implications for ISPs

11.5 The research has again given us valuable insights 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

[51] http://stakeholders.ofcom.org.uk/market-data-research/telecoms-research/broadband-speeds/main/

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. Signatory ISPs are in the process of implementing the new Code – all have committed to complying with the new Code by 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.

- **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 superfast broadband services, which increasing numbers of consumers may want to use in the future.

Ofcom's view on the advertising of broadband

11.6 As our research highlights the gap between actual and advertised 'up to' broadband speeds, we believe that a change in the guidelines around advertising is necessary in order ensure that consumers are not misled and can effectively compare the services available to them better, and to promote speed-based competition between providers.

11.7 It is our view that when speeds are used in broadband advertising they should reflect the actual speeds that consumers receive. For example, we do not believe that is it appropriate or useful to consumers that most ADSL broadband is now advertised as offering speeds of 'up to' 20Mbit/s or 24Mbit/s, when our research finds that these speeds are rarely delivered, and actual average speeds are around 6Mbit/s.

11.8 The Advertising Standards Authority (the ASA) has responsibility for broadband advertising and in May 2010 it asked the Committee for Advertising Practice (CAP) and the Broadcast Committee for Advertising Practice (BCAP) to conduct a separate review of the advice provided to ISPs on advertising practices. We have contributed to this review, which includes a public consultation into the use of speed claims in advertising. This consultation closed on 25 February 2011, and we have published our response to the consultation alongside this research report. In summary, we make the following recommendations:

- that if speed is used in advertising it must include a 'Typical Speed Range' (TSR), which should be based on average actual speeds that the 25th to 75th percentile of customers receive (i.e. the inter-quartile range);

- that this TSR must have at least equal prominence to any ‘up to’ claims made;
- that if an ‘up to’ speed is used it must represent the actual speed that a materially significant proportion of customers are capable of receiving; and
- that any TSR or ‘up to’ speed used must be based on statistically robust analysis of connection data, with the data and methodology available for public scrutiny.

Next steps

11.9 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.

11.10 With Ofcom research finding that 17% of households took mobile broadband in Q4 2010, and around a third of these had it as their sole internet connection, it is important that similar research is done on mobile broadband performance. We have commissioned separate research into the performance of mobile broadband and plan to publish the results in spring 2011.

11.11 We expect the ASA’s Committee for Advertising Practice (CAP) and Broadcast Committee for Advertising Practice (BCAP) to announce their conclusions on the use of speed in broadband advertising in Q2 2011. We will continue to engage with them on this issue, and will work with them and industry and consumer stakeholders, as appropriate, in any substantiation issues related to making claims about broadband performance.

11.12 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 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.

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).

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).

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 methodology

Overview

The technical methodology was supplied by SamKnows Ltd, Ofcom's technical partner in this research project.

The project uses hardware units installed in participants' homes to perform the tests. The chosen hardware is the Linksys WRT160NL router (although it should be noted that the device operates in a bridging mode, rather than routing). 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.

A customised OpenWRT firmware image has been developed and 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.

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*.

Speed tests

The project uses a wide variety of speed tests in order to monitor performance under different conditions.

For single-thread HTTP download, units download a 3MB file. The relatively small size of this file is compensated for by having a 100KB lead-in download/upload (which is dropped from the actual test results). This lead-in enables the TCP window to reach a sufficient size before the real transfer begins. The real transfer is then performed over the same HTTP connection (through the use of HTTP Keep-Alive to ensure the connection remains open).

For multi-thread HTTP downloads, all units download 3 x 2MB files using separate TCP sessions (in parallel). As with the single-thread tests, an initial lead-in period is used to ensure TCP window sizes are increased before measurements are made.

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.

Single-thread download tests were run once every hour for the first four weeks of testing and upload tests every 6 hours (at random intervals within the testing window). From mid-November, 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.

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

Two types of web page tests were used. The first downloaded the HTML body from a popular web site on the internet. It did not download the associated media assets. The second test downloaded the HTML and media assets of a simple web page hosted on the Ofcom website. 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.

Annex 3

Statistical methodology

Sample size

A panel of UK broadband users was drawn from a pool of 6,832 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.

Additional recruitment was undertaken between August and October 2010 to replace respondents who had left the panel, to enable analysis of super-fast broadband packages (such as BT Infinity and Virgin Media 50), to improve sample sizes for less represented ISPs and to improve the overall quality of the panel in terms of minimising weighting required. An additional 555 boxes were sent out.

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 59% of the sample contributing less than 0.5 a response towards the UK average; this is an increase since May 2010 as many ADSL operators have migrated their customer bases from 'up to' 8/10Mbit/s to 'up to' 20/24Mbit/s services. The current active participant 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 (4% of the total in November 2010, and a reduction from 8% since May 2010). In our first round of research between October 2008 and April 2009, we found that the speeds delivered by 'up to' 2Mbit/s and less connections were consistent over time and between providers. In this report we have used data from 'up to' 2Mbit/s and less connections collected in April 2009 as representative of the performance of these packages, and have weighted them in accordingly when we present overall UK performance in this report. This result was also compared to the speeds achieved by the remaining 29 respondents in the panel who use these packages.

Prior to despatch of the measurement boxes, volunteers were pre-screened and preliminary speed measurements and checks on IP addresses were undertaken, in order to reduce the impact of respondent misconceptions on the sampling.

In total 2,561 measurement units were despatched, and 1,710 of these were connected by participants between 1st November and 15th December 2010. Of these, 1,581 supplied data to the UK average, and 1,193 to the named ISP package comparisons.

