

UK broadband speeds, May 2010

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

Research Report

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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 report builds on the first round of research conducted between October 2008 and April 2009 and published in reports of January 2009 and July 2009¹ and sets out our findings for the first month of data collection (May 2010) from this second phase of research. The current research will continue until April 2012, and we expect to publish further reports at roughly six-monthly intervals.

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 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 DSL 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, and we have not been able to report on the performance of each of these packages. Instead, we have been able to gain a sufficient sample of panellists to be able to report the performance of those ISP packages with at least 250,000 residential subscribers which collectively represent over 90% of total broadband subscribers in the UK. 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 DSL 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 early 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-based broadband or satellite broadband are also not currently included in our analysis as these connections only represent a small proportion of the total broadband market in the UK.

¹ The January 2009 report included findings from the first month of data collection (23 October to 22 November 2008) and is available at <u>http://stakeholders.ofcom.org.uk/market-data-research/telecoms-research/bbspeed_jan09/</u>. The July 2009 report set out our findings over the six-month period from November 2008 to April 2009 and is available at <u>http://stakeholders.ofcom.org.uk/market-data-research/telecoms-research/tel</u>

- This research report presents information on the state of fixed-line residential broadband performance in the UK in May 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 the 2009 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 <u>market.intelligence@ofcom.org.uk</u>.

Key terms used to describe broadband speeds

In this report, we use three 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 'maximum line speed', or 'access line speed', is the maximum download speed that a line is capable of supporting.
- 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.

Key statistical concepts used in this report

This report presents the findings from research which has involved the collection and interpretation of over 18 million 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 which follows.

- We present in the report data only in cases in which there are sufficient data points to deliver a statistically sound result. This means that we only report performance when statistical analysis indicates that our findings are accurate enough to be useful. Accuracy is determined by the number of measurement tests undertaken, size of the sample (number of panellists) and also by the variation (spread or range of results) between panellists. As take-up by consumers of 8/10Mbit/s services is still greater than 20/24Mbit/s services, it was possible to achieve sample sizes sufficient for statistically meaningful analysis for more ISP packages offering 8/10Mbit/s (eight packages) than for those offering 20/24Mbit/s (five packages).
- In order to acknowledge the limited accuracy of the estimates and ensure that we
 are only highlighting differences which are statistically significant, for many charts

we do not show a value but instead show a range around the mean value which indicates the statistical confidence we have in our results. The range we use is called a 95% confidence interval, which is a statistically derived range calculated from the standard error (which is itself calculated from the sample size and the variation within the sample). A 95% confidence interval means that if we repeated the research again with a different sample assembled in the same way there would be a 95% probability that the results 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 is representative of UK broadband users as a whole we have weighted the data by ISP package, technology, LLU, rural/urban split, distance from exchange and market classification. As an example, our current panel has a higher proportion of consumers on packages with headline speeds over 10Mbit/s than the actual occurrence in the UK population, so these panellists are given low weights to ensure a representative national picture.
- We have similarly weighted the data where we are comparing the performance of individual ISPs packages by ISP LLU coverage, 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. An issue for comparing DSL broadband providers is that with this technology, speed varies by 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 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 DSL comparisons we have only included consumers who live in an area where the exchange has been 'unbundled' by at least one LLU operator². This means that ISPs using wholesale services (such as BT Wholesale's *IPstream* product) can be compared on a like-forlike basis with LLU operators.
 - We have excluded all DSL 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.

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 Ofcom first conducted research in association with research partner SamKnows Limited ("SamKnows")³ into actual broadband performance for residential connections between October 2008 and April 2009, and published findings for this time-period in January 2009 and July 2009.⁴ For the current second round of research from May 2010 to April 2012, we have updated this panel and now have over 1,500 UK residential broadband users who have connected performance monitoring equipment to their router which provides the raw performance data. 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. This report sets out our findings from the first month of data collection (May 2010), during which over 18 million tests were run.
- 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 have increased significantly over the past year

1.5 Our results show that average download speeds in the UK were 5.2Mbit/s in May 2010, up from 4.1Mbit/s in April 2009 – an increase of over 25%. This is the result of consumers increasingly moving to faster broadband services. Nearly a quarter (24%) of UK residential broadband connections had a headline speed of above 10Mbit/s in May 2010, compared to 8% in April 2009.

³ <u>http://www.samknows.com/broadband/</u>.

⁴ See footnote [1] above.

Actual broadband speeds are generally well below advertised speeds

- 1.6 Some ISPs have in the past year moved away from advertising their services on the basis of headline speeds (e.g. 'up to' 20Mbit/s). But other ISPs continue to do so. This is despite the fact that various constraints on broadband performance (including distance from 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 speeds which some ISPs continue to advertise: the average download speed received in May 2009 of 5.2Mbit/s compares to an average headline speed of 11.5Mbit/s, equivalent to 46% of the headline speed.
- 1.7 The average download speed received for 'up to' 20/24Mbit/s DSL packages was 6.5Mbit/s while for 'up to' 8/10Mbit/s DSL services it was 3.3Mbit/s. For 'up to' 20Mbit/s cable services the average download speed received was 15.7Mbit/s, and for 'up to' 10Mbit/s cable services it was 8.7Mbit/s.
- 1.8 Very few DSL broadband customers achieved average actual download speeds close to advertised 'up to' speeds. Just 13% of customers on 'up to' 8 or 10Mbit/s services received average download speeds of over 6Mbit/s, while half (50%) received average download speeds of 3Mbit/s or less. Nearly two-thirds (65%) of customers on 'up to' 20/24Mbit/s DSL packages received average download speeds of 8Mbit/s or lower, while only 2% received average download speeds of more than 14Mbit/s. Virgin Media cable customers typically received speeds which were much closer to advertised speeds, with almost 90% of those on 'up to' 10Mbit/s receiving average speeds of over 14Mbit/s.⁵

Cable broadband was significantly faster than DSL broadband services

- 1.9 Virgin Media's 'up to' 10Mbit/s and 'up to' 20Mbit/s cable packages delivered average download speeds around twice as fast as equivalent DSL packages. While much of this is due to degradation of DSL speeds over longer lines, cable services were still significantly faster when we compared them with DSL services of customers within 2km of the local exchange.
- 1.10 The fastest speed service we tested was Virgin Media's 'up to' 50Mbit/s service, which delivered average download speeds of around 34-36Mbit/s on 'single-thread' tests (when one file is downloaded) and around 45-47Mbit/s on 'multi-thread' tests (when three files are downloaded simultaneously). In later rounds of this research we are also aiming to test BT's fibre-based broadband service (*BT Infinity*) which offers advertised speeds of 'up to' 40Mbit/s.

⁵ Note that this relates to speeds measured using single-thread tests (the download of a single file). Slightly higher speeds were measured using multi-thread tests (when three files were downloaded simultaneously) (see section 8.37 below); also note that these are average speeds delivered across the UK; when we compare the performances 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 sections 8.4 and 8.9 below)

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

- 1.11 Average download speeds typically slowed down during peak periods as a result of capacity constraints on ISPs' networks (caused by simultaneous users sharing the same bandwidth). Average download speeds during the peak weekday hours of between 8pm and 10pm were 90% of average speeds throughout the day, and 75% of the average maximum download speeds received at any point during the day. Our results showed, however, that some ISP packages suffered greater slowdowns in the peak period of 8-10pm on weekdays, indicating differing levels of contention in the relevant ISPs' networks.
- 1.12 Among the 'up to' 8 or 10Mbit/s services, O2, Sky and TalkTalk's services were all significantly faster than Orange's service during peak hours, and they also showed little or no slowdown during peak hours, indicating lower levels of contention. Although Virgin Media's 10Mbit/s cable service remained significantly faster than DSL services during peak hours, there was a significantly greater slowdown during the peak hours than for some DSL providers.
- 1.13 Among the 'up to' 20/24Mbit/s services, O2, Sky and TalkTalk's services were significantly faster than BT Retail's services during peak hours, and again showed little or no slowdown during peak hours, indicating lower levels of contention. Although Virgin Media's 'up to' 20Mbit/s cable service delivered significantly faster speeds than equivalent DSL services during peak hours, it did show a significantly greater slowdown compared with off-peak times compared to some DSL providers.

Measures other than download speed also determine broadband performance

- 1.14 While we consider that download speed is the most important single metric in determining broadband performance, we also tested other performance metrics which determine the overall performance of a broadband connection. These included 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) and jitter (a measure of the stability of a connection).
- 1.15 Overall, we found that all ISP packages delivered on average a level of performance on these metrics which was satisfactory for most types of internet use. However, there were some differences between ISPs, most notably:
 - O2/Be offered faster upload speeds than comparable services from other DSL operators and Virgin Media's cable services
 - Virgin Media's 'up to' 10 and 'up to' 20Mbit/s services averaged higher jitter rates than comparable DSL services. Jitter is is particularly important for gaming and VoIP (however it should be noted that the average performance of Virgin Media was sufficient not to have a detrimental effect on the user experience).

Conclusion and next steps

1.16 This research report is a representative snapshot of the current state of residential broadband performance in May 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. This research phase is continuing until April 2012, and we plan on publishing updates around every six months, with the next report scheduled for publication in January 2011. We have also separately commissioned research into mobile broadband performance, with data collection due to take place in autumn 2010 and a report scheduled for publication in early 2011.