Figure 1 Panellist numbers

Sample set	Number
Total number of boxes dispatched	**2,561**
Total number of boxes connected	**1,710**
Excluded because of missing data, (i.e. measurements, packages, distance)	7
Excluded 'up to' 2Mbit/s	29
Other Exclusions to improve UK sample weighting (i.e. distance, market classification, region, ISP)	81
Total participants included in UK Analysis	**1581**
Total participants included in ISP Package Analysis	**1193**

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 participants 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 as, for a small proportion of respondents, the occasional test result was far in excess of what was achievable of 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 single-thread download speed tests in May was 673, from a theoretical maximum of 744 per respondent (i.e. if all panellists had their box connected on 1st May and all scheduled tests were run - tests were not run when the monitoring unit detected concurrent use of the bandwidth).

Average 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 are weighted to be representive 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.

The 'up to' 8Mbit/s services from AOL Broadband and from O2 8 did not achieve the minimum threshold of 50 against the specific criteria required and are removed from the ISP-specific findings. The 'up to' 8Mbit/s services from Orange (55) and from Plusnet (64) achieved the minimum threshold of 50 against the specific criteria required and are included in these findings with a warning regarding small sample size.

Sample panels

The results and analysis of the 1,710 panellists' measurement results were divided into two separate datasets, each weighted to targets.

- **National Panel** (over 'up to' 2Mbit/s packages): 1,581 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**: 1,193 panellists. A subset of the National Panel consisting of panellists from Geographic Markets 2 & 3 only, panellists from LLU operators (AOL Broadband, 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 a 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 and 10Mbit/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 lenth. We assessed several mthods of accomadating this ssue 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 condfidence 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 distanceband 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 upom all non-cable 20 Mbit/s packages, 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 +/- 0.5 M/bits. 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 datafile, 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 a ADSL connection who were connected to an ADSL2+ enabled exchange were considered for the 'up to' 20Mbit/s and 24Mbit/s package allocation.

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

A characteristic of 02/Be's customer base on its 20/24Mbit/s package is that line lengths are typically shorter than for other ISPs. This is the result of a historic policy of only selling higher speed packages to customers whose lines can support speeds higher than the 'up to' 8Mbit/s offered by its lower speed package. We have normalised the O2/Be data to adjust for this so that we can compare ISPs on a like-for-like basis. However, O2/Be results should be treated with some caution as normalisation may not be as effective for O2/Be due to the lower incidence of panellists with longer than average line lengths.

Intra ISP Package weights

Three ISP packages are impacted by the occurrence of statistical difference within the package assignment.

- Orange is in a phase of transition to no longer supplying on-net services to its subscribers, and the mix of on/off-net in the sample potentially affects the average results (performance of on-net LLU packages are on average higher than non–LLU services). The Orange 'up to' 8Mbit/s package (the only Orange package which we report on) was therefore weighted to the current operator split between on/off net in and distance from exchange.

- O2 and Be are reported combined as a single ISP package entity, but the product offering are considerably different. The O2/Be 'up to' 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 62.3%. 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	874	55%
0.5 to 1	419	27%
1 to 1.5	133	8%
1.5 to 2	99	6%
2 to 3	47	3%

Source: Ofcom

Overall, against the entire weight frame, the ISP Package Panel achieved a weighting efficiency of 88%. 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	55	5%
0.5 to 1	632	53%
1 to 1.5	467	39%
1.5 to 2	24	2%
2+	15	1%

Source: Ofcom

Figure 5 Weighting efficiency by ISP package

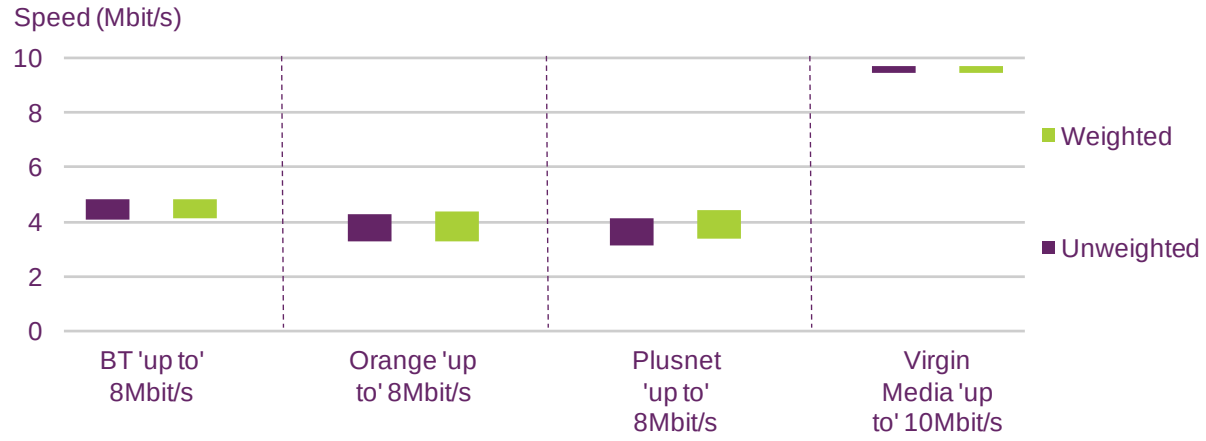
ISP package	Weighting efficiency
BT 'up to' 8Mbit/s	95%
Orange 'up to' 8Mbit/s	80%
Plusnet 'up to' 8Mbit/s	90%
Virgin Media 'up to' 10Mbit/s	100%
BT 'up to' 20Mbit/s	90%
O2/Be 'up to' 20/24Mbit/s	79%
Sky 'up to' 20Mbit/s	92%
TalkTalk 'up to' 24Mbit/s	85%
Virgin Media 'up to' 20Mbit/s	100%
BT 'up to' 40Mbit/s	95%
Virgin Media 'up to' 50Mbit/s	100%