- 1.17 While the results of our research do show some improvements in average broadband speeds since we last undertook the research in April 2009, it is clear that for many consumers current generation broadband is unable to deliver the faster speeds that would allow the use of high-bandwidth services such as internet TV, or connect multiple devices to the internet. Most broadband customers still get their service 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. It is estimated that around 2.75million households, are currently incapable of receiving a minimum speed of 2Mbit/s⁶ which the Government has targeted as part of its universal service commitment⁷. As well as working with the Government on achieving this target and ensuring that consumers are fully informed about the capabilities of different broadband services, Ofcom has also put in place a clear regulatory framework for superfast broadband⁸ which has allowed investment in next generation broadband services to begin.
- 1.18 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). We have therefore introduced a strengthened Voluntary Code of Practice on Broadband Speeds⁹ with the co-operation and agreement of ISPs. 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 then consumers whose speed is significantly less than expected will have the ability to leave their provider within three months of the start of their contract. We have published a list of signatories to the new Code on our website.¹⁰
- 1.19 Another implication of our research is that many consumers could take relatively simple steps (such as fitting an iPlate or microfilters) to improve their broadband performance. To help them do this, we have published a new consumer guide and video on our website which update the guides we originally published last year.¹¹ Consumers should also be able to find additional help and assistance on boosting speeds from their ISP.

⁶ Digital Britain report, p.54, http://www.official-documents.gov.uk/document/cm76/7650/7650.pdf http://www.culture.gov.uk/news/ministers_speeches/7132.aspx

http://stakeholders.ofcom.org.uk/binaries/consultations/nga_future_broadband/statement/statement.p df

⁹ The current version of the Code of Practice, which 50 ISPs have signed up to, can be found at <u>http://stakeholders.ofcom.org.uk/telecoms/codes-of-practice/broadband-speeds-cop/voluntary-codes-of-practice/</u>.

¹⁰ http://stakeholders.ofcom.org.uk/telecoms/codes-of-practice/broadband-speeds-cop-2010/

¹¹ http://stakeholders.ofcom.org.uk/market-data-research/telecoms-research/broadband-speeds/main/

Section 2

Introduction

Objective to ensure the provision of clear information to broadband consumers

- 2.1 In line with Ofcom's duties under the Act to further the interests of UK citizens and consumers and thereby to have regard, among other things, to the interests of consumers in respect of price, quality and value for money, Ofcom's objective is to ensure that consumers have the clearest possible information about broadband services. In our view, not only will this allow consumers to make more informed purchasing decisions and choose the most suitable service for them, it will also stimulate investment in new broadband services and technologies and allow operators who invest in their networks to distinguish themselves from other operators and thereby gain a competitive advantage.
- 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 Practice¹² (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. We undertook mystery shopping research to assess whether and to what extent ISP signatories were complying with the Code. We published the results of that research in March 2010¹³ and at the same time proposed changes to the Code to address issues raised by the research. We have now agreed a strengthened Code with ISPs which will come into effect in 2011.

As regards actual broadband speeds, which is the subject of this report, the Code states that "In addition to having information on access line speeds, consumers would also benefit from having information about the average throughput speeds which each ISP achieves in practice. Throughput speeds are an important metric for consumers since this is the download speed which they actually obtain in practice whilst using the internet". It goes on to state that "Ofcom's aim is to develop a methodology and process which is sufficiently robust to accurately assess ISPs' average throughput speed performance. To this end, Ofcom is undertaking a research programme to look at this issue in more detail and to assess the role that each of actual and average throughput speed measurements can play..."

• **Consumer education and information initiatives**. We have published consumer guides to broadband speeds¹⁴ and to buying broadband¹⁵, as well as a

¹² Voluntary Code of Practice: Broadband Speeds, <u>www.ofcom.org.uk/telecoms/ioi/copbb/</u>.

¹³ <u>http://stakeholders.ofcom.org.uk/telecoms/codes-of-practice/broadband-speeds-cop/voluntary-code/</u>.

¹⁴ Broadband Guide, <u>http://www.ofcom.org.uk/advice/guides/bbchoice.pdf</u>.

¹⁵ www.ofcom.org.uk/advice/guides/broadband.

video guide. These are designed to inform consumers about how to increase their broadband speeds received and about the considerations they may wish to take into account when purchasing a broadband service. We have updated the consumer guide to broadband speeds and the video guide to coincide with the publication of this report.¹⁶

- Publication of research into actual broadband speeds. This research report follows up on the reports we published in January 2009 and July 2009¹⁷ following 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. Of com has discussed with the Advertising Standards Authority (ASA) how broadband advertising should develop, particularly as ISPs are increasingly offering and moving their customers onto higher speed broadband packages.
- 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 available¹⁸) on the basis of actual network performance.

Rationale for the report

2.4 As indicated above, Ofcom's primary duty under the Act is to further the interests of UK citizens and consumers in carrying out our functions¹⁹. 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 services²⁰. 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 UK²¹. We are also required to have regard to the interests of consumers in respect of price, choice, quality of service and value for money²². 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 services²³. 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.²⁴

The rationale of this report is the same as that in the 2009 reports. As explained in the July 2009 report, it was necessary to commission our own independent research

¹⁹ Section 3(1) of the Act.

²² Section 3(5).

¹⁶http://stake<u>holders.ofcom.org.uk/market-data-research/telecoms-research/broadband-speeds/main/</u> ¹⁷ See footnote [1].

¹⁸ See the explanation of the limitations of the research on pages 2-3 above.

²⁰ Section 3(2)(b).

²¹ Section 3(4)(a) and (e).

²³ Section 14.

²⁴ Section 15.

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 which do not account for the impact on speed of PC set-up, or the impact 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, or 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 it is representative of residential broadband users, and also to apply appropriate statistical techniques to 'normalise' the data for DSL broadband by distance from exchange. Normalisation ensures that the final results enable like-forlike comparison between ISP packages.

The scope of the research

- 2.5 As was the case for the first round of research, for the purposes of this second round of research, 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 used some of the same members of the panel which was used for data collection in the first phase of research (October 2009 to April 2010) and was assembled in spring 2010. We will collect technical broadband performance data from this panel at least over a two-year period, until April 2012. Our desire is that the panel will be extended during this time-period to include ISP packages in the research which are not currently included. We will consider the options with SamKnows going forward. Relevant considerations include the ability to obtain a representative sample of consumers on a particular ISP package and ease of recruitment of panel members.
- 2.6 This report is the first report based on this panel performance data, and it presents performance data from the first month of data collection, May 2010. Where appropriate, we also include data from our first round of research, as published in July 2009, to show how UK residential broadband performance has changed between April 2009 and May 2010.
- 2.7 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.
- 2.8 We include two different types of download speed tests; single-thread tests (the download of a single file) and multi-thread tests (the simultaneous download of multiple files). Both are relevant to the consumer experience, and we compare the performance of both. However, we have opted to use single-thread tests for the majority of comparisons. This is because such test provides a 'pure' measure for the download of a single file, because it enables direct comparison with the research undertaken in 2009 (published in the July 2009 report) (when we only ran single-thread tests), and because we have a greater number and range of test data, enabling us to be able to report across more variables²⁵. It should be noted that

²⁵ Single-thread tests were scheduled hourly for all panellists, while multi-thread tests were scheduled twice a day. This schedule was in part informed by the practical consideration of utilising less bandwidth – including more data-hungry multi-thread test would have challenged the data usage limits associated with many of our panellists' contracts with their broadband supplier.

multi-thread tests typically deliver slightly faster speeds than single-thread tests (see section 8.37 below).

- 2.9 We include comparative data for those ISP packages for which we had large enough sample sizes to make the analysis statistically meaningful. This has comprised: the 'up to' 8 or 10Mbit/s DSL packages from AOL Broadband, BT Retail, O2/Be, Orange, Plusnet, Sky and TalkTalk; the 'up to' 20 or 24Mbit/s DSL packages from BT Retail, O2/Be, Sky and TalkTalk; and Virgin Media's 'up to' 10, 20 and 50Mbit/s cable packages.
- 2.10 For those ISPs who offer services via local loop unbundling (LLU) and have different packages for on-net and off-net customers, we only report on the performance of their 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. Separate analysis compares the aggregated performance of DSL services provided via LLU and non-LLU.
- 2.11 As raw download speed is only one of many factors that determine the performance of a broadband connection, we also include analysis of upload speed, web browsing, latency, packet loss, DNS and jitter. However, the bulk of the analysis focuses on download speeds because it 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.

Outside the scope of the research

- 2.12 ISPs packages with less than 250,000 residential customers (equivalent to less than 2% market share) are not included in the research as we did not have a sufficiently large, representative, sample for them for statistical meaningful analysis.²⁶ We are keen to include smaller ISP packages going forward, 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.²⁷
- 2.13 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 8% 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 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)).
- 2.14 We looked only at the performance of residential fixed-line broadband, which accounts for nearly 90% of the UK's residential broadband connections. Outside the scope of our research was broadband accessed by dedicated fibre networks (this

²⁶ The only exception is the Virgin Media 'up to' 50Mbit/s cable package – where the characteristics of its user base has made it possible to recruit around 50 panellists by tapping into an active online community.

²⁷ 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.

currently accounts for less than 0.5% of all broadband customers in the UK) and satellite broadband (which also has very low take-up).

- 2.15 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 expect to start to collect data in the autumn of 2010 and publish results in early 2011.
- 2.16 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

- 2.17 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 DSL 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 DSL and cable broadband
 - Section 8 looks in more detail at how ISPs and their packages vary in their performance, and considers the reasons why this may be the case. This includes a comparison of LLU-based and non-LLU services and examines the differences between single-thread and multi-thread speed tests
 - Section 9 looks at metrics other than download speed which determine broadband performance and compares ISP package performance in upload speeds, web browsing, latency, packet loss, DNS resolution and jitter.
 - Section 10 concludes the report with an overview of the implications of the findings for consumers, 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, geographical location (including distance from exchange for DSL broadband), access technology and ISP.
 - To measure a number of other factors which determine overall broadband performance: upload speeds, loading web pages, latency, packet loss, DNS and jitter.

Methodology

- 3.2 The technical methodology chosen is the same as that used in Ofcom's first round 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 section 2.5 above.
- 3.3 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 400 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).
- 3.4 We believe that this technical methodology, which was first used on a large scale for Ofcom's research from October 2008 to April 2009, represents a significant improvement from any other research into UK broadband performance, which has typically relied on software monitoring solutions which do not account for the impact on speed of PC set-up, or having more than one computer using a broadband connection. In April 2010, The Federal Communications Commission (FCC), the agency responsible for regulating telecommunications networks in the USA, announced that it was commissioning SamKnows to conduct research into broadband performance in the US, using an identical technical methodology to that used by Ofcom.
- 3.5 The performance data in this report are based on 1,506 panellists who had a broadband monitoring unit connected to their router in May 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 Geographical distribution of panellists



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

- 3.6 The technical methodology is described in Annex 2.
- 3.7 Figure 3.2 details Ofcom's proposed 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 it facilitated like-for-like comparison between ISP packages:
 - All panellists have been assigned to one of the geographic markets, and we have weighted the analysis accordingly to ensure that our overall findings are representative of UK residential broadband performance as a whole (for example, as Market 1 represents 14.2% of the UK population, we have ensured that performance data from panellists in Market 1 contributes 14.2% towards the overall computation of UK residential broadband performance).
 - For comparisons of ISP package performance we only use 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 for whom LLU services are not available.

Figure 3.2 Of com proposed definitions of geographic broadband markets

Market	Description	Exchanges	Coverage
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	3,578	14.2%
Market 2	Those geographic areas covered by exchanges where there are 2 or 3 Principal Operators present (actual or forecast) AND exchanges where there are forecast to be 4 or more Principal Operators but where the exchange serves less than 10,000 premises	722	13.8%
Market 3	Those geographic areas covered by exchanges where there are currently 4 or more Principal Operators present AND exchanges where there are forecast to be 4 or more Principal Operators but where the exchange serves 10,000 or more premises	1,287	71.3%

Source: Ofcom, Review of the wholesale broadband access markets: Consultation on market definition, market power determinations and remedies, July 2010, <u>http://stakeholders.ofcom.org.uk/binaries/consultations/wba/summary/wbacondoc.pdf</u>

Note: Principal operators are those that provide broadband services over their own access networks (BT or Virgin Media) or have deployed LLU in more than 10% of the UK



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

- 3.8 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, geographic market definition and ISP. For the provider-specific comparisons we have also 'normalised' the data for DSL 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 who have different customer profiles.
- 3.9 All weightings applied have been validated by market research company Saville Rossiter Base. We also applied some checks 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 we have 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.²⁸

²⁸ <u>http://stakeholders.ofcom.org.uk/binaries/research/telecoms-research/broadbandspeeds.pdf</u> , p20

Section 4

Overview of 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 its 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.

	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

Figure 4.1 Theoretical time taken to perform various online activities

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, a smartphone and/or tablet device, and an online gaming console connected to the internet at the same time. This demand for bandwidth is only likely to increase further as more devices such as TVs become internet-enabled and as consumers make increasing 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 some ISPs have changed 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, some ISPs do not typically advertise their services on the basis of speeds but instead simply promote them on

the basis that they will provide the fastest speed that a customer's line is capable of supporting.

- 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. Since the July 2009 report, most DSL ISPs have supplemented or replaced their existing 'up to' 8Mbit/s services with 'up to' 20/24Mbit/s services. Virgin Media has also moved its 'up to' 2Mbit/s and 4Mbit/s cable broadband customers to its 'up to' 10Mbit/s service, as well as offering 20Mbit/s and 50Mbit/s services, and is trialling 100Mbit/s and 200Mbit/s services. In addition, BT is rolling out fibre services, including its *BT Infinity* fibre-to-the-cabinet (FTTC) service 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 largest ISPs in the UK by retail market share (who have a combined market share of over 90%). It indicates a significant shift in the market towards higher headline speeds between 2009 and 2010. The average headline speed in May 2010 was 11.5Mbit/s, up from 7.1Mbit/s in April 2009.
- 4.7 We have presented the data in bands rather than detailing specific ISP packages in order to preserve the confidentiality of this 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)

A significant minority of consumers are concerned about slow broadband speeds

4.8 Previous Ofcom research has shown that while overall levels of satisfaction with broadband services are high (90%), satisfaction with the speed of connection is significantly lower (80%), and there has been a significant decrease in the proportion of people who claim to be very satisfied with the speed of their broadband connection over the past couple of years (Figure 4.3).

Figure 4.3 UK residential consumer satisfaction with aspects of fixed broadband service



Proportion of all adults with service (percent)

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

4.9 It is also evident that for a significant minority of consumers the speed of their broadband connection is a major concern. Ofcom research conducted in September-October 2008 and published in our July 2009 report into UK residential broadband speeds found that among those who were dissatisfied with their ISP, the speed of connection was most frequently cited as the single main reason for dissatisfaction (30%), marginally ahead of reliability (27%)²⁹. Residential consumers make more complaints to ISPs about slow connection speeds than about any other issue (27% of complaints).³⁰ Ofcom research finds that around one in four consumers who express an opinion claim that the actual speeds they receive are slower than the speeds they expected when they first signed up for their broadband service (Figure 4.4).

Source: Ofcom research

²⁹ UK Broadband Speeds 2009, p29, http://stakeholders.ofcom.org.uk/binaries/research/telecomsresearch/broadbandspeeds.pdf

³⁰ Consumer Complaints Market Research Report, November 2009, p19 http://stakeholders.ofcom.org.uk/binaries/consultations/complaints_procedures/annexes/annex8.pdf,

Figure 4.4 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 on page 3 above, 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 was 5.2Mbit/s, only 45% of the average headline speed of 'up to' 11.5Mbit/s (Figure 4.5).
- 4.12 Maximum line speeds are a better indicator of the actual speeds that consumers can expect than headline speeds, and we found that average download speeds were 83% of maximum speeds in May 2010³¹. It is in this context that Ofcom introduced the Voluntary Code of Practice on Broadband Speeds, implemented by ISP signatories in December 2008, through which all signatories commit to notifying consumers at the point of sale of the maximum speed their line is capable of supporting.

³¹ Note that as we were not able to run specific access line tests for our panellists, we use the highest download speed test recorded during the month as the maximum line speed



Figure 4.5 Average UK broadband speeds, May 2010

Source: SamKnows measurement data for all panel members with a connection in May 2010 Panel Base: 1506

Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in May 2010; (3) Data collected from single-thread download speed tests

4.13 Cable services generally delivered average download speeds that were much closer to advertised 'up to' speeds than DSL services. On average, the actual speeds delivered to consumers on 'up to' 8 or 'up to' 10Mbit/s DSL packages were 41% of the advertised 'up to' speed, while those on 'up to' 20 or 'up to' 24Mbit/s were 29% of the advertised 'up to' speed. Cable services on average delivered between 70% and 86% of the advertised speeds. It should be noted that this relates to actual speeds measured using single-thread tests; multi-thread tests (which involve measuring speeds when multiple files are downloaded simultaneously) delivered higher speeds for all services, and in particular for the higher speed cable packages. We found that multi-thread tests were around 25% faster than single-thread tests for Virgin Media's 'up to' 50Mbit/s package (see section 8.37).



Figure 4.6 Average download speeds (24 hours) as a proportion of headline speeds by connection headline speed and technology, May 2010

Source: SamKnows measurement data for all panel members with a connection in May 2010 Panel Base: 1506 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 singlethread download speed tests.

Average UK broadband speeds increased by over 25% between April 2009 and May 2010

4.14 Our research found that overall average UK download speeds increased from 4.1Mbit/s in April 2009 to 5.2Mbit/s in May 2010. The increasing take-up of ADSL2+ services offering theoretical maximum speeds of 'up to' 24Mbit/s (and advertised 'up to' of 20 or 24Mbit/s) contributed to this increase; however, as Figure 4.7 indicates, overall average DSL speeds (including all DSL packages at all headline speeds) increased by just 0.3Mbit/s during the period (8%). Meanwhile, the overall average speeds delivered to Virgin Media's cable customers more than doubled to 9.9Mbit/s, largely as a result of customers on 'up to' 2Mbit/s and 'up to' 4Mbit/s services being upgraded to an 'up to' 10Mbit/s service, but also partly due to a greater proportion of customers taking its 'up to' 20Mbit/s and 'up to' 50Mbit/s packages.

Figure 4.7 Estimated average download speeds for DSL and cable broadband connections, all connections including 'up to' 2Mbit/s and less, May 2010



Source: SamKnows measurement data for all panel members with a connection in May 2010 Panel Base: 1506

Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in May 2010; (3) Data collected from single-thread download speed tests

4.15 The average download speed for 'up to' 8 and 10Mbit/s connections increased by 0.1Mbit/s to 4.4Mbit/s, while average download speeds on packages with advertised speeds of 'up to' 16, 'up to' 20 and 'up to' 24Mbit/s packages fell from 9.6Mbit/s to 8.1Mbit/s. This fall in speeds is likely to be the consequence of wider selling of these higher speeds services; whereas in April 2009 all of the largest DSL operators had different speed packages, by May 2010 many of them, only offered 'up to' 20Mbit/s (e.g. BT Retail and Orange) or 'up to' 24Mbit/s (e.g. TalkTalk) packages to all 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' 20 or 24Mbit/s. Meanwhile, as the average speed for these packages of more than 'up to' 10Mbit/s has fallen, the average advertised 'up to' speed for these higher speed DSL packages has increased as ISPs have stopped selling 'up to' 16Mbit/s packages and now sell only 'up to' 20 and 'up to' 24Mbit/s packages.