Source: Ofcom

Weighted and unweighted measurement data

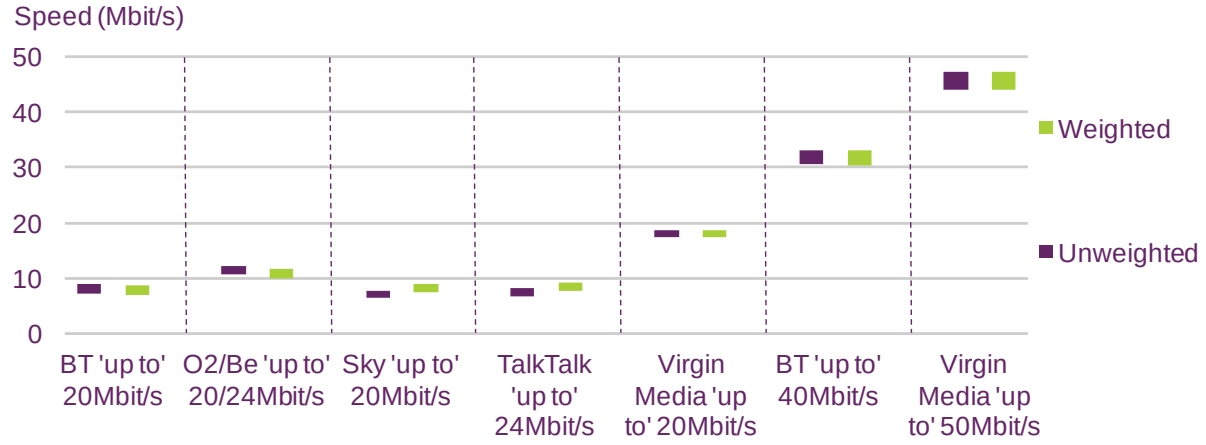
The effect of the combined overall ISP Panel weighting on the comparative relative ISP Package perform, is shown in the following tables

Figure 6 Average download speed for 'up to' 8Mbit/s and 10Mbit/s connections by ISP, 24 hours, weighted and unweighted figures, November/December 2010



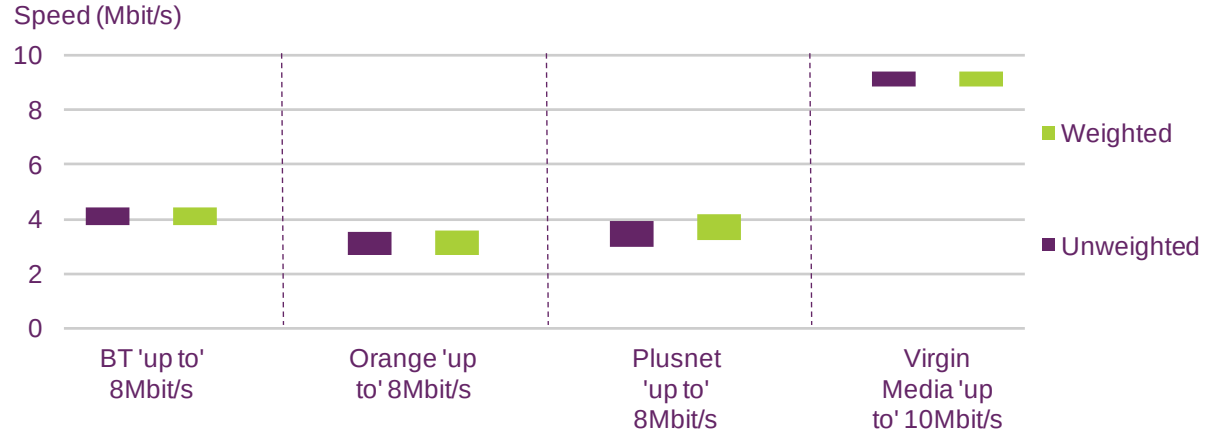
Source: SamKnows measurement data for all panel members with a connection in November/December 2010
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been 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 above connections by ISP, 24 hours, weighted and unweighted figures, November/December 2010



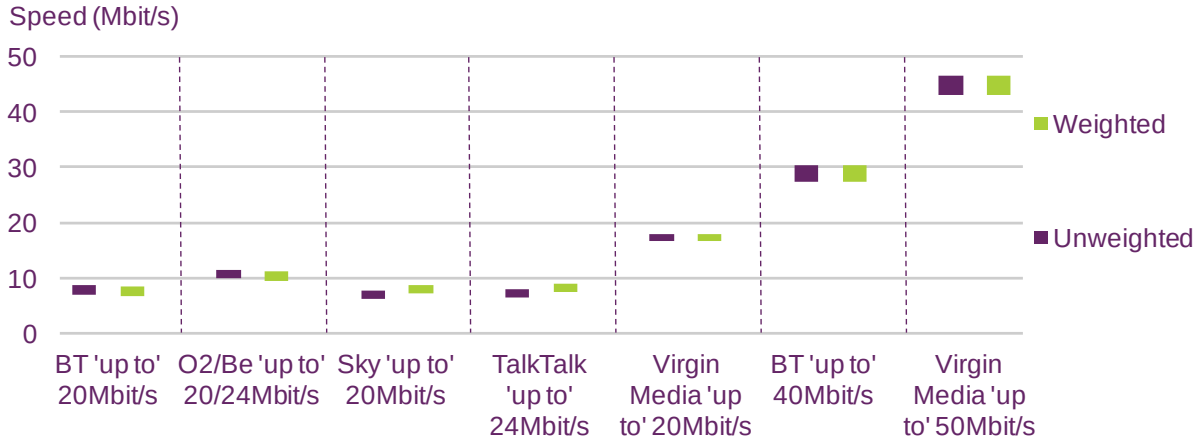
Source: SamKnows measurement data for all panel members with a connection in November/December 2010
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been 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 Peak download throughput speed for 'up to' 8Mbit/s and 10Mbit/s connections by ISP, 24 hours, weighted and unweighted figures, November/December 2010



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
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 9 Peak download throughput speed for 'up to' 20Mbit/s and above connections by ISP, 24 hours, weighted and unweighted figures, November/December 2010



Source: SamKnows measurement data for all panel members with a connection in November/December 2010
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/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

Significance testing

1. Overview

The main research report includes significance testing of the download speeds performance of different ISP packages to a 95% level of confidence. In order to provide further clarity on differences between the performance of ISP packages, in this annex we also provided differences to a 99% level of confidence (i.e. differences are detailed when they pass a 1% confidence test).