Figure 4.8Average headline and actual broadband speeds, April 2009 and May2010

Source: SamKnows measurement data for all panel members with a connection in May 2010 Panel Base: 1506 Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in May 2010; (3) Data collected from single-thread download speed tests

Why actual broadband speeds vary from headline speeds

- 4.16 Typically, a number of constraints combine to make actual broadband speeds significantly lower than headline speeds:
 - For DSL 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 DSL 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 impact performance. In June 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 networks.

- 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).
- 4.17 As DSL broadband is currently the only broadband technology which 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.
- 4.18 Figure 4.9 depicts the theoretical degradation of the maximum speeds achievable by DSL broadband as the length of line from local telephone exchange to premises increases. It shows that although second-generation DSL 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.

Figure 4.9 Theoretical maximum DSL speeds by length of line from exchange to premises



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

- 4.19 However, the diagram above provides an over-simplification of the relationship between speed and line length. DSL maximum line speeds are actually determined by the quality of the signal on the line. In turn, signal quality is a function of both the strength of a signal and electrical interference (known as electrical 'noise'). As a signal's strength reduces or noise increases, the speeds achievable by consumers reduce.
- 4.20 While line length is a reasonable proxy of signal loss on a line (and hence achievable signal strength) there is not a direct relationship between line length and signal loss: lines of the same length may have difference signal loss (also known as 'attenuation'). This could be, for instance, because they are made of different thickness wire, different types of metal or have more cable joints.

- 4.21 In addition to variations in signal strength, different lines may experience different levels of electrical noise due to other factors. For example, the quality of in-home telephone wiring is known to have a significant effect on the electrical noise that enters the line. In turn this means that lines with exactly the same signal strength may have different access line speeds.
- 4.22 This dependence on signal strength and level of noise means that for any given line length, customers can get a wide range of access line speeds. Figure 4.10 uses data provided by two ADSL2+ operators and plots the maximum line speed (also known as the 'access line speed') for a sample of around 16,000 'up to' 20Mbit/s customers against the estimated length of the line between their premises and the local exchange. Some of the spread in the results is likely to be due to inaccuracies in line length estimates (the scattering points to the top right of the chart represent high speeds on long lines, and they are likely to be anomalies). However, much of the spread is due to variations in line attenuation and noise levels.

Figure 4.10 Access line speed by estimated line length



Source: Ofcom based on data provided by two DSL operators

- 4.23 Figure 4.11 uses the same data to show the percentage of customers achieving a particular access line speed for a given line length. For example, approximately 20% of customers on 2km long lines have access lines speed greater than 11.5Mbit/s, 50% are over 7.5Mbit/s, 80% are over 4.5Mbit/s, and the average (mean) access line speed for lines of 2km is around 8Mbit/s.
- 4.24 This illustrates that it is very hard to for an ISP to predict exactly what access line speed any given line will support. However, it is possible to estimate with a degree of certainty that a customer's access line speed will fall within a range. For example, there is a 60% probability that a customer on a 2km line will have an access line speed of between 4.5 and 11.5Mbit/s (and only a 20% chance that it will fall below 4.5Mbit/s).
- 4.25 As explained above, under Ofcom's Voluntary Code of Practice on Broadband Speeds, ISP signatories are obliged to provide estimates of access line speed before signing customers up to a DSL-based package. Currently, many ISPs are providing estimates of access line speed based on the median for a particular line length. But these estimates will be incorrect for many customers. For example, customers with 2km line lengths are likely to be quoted an estimate of 7.5Mbit/s. But 50% of these

customers will have a speed below 7.5Mbit/s and 20% of these customers will have an access line speed of below 4.5Mbit/s.

4.26 It would therefore be more accurate, and would better manage customers' expectations, if customers were given an estimate in the form of a range, rather than a single point estimate, and ISPs who have signed up to the strengthened Code we have introduced will commit to providing a range which indicates access line speeds with 60% probability. Nevertheless, the difficulty of predicting with perfect accuracy the extent of noise on a customer's individual line mean there will always be some degree of inaccuracy in providing access line speed estimates. For this reason the strengthened Code commits signatory ISPs to give customers whose access line speed is significantly below the estimate provided at point of sale the ability to leave their contracts without penalty if their ISP cannot resolve the problem.



Figure 4.11 Distribution of access line speeds by line length

Source: Ofcom based on data provided by two DSL operators

The distribution of actual broadband speeds

- 4.27 Given this variation in maximum line speeds, it is not surprising that, for DSL broadband, there is wide variation in average download speeds received among consumers on packages with the same 'up to' headline speed. Figures 4.12 and 4.13 show the distribution of average download speeds received by panellists on 'up to' 8 or 10Mbit/s DSL packages and 'up to' 20 or 24Mbit/s DSL packages. In addition to the wide variation in performance, it is striking how few consumers receive average download speeds which are close to headline speeds.
- 4.28 For example, only around one in eight of our sample on 'up to' 8 or 10Mbit/s DSL headline speed packages received average download speeds of over 6Mbit/s and around half received 3Mbit/s or less (Figure 4.12). Similarly, among panellists on 'up to' 20 or 24Mbit/s DSL packages, less than 3% received average download speeds in excess of 14Mbit/s and around two-thirds received average download speeds of 8Mbit/s or less.



Figure 4.12 Average download speeds for DSL panellists on 'up to' 8Mbit/s and 'up to' 10Mbit/s packages

Source: SamKnows measurement data for panel members with a connection in May 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 DSL 'up to' 8/10Mbit/s residential customers as a whole; (2) Data collected from single-thread download speed tests





Proportion of panellists

Source: SamKnows measurement data for panel members with a connection in May 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 DSL 'up to' 20/24Mbit/s residential customers as a whole; (2) Data collected from single-thread download speed tests

4.29 There was less variation in the average download speeds delivered to cable panellists, with more than half of panellists on Virgin Media's 'up to' 10Mbit/s package receiving average download speeds of over 9Mbit/s, and fewer than one in ten receiving average download speeds of 7Mbit/s or less (Figure 4.14). Similarly, more than 80% of panellists on Virgin Media's 'up to' 20Mbit/s service received an average download speed in excess of 14Mbit/s and over 60% of those on its 'up to' 50Mbit/s received more than 35Mbit/s. (Note that these average download speeds are based on single-thread tests, section 8.37 below details that multi-thread test results had higher speeds for all packages, with the biggest increase for higher speed

packages). However, it is notable that some cable customers get average speeds which are significantly lower than the headline speed. This may be because of network contention, or some lines still being set to a legacy profile (e.g. 4Mbit/s), or it may be due to faults on the customer's modem.

Figure 4.14 Average download speeds for cable panellists on an 'up to' 10Mbit/s package



Source: SamKnows measurement data for panel members with a connection in May 2010, Notes: (1) Data have been weighted to regional coverage to ensure that they are representative of UK cable 'up to' 10Mbit/s residential customers as a whole; (2) Data collected from single-thread download speed tests

Figure 4.15 Average download speeds for cable panellists on an 'up to' 20Mbit/s package



Source: SamKnows measurement data for panel members with a connection in May 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 single-thread download speed tests

Figure 4.16 Average download speeds for cable panellists on an 'up to' 50Mbit/s package



Source: SamKnows measurement data for panel members with a connection in May 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 single-thread download speed tests

How we explore variations in broadband speeds

- 4.30 The following sections of this report examine why download speeds are typically below headline speeds and look in particular at the influence of the following factors:
 - Geographical location.
 - Time of day.
 - Access technology.
 - ISP.
- 4.31 Our technical approach to speed measurement did not allow us to report on other factors which influence actual download speeds, including:
 - Wiring into the home, and internal wiring within the house.
 - Electrical interference (which may be reduced if a filter is being used).
- 4.32 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 or the wireless connection.
 - The speed of the particular websites visited or applications used by the consumer.

- 4.33 In addition, the measure which we focus on in this report actual download (or 'throughput') speed is not the only driver of broadband performance. Other indicators which can determine the overall broadband experience include upload speeds, web browsing, latency, jitter, DNS look-up times and DNS failure rates. We examine these further in section 9.
- 4.34 Nevertheless, we believe that focusing on download speed is useful because, other than price, it is 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.
- 4.35 There are two measures of download speeds: the speed of downloading a single file (which is measured with a single-thread test), and the speed of downloading multiple files simultaneously (which is measured with a multi-thread test). Both types of test are relevant to the user experience: single-thread tests replicate one computer downloading a single file (for example a music or a video file); while multi-thread tests replicate web page downloads, peer-to-peer configurations, or multiple PCs simultaneously downloading files using the same broadband connection.
- 4.36 Analysis in section 8.37 compares the performance of single and multi-thread tests by ISP package and finds that there is a direct relationship between the results of single-thread and multi-thread tests, and that multi-thread tests typically record faster speeds, particularly for higher speed packages. However, we have opted to use single-thread tests for the majority of comparisons in this section. This is because it provides a 'pure' measure for the download of a single file, it enables direct comparison with the first phase of research published in July 2009 (when we only ran single-thread tests), and because we have a greater number and range of test data, enabling us to be able to report across more variables³².

³² Single-thread tests were scheduled hourly for all panellists, while multi-thread tests were scheduled twice a day. This schedule was in part informed by the practical consideration of utilising less bandwidth – including more data-hungry multi-thread test would have challenged the data usage limits associated with many of our panellists' contracts with their broadband supplier.

Section 5

Variation of speeds by geographical location

Overview

- 5.1 There are two key drivers of variations of speeds by geographical location:
 - For DSL 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. Only half of UK households have access to Virgin Media's cable services, which offer speeds of 'up to' 50Mbit/s, while around 85% of the population have access to ADSL2+ services, offering speeds of 'up to' 20 or 24Mbit/s, and 15% of the population only have access to ADSL1 services, offering a maximum speed of 'up to' 8Mbit/s (and actual speeds typically much lower than this).

DSL broadband speeds decline as distance from exchange increases

- 5.2 As detailed above, it is a characteristic of DSL 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 sections 4.17 to 4.25 above 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 2.4km. 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 DSL 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 distance from exchange among panellists

Source: Ofcom using data supplied by SamKnows

- 5.4 Figure 5.2 shows a plot of line length against download speed compiled from the results of multi-thread tests conducted between 4am and 6am. These give a good indication of the maximum speed a line is capable of delivering, and show that none of our panellists on 'up to' 20 or 'up to' 24Mbit/s DSL packages ever received download speeds of more than 20Mbit/s, and few ever received speeds of more than 18Mbit/s. It also indicates that there was a cluster of 'up to' 8/10Mbit/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 either by the limitations of ADSL1 technology (compared to ADSL2+ which support theoretical speeds of up to' 8Mbit/s), or are being throttled at around 7Mbit/s as they have signed up for an 'up to' 8Mbit/s package.³³
- 5.5 It is also clear in Figure 5.2 that there is a relationship between the maximum download speed delivered and the length of the line, 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, 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.
- 5.6 The distribution in Figure 5.2 is similar to that shown in Figure 4.10 above, which plots line lengths against access line speeds. However, the maximum speeds we report (based on the highest download speed achieved on any single-thread test in May 2010) are generally a little lower than ISP-reported access line speeds. A reason for this is because the access line speed captures the modem synchronisation speeds, but actual speeds delivered are always less than this because some of the available capacity is used by critical communications protocols (e.g. ATM and TCP) which are required for the connection to operate. ISPs typically limit the bandwidth available for end users' data in order that there is sufficient capacity for this other 'overhead' data. For example, if a line synchronises (connects to the DSLAM at the exchange) at 8128kbit/s (~8Mbit/s), systems such as the BT Broadband Remote Access Server (BRAS) system limit user traffic to 7.15Mbit/s.

Figure 5.2 Distance from exchange and average download speeds achieved by panellists on 'up to' 8/10Mbit/s and 'up to' 20/24Mbit/s DSL packages, 4am to 5am multi-thread test results, May 2010



Source: SamKnows measurement data for all panellists with a DSL connection in May 2010 Note: This data is unadjusted so is not directly comparable with data elsewhere which has 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 no panellist receiving average speeds of more than 18Mbit/s. This is primarily due to download speeds being constrained by contention within ISPs' networks; however, average speeds are also measured using single-thread tests, which deliver slightly lower speeds than multi-thread tests (see section 8.37 below).

Figure 5.3 Distance from exchange and average download speeds achieved by panellists on 'up to' 8/10Mbit/s and 'up to' 20/24Mbit/s DSL packages



Source: SamKnows measurement data for all panellists with a DSL connection in May 2010 Note: This data is unadjusted so is not directly comparable with data elsewhere which has 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 speeds services. Virgin
Media's cable service is available to 49% of the UK population, primarily those who live in urban areas; by March 2010, BT had upgraded exchanges serving around 55% of the UK population (again primarily in urban areas) to ADSL2+, which offers theoretical speeds of 'up to' 24Mbit/s compared to the theoretical 8Mbit/s available via ADSL1; and LLU services are available to around 85% of the population. 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 speed delivered to residential fixed-line broadband consumers in urban areas (5.8Mbit/s) was over twice the average 2.7Mbit/s delivered to rural consumers (Figure 5.4).

Figure 5.4 Estimated average and maximum download speeds for broadband connections in rural & urban areas, May 2010



Source: SamKnows measurement data for all panel members with a connection in May 2010, Panel Base: 1506

Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in May 2010 and an estimated split between rural and urban areas; (3) Data collected from single-thread download speed tests

5.9 Another reason for rural consumers experiencing slower average download speeds than rural consumers is that the length of line from exchange to premises is typically longer in rural areas. Among our DSL panellists, the average line length for rural consumers was 4,066m, compared to an average of 1,788m for urban consumers. Figure 5.5 indicates that both maximum and average download speeds were significantly slower for DSL consumers in rural areas on 'up to' 8 or 'up to' 10Mbit/s packages, and on 'up to' 20 or 24Mbit/s packages. In addition to having typically shorter line lengths, the greater availability of LLU services in urban areas may also be a factor.



Figure 5.5 Average and maximum download speeds for DSL broadband connections in rural & urban areas

Source: SamKnows measurement data for all panel members with a connection in May 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 single-thread download speed tests

Geographic market situation

- 5.10 Different areas of the country have a different range of providers available. In some locations it is only possible to obtain broadband services using lines operated by BT Wholesale. But in other parts of the country, there is a wider range of providers available, both via cable and via operators who have taken over BT lines using local-loop unbundling. We wanted to see how download speeds varied between these different areas.
- 5.11 Of com considers three separate geographic markets for wholesale broadband provision (see section 3.7 above)³⁴:
 - 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 by exchanges where there are two
 or three Principal Operators³⁵ present (actual or forecast) AND exchanges where
 there are forecast to be four or more Principal Operators but where the exchange
 serves less than 10,000 premises,
 - Market 3 Those geographic areas covered by exchanges where there are currently four or more Principal Operators present AND exchanges where there

³⁴ 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: final explanatory statement and notification*, May 2008, available at

http://www.ofcom.org.uk/consult/condocs/wbamr07/statement/statement.pdf.

³⁵ Principal operators are those that provide broadband services over their own access networks (BT or Virgin Media₈) or have deployed LLU in more than 10% of the UK

are forecast to be four or more Principal Operators but where the exchange serves 10,000 or more premises

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.

- 5.12 Consumers living in areas designated as Market 1 on average received download speeds significantly slower than those who live in areas designated as Markets 2 or 3. (Figure 5.6). Average broadband download speeds in Market 1 areas were just 2.7Mbit/s compared to 4.9Mbit/s in Market 2 areas and 5.9Mbit/s in Market 3 areas. Please note that we did not sample by technology within Markets and made no distinction made between Markets 2 and 3, hence although these results provide a good comparison between Markets, they will not match the overall national results.
- 5.13 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 meaning that DSL services will tend to be slower than those in Markets 2 and 3;
 - consumers living in Market 2 and 3 areas will have access to LLU-based services, and therefore the availability and take-up of 'up to' 20 and 24Mbit/s services will be higher than in Market 1 areas, where 'up to' 20Mbit/s services are currently being rolled out; and
 - there is higher availability of cable broadband services (which tend to be faster than those provided using DSL and are available to 49% of the UK population) in Market 3 areas than in Market 2 areas, and very low availability in Market 3 areas.

Figure 5.6 Average and maximum download speeds by geographic market, May 2010



Source: SamKnows measurement data for all panel members with a connection in May 2010, Panel Base: 1506

Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in May 2010 and an estimated split between rural and urban areas; (3) Data collected from single-thread download speed tests 5.14 Figure 5.7 below shows our estimate 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). This analysis suggests that maximum and average speeds in England were around 0.5Mbit/s higher than those in Scotland, Wales and Northern Ireland. 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 average published elsewhere in this report.

Figure 5.7 Estimated average and maximum download speeds by UK nation, May 2010



Source: SamKnows measurement data for all panel members with a connection in May 2010, Panel Base: 1506

Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in May 2010 and an estimated split between nations; (3) Data collected from single-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 geographical 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 during the peak evening period of 8-10pm were on average across all panellists around 75% 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 90% of the average download speeds recorded throughout the day.
- 6.2 Both of these figures are comparable to those recorded in April 2009 when average download peak-time speeds were 77% of maximum download speeds and 90% of the average recorded throughout the day.
- 6.3 Speeds in the 'working' hours of 9am-5pm Monday to Friday were marginally (1%) faster than overall average speeds. Figure 6.1 indicates that there is a similar pattern across all types of DSL and cable services. It should be noted, however, that there is some variation between DSL providers in terms of peak-time performance (see section 8).
- 6.4 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 also 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).
- 6.5 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, May 2010

Source: SamKnows measurement data for all panel members with a connection in May 2010, Panel Base: 1506

Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in May 2010; (3) Data collected from single-thread download speed tests

On average, cable services showed greater slowdown during peak hours than DSL

6.6 Figure 6.2 shows the average download speeds delivered to panellists on DSL packages of 'up to' 8/10Mbit/s by the hour of the day. It indicates that speeds were fastest in the early morning, and slowed down during the 'peak' evening period. Average download speeds in the fastest hour of 5-6am (3.5Mbit/s) were 16% faster than the 3.0Mbit/s recorded in the slowest period of 9-10pm. For 'up to' 10Mbit/s cable services the difference between the fastest speed recorded (9.0Mbit/s at 2-3am) and the slowest (7.7Mbit/s at 9-10pm) hours was slightly higher, with the fastest speed being 18% higher than the lowest one. (It should be noted, however, that there is variation between DSL providers in terms of peak-time performance, see section 8.20).

Figure 6.2 Average download speed by hour of day for DSL panellists on 'up to' 8 and 10Mbit/s packages, May 2010



Source: SamKnows measurement data for all panel members with a connection in May 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 DSL 'up to' 8/10Mbit/s residential customers as a whole; (2) Data collected from single-thread download speed tests

Figure 6.3 Average download speed by hour of day for cable panellists on 'up to' 10Mbit/s package



Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Data have been weighted to regional coverage to ensure that they are representative of UK cable 'up to' 10Mbit/s residential customers as a whole; (2) Data collected from single-thread download speed tests

6.7 A similar pattern emerged when comparing the highest and lowest recorded hourly average download speeds for 'up to' 20/24Mbit/s DSL packages and 'up to' 20bit/s cable packages (Figures 6.4 and 6.5). Although cable customers on 'up to' 20Mbit/s packages receive significantly higher speeds than customers on 'up to' 20/24Mbit/s DSL services, the decrease in speeds was more marked for cable customers, with speeds in the fastest hour of 6-7am (16.7Mbit/s) being 19% higher than those in the slowest hour of 9-10pm (14.1Mbit/s), compared to a 14% difference between the

highest (6.8Mbit/s at 3-4am) and lowest (6.0Mbit/s at 9-10pm) values for 'up to' 20/24Mbit/s DSL packages.