In this annex we also include significance testing for the performance of ISP packages against other performance measures: upload speeds, web browsing, latency, packet loss, DNS resolution time and jitter.

2. Significant differences in speeds between ISP packages to a 99% level of confidence

Figure 1 Significant differences to a 99% level of confidence between average speeds on 'up to' 8Mbit/s and 10Mbit/s packages, 24 hours, November/December 2010

ISP package	Is slower than...	Is faster than...
BT 'up to' 8Mbit/s	Virgin Media	
Orange 'up to' 8Mbit/s	Virgin Media	
Plusnet 'up to' 8Mbit/s*	Virgin Media	
Virgin Media 'up to' 10Mbit/s		BT, Orange and Plusnet

Source: Ofcom
**Caution: small sample size*
Note: Significant differences to a 95% level of confidence are provided in the main report

Figure 2 Significant differences to a 99% level of confidence between average speeds on 'up to' 20Mbit/s and above packages, 24 hours, November/December 2010

ISP package	Is slower than...	Is faster than...
Comparison of 'up to' 20/24Mbit/s packages		
BT 'up to' 20Mbit/s	O2/Be and Virgin Media	
O2/Be 'up to' 20/24Mbit/s	Virgin Media	BT and Sky
Sky 'up to' 20Mbit/s	O2/Be and Virgin Media	
TalkTalk 'up to' 24Mbit/s	Virgin Media	
Virgin Media 'up to' 20Mbit/s		BT, O2/Be, Sky and TalkTalk
Comparison of 'up to' 40/50Mbit/s packages		
BT 'up to' 40Mbit/s	Virgin Media	
Virgin Media 'up to' 50Mbit/s		BT

Source: Ofcom
Note: Significant differences to a 95% level of confidence are provided in the main report

Figure 3 Significant differences to a 99% level of confidence between average speeds on 'up to' 8Mbit/s and 10Mbit/s packages, 8 to 10pm weekdays, November/December 2010

ISP package	Is slower than...	Is faster than...
BT 'up to' 8Mbit/s	Virgin Media	
Orange 'up to' 8Mbit/s*	Virgin Media	
Plusnet 'up to' 8Mbit/s	Virgin Media	
Virgin Media 'up to' 10Mbit/s		BT, Orange and Plusnet

Source: Ofcom
**Caution: small sample size*
Note: Significant differences to a 95% level of confidence are provided in the main report

Figure 4 Significant differences to a 99% level of confidence between average speeds on 'up to' 20Mbit/s and above packages, 8 to 10pm weekdays, November/December 2010

ISP package	Is slower than...	Is faster than...
Comparison of 'up to' 20/24Mbit/s packages		
BT 'up to' 20Mbit/s	O2/Be and Virgin Media	
O2/Be 'up to' 20/24Mbit/s	Virgin Media	BT and Sky
Sky 'up to' 20Mbit/s	O2/Be and Virgin Media	
TalkTalk 'up to' 24Mbit/s	Virgin Media	
Virgin Media 'up to' 20Mbit/s		BT, O2/Be, Sky and TalkTalk
Comparison of 'up to' 40/50Mbit/s packages		
BT 'up to' 40Mbit/s	Virgin Media	
Virgin Media 'up to' 50Mbit/s		BT

Source: Ofcom
Note: Significant differences to a 95% level of confidence are provided in the main report

Figure 5 Significant differences to a 99% level of confidence between average, peak time and maximum upload speeds on 'up to' 8Mbit/s and 10Mbit/s packages, November/December 2010

	24 hours		8-10pm weekday		Maximum	
ISP package	Is slower than...	Is faster than...	Is slower than...	Is faster than...	Is slower than...	Is faster than...
BT 'up to' 8Mbit/s*	Virgin Media		Virgin Media		Virgin Media	
Orange 'up to' 8Mbit/s*						
Plusnet 'up to' 8Mbit/s*	Virgin Media				Virgin Media	
Virgin Media 'up to' 10Mbit/s*		BT and Plusnet		BT		BT and Plusnet

Source: Ofcom
**Caution: small sample size*
Note: Significant differences to a 95% level of confidence are provided in the main report

Figure 6 Significant differences to a 99% level of confidence between average, peak time and maximum upload speeds on 'up to' 20Mbit/s and above packages, November/December 2010

	24 hours		8-10pm weekday		Maximum	
ISP package	**Is slower than...**	**Is faster than...**	**Is slower than...**	**Is faster than...**	**Is slower than...**	**Is faster than...**
Comparison of 'up to' 20/24Mbit/s packages						
BT 'up to' 20Mbit/s*	O2/Be		O2/Be		O2/Be	
O2/Be 'up to' 20/24Mbit/s*		BT, Sky and TalkTalk		BT, Sky and TalkTalk		BT, Sky and TalkTalk
Sky 'up to' 20Mbit/s*	O2/Be and Virgin Media		O2/Be		O2/Be	
TalkTalk 'up to' 24Mbit/s*	O2/Be		O2/Be		O2/Be	
Virgin Media 'up to' 20Mbit/s*		Sky				
Comparison of 'up to' 40/50Mbit/s packages						
BT 'up to' 40Mbit/s*		Virgin Media		Virgin Media		Virgin Media
Virgin Media 'up to' 50Mbit/s*	BT		BT		BT	