Source: SamKnows measurement data for all panel members with a connection in May 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 DSL 'up to' 20/24Mbit/s residential customers as a whole; (2) Data collected from single-thread download speed tests

Figure 6.5 Average download speed by hour of day for cable panellists on 'up to' 20Mbit/s package



Source: SamKnows measurement data for panel members with a connection in May 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 single-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 DSL broadband (that is, broadband delivered over the copper wires which form the Public Switched Telephone Network or fixed voice network) and 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).
- 7.2 Outside the scope for our research was broadband accessed by dedicated fibre networks (this currently accounts for less than 0.1% 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 early 2011. Data published by measurement company Epitiro in June 2009 suggested that mobile broadband at headline speeds of 'up to' 3.6Mbit/s or 'up to' 7.2Mbit/s typically deliver average download speeds of less than 1Mbit/s, significantly slower than any DSL or cable packages.³⁶
- 7.4 Over 75% of fixed-line broadband connections in the UK are delivered by DSL 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 DSL broadband degrades as length of the line from the exchange gets longer (see Figure 4.9 above). 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 4.9 above, the speed of ADSL2+ broadband degrades more quickly over the length of the copper wire from exchange to premises than ADSL1, 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

³⁶ www.epitiro.com/news/epitiro-publishes-uk-mobile-broadband-research.html

this standard. By the end of March 2010, BT had upgraded around 850 exchanges to ADSL2+, serving around 55% of the UK population. It has announced plans to extend this to exchanges serving around 75% of the population by Spring 2011.³⁷

7.5 Over 20% of broadband connections in the UK are made via cable and Virgin Media's cable services are available to around half of UK households, delivering broadband via its hybrid fibre and co-axial cable network. Unlike DSL, cable broadband does not degrade with distance from 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 at 'up to' 50Mbit/s services.

Cable broadband services were significantly faster than DSL 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 May 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 DSL customers; on average, cable customers on 'up to' 10Mbit/s packages receive speeds more than twice as high as DSL customers on 'up to' 8 or 10Mbit/s services. The average download speeds of 'up to' 10Mbit/s cable services is faster than the average download speeds of ADSL2+ services offered at 'up to' 20 or 24Mbit/s.
- 7.8 The difference between cable and DSL was also repeated for higher-speed packages. Cable customers on a headline speed of 20Mbit/s on average receive speeds more than twice as fast as ADSL2+ packages at 'up to' 20/24Mbit/s or more. For both sets of customers, actual speeds measured using single-thread tests were well below advertised headline speed; however, as detailed in section 8.37 below, higher speeds were measured using multi-thread tests.
- 7.9 It should be noted that the average performance is based on data collected during May 2010. Many DSL operators (including BT, Sky and TalkTalk) now only advertise 'up to' 20 or 24Mbit/s packages, and are upgrading all or many of their existing customer bases from headline speeds of 'up to' 2, 8 or 10Mbit/s to packages with a headline speed of 20 or 24Mbit/s. This is likely to affect the future average performance of these higher speed packages. For example, it is logical that the mix of customers on 'up to' 20 or 24Mbit/s packages will change, as those with lines which are not physically capable of supporting speeds higher than (for example) 8Mbit/s subscribe to an 'up to' 20 or 24Mbt/s package, when previously they would

³⁷ <u>http://www.btplc.com/today/art98419.html</u>

have subscribed to an 'up to' 8Mbit/s package. The effect of this may therefore be a future fall in the average speed of 'up to' 20/24Mbit/s packages.





Source: SamKnows measurement data for all panel members with a connection in May 2010 Panel Base: 1506

Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in May 2010; (3) Data collected from single-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

- 7.10 As detailed in section 4 above, the performance of DSL services is highly dependent on distance from 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' 8 or 10Mbit/s package to an 'up to' 20 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.
- 7.11 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' 20/24Mbit/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 order to understand the maximum speed that may be available to them.³⁸ A more detailed set of factors on what should be considered when purchasing broadband is

³⁸ 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.

available in Ofcom's consumer guide to buying broadband.³⁹

³⁹ <u>http://stakeholders.ofcom.org.uk/market-data-research/telecoms-research/broadband-speeds/main/</u>

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 DSL 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.

ISP packages for whom 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):
 - AOL Broadband's 'up to' 8Mbit/s DSL service;
 - BT Retail's 'up to' 8Mbit/s and 'up to' 20Mbit/s DSL services;
 - O2/Be's 'up to' 8Mbit/s and 'up to' 20/24Mbit/s DSL services (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 DSL service;
 - Plusnet's 'up to' 8Mbit/s DSL service (note that although Plusnet is owned by BT, it was considered separately as parts of the network are different);
 - Sky's 'up to' 10Mbit/s and 'up to' 20Mbit/s DSL services;
 - TalkTalk's 'up to' 8Mbit/s and 'up to' 24Mbit/s DSL services; and
 - Virgin Media's 'up to' 10Mbit/s, 'up to' 20Mbit/s and 'up to' 50Mbit/s cable services.
- 8.3 We were only able to generate enough data to deliver statistically reliable results for ISP packages which have more than 250,000 residential customers⁴⁰; these accounted for over 90% of broadband connections in May 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 also section 2.12 above.

⁴⁰ The only exception is the Virgin Media 'up to' 50Mbit/s cable package – where the characteristics of its user base has made it possible to recruit around 50 panellists by tapping into an active online community.

- 8.4 In a change from the July 2009 report, for comparisons of ISP package performance in the present research we only used panellists who live within geographic Markets 2 and 3 (see section 3.7 above)⁴¹. 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 DSL operators who offer services using LLU, we only included 'on-net' customers, i.e. those customers who are served from an exchange which their ISP has unbundled; these operators are AOL Broadband, O2/Be, Sky and TalkTalk.⁴² In April 2010, Orange announced that it was handing control of its LLU network to BT Wholesale; accordingly, an 'on-net'/ off-net' split of Orange's customers is no longer relevant, and we therefore include all of Orange's customer base within the analysis. We have, however, weighted the data to match Orange's previous LLU/non-LLU split to ensure that our sample is representative of the whole Orange customer base.
- 8.6 It should be noted that for some LLU operators it is not always clear to consumers if 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. The end of this section explores this at an aggregate level by comparing LLU and non-LLU services (sample sizes were not sufficient to enable comparisons of off-net services by ISP).

Methodological considerations

- 8.7 In the last 12 months, some ISPs have changed their package offerings. Whereas previously they all offered 'up to' 8Mbit/s packages as standard, BT Retail and Orange now offer 'up to' 20Mbit/s as the standard on all packages, and TalkTalk offer 'up to' 24Mbit/s as the standard on all its products⁴³. However, in May 2010 these providers still had large numbers of 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). As all three operators are currently upgrading their existing base to the higher headline speed product, it was a challenge within the research to allocate panellists to the most appropriate package. However, 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 customers as on an 'up to' 20Mbit/s package, when the majority of their subscription base had purchased and were still receiving an 'up to' 8Mbit/s service.
- 8.8 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

⁴¹ This restriction was not necessary for the 2008/2009 research, as on-net and off-net performance was aggregated in reporting the performance of LLU operators. ⁴² This is a change from the July 2009 report, where we considered on-net and off-net customers in

the aggregate.

⁴³ Sky has also followed this trend, re-structuring its tariffs so that all packages are 'up to' 20Mbit/s from 1 June 2010; as the data in this report was collected in May 2010, this was not a concern in allocating Sky's customers to the most appropriate package.

the higher speed package and live 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.

- 8.9 In order to provide a like-for-like comparison, we have weighted the data for the DSL 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 DSL broadband is that performance degrades over the length of the copper wire.)
 - Data have been normalised using the straight-line distance from exchange to sixdigit 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 "unnormalised" 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 DSL customers in geographic Markets 2 and 3 (around 5%); however it does have the impact of slightly increasing the average download speeds of all DSL 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 is presented).
 - Data for the cable operator, Virgin Media, have been weighted by its network footprint in order to enable direct comparison with DSL 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.
- 8.10 We consider that the data set out below represents an accurate assessment of the comparative download speeds achieved by the ISP packages included in the research during May 2010. However, caution should be applied in drawing conclusions from this research given its limitations. In particular, we highlight the following constraints:
 - The data represents a 'snapshot' of the market in May 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. July 2010) or future performance (see section 8.7 above).
 - 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 DSL 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 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.⁴⁴
- We only consider average download speed in this section of the report. There are many other factors which affect the user experience, including upload speeds, time to load web pages, latency, packet loss and DNS resolution times. These factors are considered in section 9 of this report.
- Much of our analysis details the results from single-thread tests, i.e. speed when downloading a single-file. An alternative measure is a multi-thread test, which measures the speed when multiple files are downloaded simultaneously. We ran both types of test in the research. Analysis at the end of this section finds that there is a direct relationship between the results of single-thread and multi-thread tests (i.e. ISP packages performing faster on single-thread tests also performed faster on multi-thread tests), but that multi-thread tests typically delivered faster speeds than single-thread tests, particularly for higher speed packages. We have chosen to focus much of our analysis on single-thread tests because we have a greater volume of data to draw statistically meaningful conclusions across a number of variables, because it is a an easily understandable metric (the speed at which a single file is downloaded), and because the relative performance among ISP packages is the same for single- and multi-thread tests. Nevertheless, it must be noted that multi-thread tests represent a valid way of assessing how performance relates to advertised 'up to' speeds or access line speeds. Multi-thread test results are compared to single-thread test results in Section 8.37 below
- 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 cable services, given ease of recruitment of panel members). We are keen to include additional ISP packages going forward, if feasible, and consider the options with SamKnows. Relevant considerations include the ability to obtain a representative sample of consumers on a particular ISP package and ease of recruitment of panel members.

Results over the 24-hour period

8.11 Figure 8.1 illustrates the differences among ISP packages of 'up to' 8 or 10Mbit/s for the average of all the single-thread download speed tests run 24 hours a day, every day in May 2010. 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

⁴⁴ Voluntary Code of Practice: Broadband Speeds, www.ofcom.org.uk/telecoms/ioi/copbb/

95% probability that the actual average speed for all customers (i.e. not just customers within our sample) falls within the range shown. 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 significance (tables detailing differences at a 1% test of significance are provided in Annex 4).

8.12 Our research found that the average actual download speeds received by Virgin Media cable customers on 'up to' 10Mbit/s (8.6 to 9.0Mbit/s) were significantly higher than those delivered by any of the DSL operators' 'up to' 8 or 10Mbit/s packages included in this research. Among the DSL operators, there were not any significant differences in performance over the 24-hour period although there were differences during other times of the day (see Figures 8.10 and 8.18 below).

Figure 8.1 Average download speeds for 'up to' 8 or 10Mbit/s ISP packages, 24 hours, May 2010





Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: Small sample size (<50)

Notes: (1) Only includes DSL 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 DSL 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-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, May 2010

ISP package	Is slower than	Is faster than
AOLbb 'up to' 8Mbit/s*	Virgin Media	
BT 'up to' 8Mbit/s	Virgin Media	
O2/Be 'up to' 8Mbit/s	Virgin Media	
Orange 'up to' 8Mbit/s*	Virgin Media	
Plusnet 'up to' 8Mbit/s	Virgin Media	
Sky 'up to' 10Mbit/s	Virgin Media	
TalkTalk 'up to' 8Mbit/s	Virgin Media	
Virgin Media 'up to' 10Mbit/s		AOLbb, BT, O2/Be, Orange, Plusnet, Sky and TalkTalk

Source: Ofcom

*Caution: small sample size (<50)

- 8.13 Figure 8.3 applies the same analysis to higher speed ISP packages. Again, it finds that Virgin Media's cable service delivers significantly faster download speeds than DSL equivalents, with average download speeds of 15.2 to 16.5Mbit/s on its 'up to' 20Mbit/s service compared to average download speeds ranging from 6.1 to 9.7Mbit/s delivered by DSL providers on 'up to' 20 or 24Mbit/s packages.
- 8.14 Virgin Media's 'up to' 50Mbit/s service delivers average speeds between 33.4Mbit/s and 36.7Mbit/s. It should also be noted that these speeds are from single-thread test. Multi-thread tests delivered higher speeds for all packages, with the gap between single- and multi-thread test results increasing in proportion to speed; section 8.37 below finds that multi-thread testing of Virgin Media's 'up to' 50Mbit/s cable service delivered speeds around 9Mbit/s faster than single-thread testing.
- 8.15 Among the DSL operators, the average download speeds delivered by O2/Be were significantly faster than those delivered by BT Retail. However, this may not be the result of inherently better network performance; it may alternatively be the consequence of O2/Be having on average shorter line lengths which comes as a result of its strategy of only selling its higher speed packages to customers whose lines can support speeds higher than the 'up to' 8Mbit/s offered by its lower speed package. ⁴⁵ See Figure 8.7 for an analysis of the performance of 'up to' 20 and 24Mbit/s packages when only panellists living within 2km of the exchange are included.

⁴⁵ Because of the systematically different profile of O2/Be's customer base to that of other ISPs it was both not possible and also not appropriate to normalise line lengths to the same profile of other ISPs. Therefore, we instead weighted O2/Be to its own profile (See Annex 3 for details). It is also worth noting that O2/Be and Plusnet are the only large DSL ISPs who still price their packages primarily by speed (i.e. with higher speed services on more expensive tariffs); other operators (BT Retail, Sky, Orange) currently price primarily by usage limit (i.e. with the least expensive tariffs having a modest data cap and higher prices packages having higher or 'unlimited' data caps)

Figure 8.3 Average download speeds for 'up to' 20Mbit/s and above ISP packages, 24 hours, May 2010



Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Only includes DSL 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 DSL 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-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

Figure 8.4 Significant differences to a 95% level of confidence between average download speeds on 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, 24 hours, May 2010

ISP package	Is slower than	Is faster than
BT 'up to' 20Mbit/s	O2/Be and Virgin Media	
O2/Be 'up to' 20/24Mbit/s	Virgin Media	BT
Sky 'up to' 20Mbit/s	Virgin Media	
TalkTalk 'up to' 24Mbit/s	Virgin Media	
Virgin Media 'up to' 20Mbit/s		BT, O2/Be, Sky and TalkTalk

Source: Ofcom

- 8.16 Figures 8.5 and 8.6 compare the performance of 'up to' 8 and 10Mbit/s and 'up to' 20 and 24Mbit/s packages when only panellists who live within 2km of the exchange are included. It shows that the performance of all the DSL operator packages improved compared to the analysis including all customers within 5km of the exchange, as a result of shorter average line lengths (and therefore less degradation of speed). However, the performance of Virgin Media's cable services is still significantly faster than comparable DSL services. (Note that although the distance from exchange is immaterial for Virgin Media cable customers, we have included them in the analysis in order to illustrate how the performance of cable varies from that of DSL among this sub-set of consumers).
- 8.17 This analysis of the higher speed packages (Figure 8.6) largely adjusts for distortions created by O2/Be's different customer profile, and it finds that there is no significant difference between the speeds delivered by O2/Be and those delivered by Sky and TalkTalk.







Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: Small sample size (<50)

Notes: (1) Only includes DSL customers within 2km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for DSL 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-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 download speeds on 'up to' 8Mbit/s and 'up to' 10Mbit/s packages within 2km of the exchange, 24 hours, May 2010

ISP package	Is slower than	Is faster than
AOLbb 'up to' 8Mbit/s*	Virgin Media	
BT 'up to' 8Mbit/s	Virgin Media	
O2/Be 'up to' 8Mbit/s	Virgin Media	
Orange 'up to' 8Mbit/s*	Virgin Media	
Plusnet 'up to' 8Mbit/s	Virgin Media	
Sky 'up to' 10Mbit/s	Virgin Media	
TalkTalk 'up to' 8Mbit/s	Virgin Media	
VirginMedia 'up to' 10Mbit/s		AOLbb, BT, O2/Be, Orange, Plusnet, Sky and TalkTalk

Source: Ofcom

*Caution: small sample size (<50)

Figure 8.7 Average download speeds for 'up to' 20Mbit/s and above ISP packages for panellists within 2km of the exchange, 24 hours, May 2010





Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: Small sample size (<50)

Notes: (1) Only includes DSL customers within 2km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for DSL 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-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

Figure 8.8 Significant differences to a 95% level of confidence between average download speeds on 'up to' 20Mbit/s and 'up to' 24Mbit/s packages within 2km of the exchange, 24 hours, May 2010

ISP package	Is slower than	Is faster than
BT 'up to' 20Mbit/s	O2/Be and Virgin Media	
O2/Be 'up to' 20/24Mbit/s	Virgin Media	BT
Sky 'up to' 20Mbit/s	Virgin Media	
TalkTalk 'up to' 24Mbit/s	Virgin Media	
Virgin Media 'up to' 20Mbit/s		BT, O2/Be, Sky and TalkTalk

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

Results during peak periods

- 8.18 The effect of contention in ISPs' networks is shown in Figures 8.9 and 8.10 which look specifically at performance during the peak period between 8pm and 10pm on weekdays⁴⁶. In aggregate, performance in this peak period is around 10% slower than over the 24-hour period.
- 8.19 Figure 8.9 indicates that during these peak hours, Virgin Media's 'up to' 10Mbit/s cable service remains significantly faster than any DSL operator's 'up to' 8Mbit/s package, delivering average download speeds of 7.5 to 8.0Mbit/s, compared to the range of DSL package performance from 3.4 to 5.0Mbit/s.

⁴⁶ Data from the London Internet Exchange indicates that in data transfer in these peak evening hours are around four times as high as in the off-peak early hours of the morning, <u>https://stats.linx.net/</u>

8.20 Among the DSL operators, O2/Be and Sky were significantly faster during these peak hours than Orange, while O2/Be was also significantly faster than Plusnet. Orange also has 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. The smallest difference between average download speeds and peak-period download speeds are experienced by panellists with O2/Be and Sky packages, suggesting that these networks are least affected by contention among the ISPs for which we have data.

Figure 8.9 Average download throughput speeds for 'up to' 8 and 10Mbt/s packages, 8-10pm weekdays, May 2010

Speed (Mbit/s)



Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: Small sample size (<50)

Notes: (1) Only includes DSL 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 DSL 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-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

Figure 8.10 Significant differences to a 95% level of confidence between average speeds on 'up to' 8Mbit/s and 'up to' 10Mbit/s packages, 8-10pm weekdays, May 2010

ISP package	Is slower than	Is faster than
AOLbb 'up to' 8Mbit/s*	Virgin Media	
BT 'up to' 8Mbit/s	O2/Be and Virgin Media	
O2/Be 'up to' 8Mbit/s	Virgin Media	BT, Orange, Plusnet and TalkTalk
Orange 'up to' 8Mbit/s*	O2/Be, Sky and Virgin Media	
Plusnet 'up to' 8Mbit/s	O2/Be and Virgin Media	
Sky 'up to' 10Mbit/s	Virgin Media	Orange
TalkTalk 'up to' 8Mbit/s	O2/Be and Virgin Media	
Virgin Media 'up to' 10Mbit/s		AOL bb, BT, O2/Be, Orange, Plusnet, Sky and TalkTalk

Source: Ofcom

*Caution: small sample size (<50)

8.21 Among the 'up to' 20 and 24Mbit/s packages, Virgin Media's cable service delivers significantly faster peak-time download speeds than comparable DSL packages (13.4 to 14.9Mbit/s compared to the range of DSL package performance of 5.6 to 9.4Mbit/s. O2/Be delivered significantly faster download speeds in the peak period than BT and TalkTalk (a driver of this may be O2/Be's sales strategy where they have generally only sold higher speed packages to consumers with lines that can support higher speeds (see section 8.15 above)).