Source: Ofcom
Note: Significant differences to a 95% level of confidence are provided in the main report

3. Significant differences in other performance measures between ISP packages to a 95% level of confidence

Figure 7 Significant differences to a 95% level of confidence between average and peak time to load web pages by ISP package for 'up to' 8Mbit/s and 10Mbit/s ISP packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	**Is slower than...**	**Is faster than...**	**Is slower than...**	**Is faster than...**
BT 'up to' 8Mbit/s	Virgin Media		Virgin Media	
Orange 'up to' 8Mbit/s*	Virgin Media		Virgin Media	
Plusnet 'up to' 8Mbit/s	Virgin Media		Virgin Media	
Virgin Media 'up to' 10Mbit/s		BT, Orange and Plusnet		BT, Orange and Plusnet

Source: Ofcom
**Caution: small sample size*

Figure 8 Significant differences to a 95% level of confidence between average and peak time to load web pages by ISP package for 'up to' 20Mbit/s and above ISP packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	**Is slower than...**	**Is faster than...**	**Is slower than...**	**Is faster than...**
Comparison of 'up to' 20/24Mbit/s packages				
BT 'up to' 20Mbit/s	Virgin Media		O2/Be and Virgin Media	
O2/Be 'up to' 20/24Mbit/s		Sky and TalkTalk		BT, Sky and TalkTalk
Sky 'up to' 20Mbit/s	O2/Be and Virgin Media	TalkTalk	O2/Be and Virgin Media	TalkTalk
TalkTalk 'up to' 24Mbit/s	O2/Be, Sky and Virgin Media		O2/Be, Sky and Virgin Media	
Virgin Media 'up to' 20Mbit/s		BT, Sky and TalkTalk		BT, Sky and TalkTalk
Comparison of 'up to' 40/50Mbit/s packages				
BT 'up to' 40Mbit/s	Virgin Media		Virgin Media	
Virgin Media 'up to' 50Mbit/s		BT		BT

Source: Ofcom

Figure 9 Significant differences to a 95% level of confidence between average and peak time latency by ISP package for 'up to' 8Mbit/s and 10Mbit/s ISP packages, average and peak times, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is worse than...	Is better than...	Is worse than...	Is better than...
BT 'up to' 8Mbit/s	Virgin Media	Orange	Virgin Media	
Orange 'up to' 8Mbit/s	BT, Plusnet and Virgin Media		Virgin Media	
Plusnet 'up to' 8Mbit/s	Virgin Media	Orange		
Virgin Media 'up to' 10Mbit/s		BT, Orange and Plusnet		BT and Orange

Source: Ofcom

Figure 10 Significant differences to a 95% level of confidence between average and peak time latency by ISP package for 'up to' 20Mbit/s and above ISP packages, average and peak times, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is worse than...	Is better than...	Is worse than...	Is better than...
Comparison of 'up to' 20/24Mbit/s packages				
BT 'up to' 20Mbit/s	O2/Be	Sky and TalkTalk	O2/Be	Sky and TalkTalk
O2/Be 'up to' 20/24Mbit/s		BT, Sky and TalkTalk		BT, Sky, TalkTalk and Virgin Media
Sky 'up to' 20Mbit/s	BT, O2/Be and Virgin Media		BT, O2/Be and Virgin Media	
TalkTalk 'up to' 24Mbit/s	BT, O2/Be and Virgin Media		BT and O2/Be	
Virgin Media 'up to' 20Mbit/s		Sky and TalkTalk	O2/Be	Sky
Comparison of 'up to' 40/50Mbit/s packages				
BT 'up to' 40Mbit/s				
Virgin Media 'up to' 50Mbit/s				

Source: Ofcom

Figure 11 Significant differences to a 95% level of confidence between average packet loss by ISP package for 'up to' 8Mbit/s and 10Mbit/s connections, November/December 2010

	24 hours		8-10pm weekday	
ISP package	**Is worse than...**	**Is better than...**	**Is worse than...**	**Is better than...**
BT 'up to' 8Mbit/s				Orange
Orange 'up to' 8Mbit/s			BT and Plusnet	
Plusnet 'up to' 8Mbit/s				Orange
Virgin Media 'up to' 10Mbit/s				

Source: Ofcom
Note: No significant differences over the 24-hour period

Figure 12 Significant differences to a 95% level of confidence between average packet loss by ISP package for 'up to' 20Mbit/s and above connections, November/December 2010

	24 hours		8-10pm weekday	
ISP package	**Is worse than...**	**Is better than...**	**Is worse than...**	**Is better than...**
Comparison of 'up to' 20/24Mbit/s packages				
BT 'up to' 20Mbit/s				TalkTalk and Virgin Media
O2/Be 'up to' 20/24Mbit/s				
Sky 'up to' 20Mbit/s		TalkTalk		TalkTalk and Virgin Media
TalkTalk 'up to' 24Mbit/s	Sky		BT and Sky	
Virgin Media 'up to' 20Mbit/s			BT and Sky	
Comparison of 'up to' 40/50Mbit/s packages				
BT 'up to' 40Mbit/s	Virgin Media			
Virgin Media 'up to' 50Mbit/s		BT		

Source: Ofcom

Figure 13 Significant differences to a 95% level of confidence between DNS resolution time by ISP package for 'up to' 8Mbit/s and 10Mbit/s packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is slower than...	Is faster than...	Is slower than...	Is faster than...
BT 'up to' 8Mbit/s	Virgin Media	Orange	Virgin Media	Orange
Orange 'up to' 8Mbit/s	BT, Plusnet and Virgin Media		BT, Plusnet and Virgin Media	
Plusnet 'up to' 8Mbit/s	Virgin Media	Orange	Virgin Media	Orange
Virgin Media 'up to' 10Mbit/s		BT, Orange and Plusnet		BT, Orange and Plusnet

Source: Ofcom

Figure 14 Significant differences to a 95% level of confidence between DNS resolution time by ISP package for 'up to' 20Mbit/s and above packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is slower than...	Is faster than...	Is slower than...	Is faster than...
Comparison of 'up to' 20/24Mbit/s packages				
BT 'up to' 20Mbit/s	O2/Be and Virgin Media	TalkTalk and Sky	Virgin Media	TalkTalk and Sky
O2/Be 'up to' 20/24Mbit/s	Virgin Media	BT, TalkTalk and Sky		TalkTalk and Sky
Sky 'up to' 20Mbit/s	BT, O2/Be, TalkTalk and Virgin Media		BT, O2/Be, TalkTalk and Virgin Media	
TalkTalk 'up to' 24Mbit/s	BT, O2/Be and Virgin Media	Sky	BT, O2/Be and Virgin Media	Sky
Virgin Media 'up to' 20Mbit/s		BT, O2/Be, TalkTalk and Sky		BT, TalkTalk and Sky
Comparison of 'up to' 40/50Mbit/s packages				
BT 'up to' 40Mbit/s				
Virgin Media 'up to' 50Mbit/s				

Source: Ofcom

Figure 15 Significant differences to a 95% level of confidence between DNS failure rates by ISP package for 'up to' 8Mbit/s and 10Mbit/s packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is worse than...	Is better than...	Is worse than...	Is better than...
BT 'up to' 8Mbit/s	Plusnet and Virgin Media			
Orange 'up to' 8Mbit/s				
Plusnet 'up to' 8Mbit/s		BT		Virgin Media
Virgin Media 'up to' 10Mbit/s		BT	Plusnet	

Source: Ofcom

Figure 16 Significant differences to a 95% level of confidence between DNS failure rates by ISP package for 'up to' 20Mbit/s and above packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is worse than...	Is better than...	Is worse than...	Is better than...
Comparison of 'up to' 20/24Mbit/s packages				
BT 'up to' 20Mbit/s	TalkTalk and Virgin Media			O2/Be
O2/Be 'up to' 20/24Mbit/s	TalkTalk and Virgin Media		BT, TalkTalk and Virgin Media	
Sky 'up to' 20Mbit/s				
TalkTalk 'up to' 24Mbit/s		BT and O2/Be		O2/Be
Virgin Media 'up to' 20Mbit/s		BT and O2/Be		O2/Be
Comparison of 'up to' 40/50Mbit/s packages				
BT 'up to' 40Mbit/s	Virgin Media			
Virgin Media 'up to' 50Mbit/s		BT		

Source: Ofcom

Figure 17 Significant differences to a 95% level of confidence between average and peak time upstream jitter by ISP package for 'up to' 8Mbit/s and 10Mbit/s packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is worse than...	Is better than...	Is worse than...	Is better than...
BT 'up to' 8Mbit/s		Virgin Media		Virgin Media
Orange 'up to' 8Mbit/s		Plusnet and Virgin Media		Plusnet and Virgin Media
Plusnet 'up to' 8Mbit/s	Orange	Virgin Media	Orange	Virgin Media
Virgin Media 'up to' 10Mbit/s	BT, Orange and Plusnet		BT, Orange and Plusnet	

Source: Ofcom

Figure 18 Significant differences to a 95% level of confidence between average and peak time upstream jitter by ISP package for 'up to' 20Mbit/s and above packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is worse than...	Is better than...	Is worse than...	Is better than...
Comparison of 'up to' 20/24Mbit/s packages				
BT 'up to' 20Mbit/s		Virgin Media		Virgin Media
O2/Be 'up to' 20/24Mbit/s		Sky, TalkTalk and Virgin Media		Sky and Virgin Media
Sky 'up to' 20Mbit/s	O2/Be	Virgin Media	O2/Be	Virgin Media
TalkTalk 'up to' 24Mbit/s	O2/Be	Virgin Media		Virgin Media
Virgin Media 'up to' 20Mbit/s	BT, O2/Be, Sky and TalkTalk		BT, O2/Be, Sky and TalkTalk	
Comparison of 'up to' 40/50Mbit/s packages				
BT 'up to' 40Mbit/s		Virgin Media		Virgin Media
Virgin Media 'up to' 50Mbit/s	BT		BT	

Source: Ofcom

Figure 19 Significant differences to a 95% level of confidence between average and peak time downstream jitter by ISP package for 'up to' 8Mbit/s and 10Mbit/s packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is worse than...	Is better than...	Is worse than...	Is better than...
BT 'up to' 8Mbit/s		Orange		Plusnet and Virgin Media
Orange 'up to' 8Mbit/s	BT			
Plusnet 'up to' 8Mbit/s			BT	
Virgin Media 'up to' 10Mbit/s			BT	

Source: Ofcom

Figure 20 Significant differences to a 95% level of confidence between average and peak time downstream jitter by ISP package for 'up to' 20Mbit/s and above packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is worse than...	Is better than...	Is worse than...	Is better than...
Comparison of 'up to' 20/24Mbit/s packages				
BT 'up to' 20Mbit/s		Sky and TalkTalk	O2/Be	
O2/Be 'up to' 20/24Mbit/s		Sky and TalkTalk		BT, Sky, TalkTalk and Virgin Media
Sky 'up to' 20Mbit/s	BT, O2/Be and Virgin Media		O2/Be	
TalkTalk 'up to' 24Mbit/s	BT, O2/Be and Virgin Media		O2/Be	
Virgin Media 'up to' 20Mbit/s		Sky and TalkTalk	O2/Be	
Comparison of 'up to' 40/50Mbit/s packages				
BT 'up to' 40Mbit/s				
Virgin Media 'up to' 50Mbit/s				

Source: Ofcom
Note: No significant differences among the 'up to' 40Mbit/s and 50Mbit/s ISP packages

To a 99% level of confidence

Figure 21 Significant differences to a 99% level of confidence between average and peak time to load web pages by ISP package for 'up to' 8Mbit/s and 10Mbit/s ISP packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	**Is slower than...**	**Is faster than...**	**Is slower than...**	**Is faster than...**
BT 'up to' 8Mbit/s	Virgin Media		Virgin Media	Orange
Orange 'up to' 8Mbit/s*	Virgin Media		BT, Plusnet and Virgin Media	
Plusnet 'up to' 8Mbit/s	Virgin Media		Virgin Media	Orange
Virgin Media 'up to' 10Mbit/s		BT, Orange and Plusnet		BT, Orange and Plusnet

Source: Ofcom
**Caution: small sample size*

Figure 22 Significant differences to a 99% level of confidence between average and peak time to load web pages by ISP package for 'up to' 20Mbit/s and above ISP packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	**Is slower than...**	**Is faster than...**	**Is slower than...**	**Is faster than...**
Comparison of 'up to' 20/24Mbit/s packages				
BT 'up to' 20Mbit/s			Virgin Media	
O2/Be 'up to' 20/24Mbit/s		TalkTalk		TalkTalk
Sky 'up to' 20Mbit/s	Virgin Media			
TalkTalk 'up to' 24Mbit/s	O2/Be and Virgin Media		O2/Be and Virgin Media	
Virgin Media 'up to' 20Mbit/s		Sky and TalkTalk		BT and TalkTalk
Comparison of 'up to' 40/50Mbit/s packages				
BT 'up to' 40Mbit/s	Virgin Media			
Virgin Media 'up to' 50Mbit/s		BT		

Source: Ofcom

Figure 23 Significant differences to a 99% level of confidence between average and peak time latency by ISP package for 'up to' 8Mbit/s and 10Mbit/s ISP packages, average and peak times, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is worse than...	Is better than...	Is worse than...	Is better than...
BT 'up to' 8Mbit/s	Virgin Media			
Orange 'up to' 8Mbit/s	Virgin Media			
Plusnet 'up to' 8Mbit/s	Virgin Media			
Virgin Media 'up to' 10Mbit/s		BT, Orange and Plusnet		

Source: Ofcom

Figure 24 Significant differences to a 99% level of confidence between average and peak time latency by ISP package for 'up to' 20Mbit/s and above ISP packages, average and peak times, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is worse than...	Is better than...	Is worse than...	Is better than...
Comparison of 'up to' 20/24Mbit/s packages				
BT 'up to' 20Mbit/s	O2/Be			
O2/Be 'up to' 20/24Mbit/s		BT, Sky and TalkTalk		Sky and TalkTalk
Sky 'up to' 20Mbit/s	O2/Be and Virgin Media		O2/Be	
TalkTalk 'up to' 24Mbit/s	O2/Be		O2/Be	
Virgin Media 'up to' 20Mbit/s		Sky		
Comparison of 'up to' 40/50Mbit/s packages				
BT 'up to' 40Mbit/s				
Virgin Media 'up to' 50Mbit/s				

Source: Ofcom

Figure 25 Significant differences to a 99% level of confidence between average packet loss by ISP package for 'up to' 8Mbit/s and 10Mbit/s connections, November/December 2010

	24 hours		8-10pm weekday	
ISP package	**Is worse than...**	**Is better than...**	**Is worse than...**	**Is better than...**
BT 'up to' 8Mbit/s				Orange
Orange 'up to' 8Mbit/s			BT	
Plusnet 'up to' 8Mbit/s				
Virgin Media 'up to' 10Mbit/s				

Source: Ofcom
Note: No significant differences over the 24-hour period

Figure 26 Significant differences to a 99% level of confidence between average packet loss by ISP package for 'up to' 20Mbit/s and above connections, November/December 2010

	24 hours		8-10pm weekday	
ISP package	**Is worse than...**	**Is better than...**	**Is worse than...**	**Is better than...**
Comparison of 'up to' 20/24Mbit/s packages				
BT 'up to' 20Mbit/s				
O2/Be 'up to' 20/24Mbit/s				
Sky 'up to' 20Mbit/s		TalkTalk		TalkTalk
TalkTalk 'up to' 24Mbit/s	Sky		Sky	
Virgin Media 'up to' 20Mbit/s				
Comparison of 'up to' 40/50Mbit/s packages				
BT 'up to' 40Mbit/s				
Virgin Media 'up to' 50Mbit/s				

Source: Ofcom
Note: No significant differences among the 'up to' 40Mbit/s and 50Mbit/s ISP packages

Figure 27 Significant differences to a 99% level of confidence between DNS resolution time by ISP package for 'up to' 8Mbit/s and 10Mbit/s packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is slower than...	Is faster than...	Is slower than...	Is faster than...
BT 'up to' 8Mbit/s	Virgin Media	Orange	Virgin Media	Orange
Orange 'up to' 8Mbit/s	BT, Plusnet and Virgin Media		BT, Plusnet and Virgin Media	
Plusnet 'up to' 8Mbit/s	Virgin Media	Orange	Virgin Media	Orange
Virgin Media 'up to' 10Mbit/s		BT, Orange and Plusnet		BT, Orange and Plusnet

Source: Ofcom

Figure 28 Significant differences to a 99% level of confidence between DNS resolution time by ISP package for 'up to' 20Mbit/s and above packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is slower than...	Is faster than...	Is slower than...	Is faster than...
Comparison of 'up to' 20/24Mbit/s packages				
BT 'up to' 20Mbit/s	Virgin Media	Sky and TalkTalk	Virgin Media	Sky and TalkTalk
O2/Be 'up to' 20/24Mbit/s	Virgin Media	Sky and TalkTalk		Sky and TalkTalk
Sky 'up to' 20Mbit/s	BT, O2/Be, TalkTalk and Virgin Media		BT, O2/Be, TalkTalk and Virgin Media	
TalkTalk 'up to' 24Mbit/s	BT, O2/Be and Virgin Media	Sky	BT, O2/Be and Virgin Media	Sky
Virgin Media 'up to' 20Mbit/s		BT, O2/Be, Sky and TalkTalk		BT, Sky and TalkTalk
Comparison of 'up to' 40/50Mbit/s packages				
BT 'up to' 40Mbit/s				
Virgin Media 'up to' 50Mbit/s				

Source: Ofcom

Figure 29 Significant differences to a 99% level of confidence between DNS failure rates by ISP package for 'up to' 8Mbit/s and 10Mbit/s packages, November/December 2010

Source: Ofcom

	24 hours		8-10pm weekday	
ISP package	**Is worse than...**	**Is better than...**	**Is worse than...**	**Is better than...**
BT 'up to' 8Mbit/s	Plusnet and Virgin Media			
Orange 'up to' 8Mbit/s				
Plusnet 'up to' 8Mbit/s		BT		
Virgin Media 'up to' 10Mbit/s		BT		

Figure 30 Significant differences to a 99% level of confidence between DNS failure rates by ISP package for 'up to' 20Mbit/s and above packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	**Is worse than...**	**Is better than...**	**Is worse than...**	**Is better than...**
Comparison of 'up to' 20/24Mbit/s packages				
BT 'up to' 20Mbit/s	TalkTalk and Virgin Media			O2/Be
O2/Be 'up to' 20/24Mbit/s	Virgin Media		BT, TalkTalk and Virgin Media	
Sky 'up to' 20Mbit/s				
TalkTalk 'up to' 24Mbit/s		BT		O2/Be
Virgin Media 'up to' 20Mbit/s		BT and O2/Be		O2/Be
Comparison of 'up to' 40/50Mbit/s packages				
BT 'up to' 40Mbit/s	Virgin Media			
Virgin Media 'up to' 50Mbit/s		BT		

Source: Ofcom

Figure 31 Significant differences to a 99% level of confidence between average and peak time upstream jitter by ISP package for 'up to' 8Mbit/s and 10Mbit/s packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is worse than...	Is better than...	Is worse than...	Is better than...
BT 'up to' 8Mbit/s		Virgin Media	Orange	Virgin Media
Orange 'up to' 8Mbit/s		Virgin Media		BT, Plusnet and Virgin Media
Plusnet 'up to' 8Mbit/s		Virgin Media	Orange	Virgin Media
Virgin Media 'up to' 10Mbit/s	BT, Orange and Plusnet		BT, Orange and Plusnet	

Source: Ofcom

Figure 32 Significant differences to a 99% level of confidence between average and peak time upstream jitter by ISP package for 'up to' 20Mbit/s and above packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is worse than...	Is better than...	Is worse than...	Is better than...
Comparison of 'up to' 20/24Mbit/s packages				
BT 'up to' 20Mbit/s		Virgin Media		Virgin Media
O2/Be 'up to' 20/24Mbit/s		Virgin Media		Sky and Virgin Media
Sky 'up to' 20Mbit/s		Virgin Media	O2/Be	Virgin Media
TalkTalk 'up to' 24Mbit/s		Virgin Media		Virgin Media
Virgin Media 'up to' 20Mbit/s	BT, O2/Be, Sky and TalkTalk		BT, O2/Be, Sky and TalkTalk	
Comparison of 'up to' 40/50Mbit/s packages				
BT 'up to' 40Mbit/s		Virgin Media		Virgin Media
Virgin Media 'up to' 50Mbit/s	BT		BT	

Source: Ofcom

Figure 33 Significant differences to a 99% level of confidence between average and peak time downstream jitter by ISP package for 'up to' 8Mbit/s and 10Mbit/s packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is worse than...	Is better than...	Is worse than...	Is better than...
BT 'up to' 8Mbit/s				Virgin Media
Orange 'up to' 8Mbit/s				
Plusnet 'up to' 8Mbit/s				
Virgin Media 'up to' 10Mbit/s			BT	

Source: Ofcom
Note: No significant differences over the 24-hour period

Figure 34 Significant differences to a 99% level of confidence between average and peak time downstream jitter by ISP package for 'up to' 20Mbit/s and above packages, November/December 2010

	24 hours		8-10pm weekday	
ISP package	Is worse than...	Is better than...	Is worse than...	Is better than...
Comparison of 'up to' 20/24Mbit/s packages				
BT 'up to' 20Mbit/s		TalkTalk		O2/Be
O2/Be 'up to' 20/24Mbit/s		Sky and TalkTalk	BT, Sky and TalkTalk	
Sky 'up to' 20Mbit/s	O2/Be			O2/Be
TalkTalk 'up to' 24Mbit/s	BT and O2/Be			O2/Be
Virgin Media 'up to' 20Mbit/s				
Comparison of 'up to' 40/50Mbit/s packages				
BT 'up to' 40Mbit/s				
Virgin Media 'up to' 50Mbit/s				

Source: Ofcom
Note: No significant differences among the 'up to' 40Mbit/s and 50Mbit/s ISP packages