Figure 8.11 Average download throughput speeds for 'up to' 20Mbit/s and above packages, 8-10pm weekdays, May 2010



Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Only includes DSL 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 DSL 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-thread download speed tests; (5)The range shown represents a 95% confidence interval around the mean

Figure 8.12 Significant differences to a 95% level of confidence between average speeds on 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, 8-10pm weekdays, May 2010

ISP package	Is slower than	Is faster than
BT 'up to' 20Mbit/s	O2/Be and Virgin Media	
O2/Be 'up to' 20/24Mbit/s	Virgin Media	BT and TalkTalk
Sky 'up to' 20Mbit/s	Virgin Media	
TalkTalk 'up to' 24Mbit/s	O2/Be and Virgin Media	
Virgin Media 'up to' 20Mbit/s		BT, O2/Be, Sky and TalkTalk

Source: Ofcom

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

Results during 'working hours'

8.22 There were smaller differences between ISPs during the 'working hours' of between 9am and 5pm, Monday to Friday, when contention in the networks has less impact (Figure 8.13). During this period, Virgin Media's 'up to' 10Mbit/s cable service were faster than any comparable DSL operators, and there were no significant differences between any of the 'up to' 8 or 10Mbit/s DSL packages for which data were available. 8.23 Among the packages of 'up to' 20Mbit/s and over, the data for weekday 9am to 5pm is very similar to the 24-hour average data. Virgin Media's 'up to' 20Mbit/s cable package is significantly faster than comparable DSL packages, and O2/Be's 20/24Mbit/s package was faster than BT Retail's 'up to' 20Mbit/s service (again, a driver of this may be O2/Be's sales strategy where they have generally only sold higher speed packages to consumers with lines that can support higher speeds (see section 8.15 above)).

Figure 8.13 Average download speeds for 'up to' 8 and 10Mbit/s ISP packages, 9am to 5pm weekdays, May 2010



Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: Small sample size (<50)

Notes: (1) Only includes DSL 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 DSL 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-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

Figure 8.14 Significant differences to a 95% level of confidence between average speeds on 'up to' 8Mbit/s and 'up to' 10Mbit/s packages, 9am to 5pm weekdays, May 2010

ISP package	Is slower than	Is faster than
AOLbb 'up to' 8Mbit/s*	Virgin Media	
BT 'up to' 8Mbit/s	Virgin Media	
O2/Be 'up to' 8Mbit/s	Virgin Media	
Orange 'up to' 8Mbit/s*	Virgin Media	
Plusnet 'up to' 8Mbit/s	Virgin Media	
Sky 'up to' 10Mbit/s	Virgin Media	
TalkTalk 'up to' 8Mbit/s	Virgin Media	
Virgin Media 'up to' 10Mbit/s		AOL bb, BT, O2/Be, Orange, Plusnet, Sky and TalkTalk

Source: Ofcom

*Caution: small sample size (<50)





Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Only includes DSL 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 DSL 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-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

Figure 8.16 Significant differences to a 95% level of confidence between average download speeds on 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, 9am to 5pm weekdays, May 2010

ISP package	Is slower than	Is faster than
BT 'up to' 20Mbit/s	O2/Be and Virgin Media	
O2/Be 'up to' 20/24Mbit/s	Virgin Media	BT
Sky 'up to' 20Mbit/s	Virgin Media	
TalkTalk 'up to' 24Mbit/s	Virgin Media	
Virgin Media 'up to' 20Mbit/s		BT, O2/Be, Sky and TalkTalk

Source: Ofcom

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

Results during weekends

- 8.24 Average download speeds at the weekend during the hours of 10am and 10pm were very similar to the average speeds during daytime weekdays for all ISP packages (see Figures 8.17 and 8.18). Virgin Media's 'up to' 10Mbit/s package was faster than the comparable DSL services, while O2/Be's 'up to' 8Mbit/s packages was faster than Orange's.
- 8.25 Among the 'up to' 20 and 24Mbit/s package' Virgin Media's 'up to' 20Mbit/s cable package was significantly faster than comparable DSL packages, and O2/Be's 20/24Mbit/s package was faster than BT Retail's 'up to' 20Mbit/s service (once more, a driver of this may be O2/Be's sales strategy where they have generally only sold higher speed packages to consumers with lines that can support higher speeds (see section 8.15 above)).



Figure 8.17 Average download speeds for 'up to' 8 and 10Mbit/s ISP packages, 10am to 10pm weekends, May 2010

Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: Small sample size (<50)

Notes: (1) Only includes DSL 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 DSL 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-thread download speed tests; (5)The range shown represents a 95% confidence interval around the mean

Figure 8.18 Significant differences to a 95% level of confidence between average download speeds on 'up to' 8Mbit/s and 'up to' 10Mbit/s packages, 10am to 10pm weekends, May 2010

ISP package	Is slower than	Is faster than
AOLbb 'up to' 8Mbit/s*	Virgin Media	
BT 'up to' 8Mbit/s	Virgin Media	
O2/Be 'up to' 8Mbit/s	Virgin Media	Orange
Orange 'up to' 8Mbit/s*	O2/Be and Virgin Media	
Plusnet 'up to' 8Mbit/s	Virgin Media	
Sky 'up to' 10Mbit/s	Virgin Media	
TalkTalk 'up to' 8Mbit/s	Virgin Media	
Virgin Media 'up to' 10Mbit/s		AOL bb, BT, O2/Be, Orange, Plusnet, Sky and TalkTalk

Source: Ofcom

*Caution: small sample size (<50)

Figure 8.19 Average download speeds for 'up to' 20Mbit/s and above packages, 10am to 10pm weekends, May 2010



Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Only includes DSL 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 DSL 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-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

Figure 8.20 Significant differences to a 95% level of confidence between average download speeds on 'up to' 20Mbit/s and 'up to' 24Mbit/s packages, 10am to 10pm weekends, May 2010

ISP package	Is slower than	Is faster than
BT 'up to' 20Mbit/s	O2/Be and Virgin Media	
O2/Be 'up to' 20/24Mbit/s	Virgin Media	BT
Sky 'up to' 20Mbit/s	Virgin Media	
TalkTalk 'up to' 24Mbit/s	Virgin Media	
Virgin Media 'up to' 20Mbit/s		BT, O2/Be, Sky and TalkTalk

Source: Ofcom

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

Summary of results

8.26 Figures 8.21 and 8.22 depict the average performance by ISP packages in May 2010 over a 24-hour period and in the peak period of 8pm to 10pm weekdays to a 95% confidence interval around the mean.





Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: Small sample size (<50)

Notes: (1) Only includes DSL 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 DSL 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-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean





Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Only includes DSL 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 DSL 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-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

8.27 Figure 8.23 summarises the speeds achieved by all ISPs in different time periods to a 95% confidence interval around the mean.

	Average download throughput speed during period (Mbit/s)				
	24 hours	8-10pm weekdays	9am-5pm weekdays	10am-10pm weekends	1am-6am
AOLbb 'up to' 8Mbit/s*	3.6 to 4.7	3.4 to 4.4	3.7 to 4.8	3.6 to 4.7	3.7 to 4.8
BT 'up to' 8Mbit/s	3.8 to 4.5	3.4 to 4.1	3.8 to 4.5	3.7 to 4.4	3.9 to 4.7
O2/Be 'up to' 8Mbit/s	4.3 to 5.0	4.2 to 5.0	4.3 to 5.0	4.2 to 5.0	4.3 to 5.0
Orange 'up to' 8Mbit/s*	3.3 to 4.2	2.6 to 3.4	3.3 to 4.3	3.0 to 3.8	3.6 to 4.7
Plusnet 'up to' 8Mbit/s	3.3 to 4.2	3.0 to 3.9	3.3 to 4.3	3.2 to 4.1	3.4 to 4.4
Sky 'up to' 10Mbit/s	3.9 to 4.9	3.8 to 4.9	3.8 to 4.9	3.9 to 5.0	3.9 to 5.0
TalkTalk 'up to' 8Mbit/s	3.6 to 4.3	3.4 to 4.1	3.6 to 4.3	3.6 to 4.3	3.6 to 4.3
Virgin Media 'up to' 10Mbit/s	8.6 to 9.0	7.5 to 8.0	8.8 to 9.2	8.2 to 8.7	8.9 to 9.3
BT 'up to' 20Mbit/s	6.1 to 7.6	5.6 to 7.0	6.2 to 7.7	6.0 to 7.4	6.2 to 7.8
O2/Be 'up to' 20/24Mbit/s	8.1 to 9.7	7.9 to 9.4	8.1 to 9.7	8.0 to 9.5	8.2 to 9.8
Sky 'up to' 20Mbit/s	7.0 to 8.6	6.9 to 8.5	7.0 to 8.6	7.0 to 8.6	7.0 to 8.6
TalkTalk 'up to' 24Mbit/s	6.5 to 8.4	5.9 to 7.6	6.6 to 8.5	6.4 to 8.2	6.7 to 8.7
Virgin Media 'up to' 20Mbit/s	15.2 to 16.5	13.4 to 14.9	15.5 to 16.8	14.7 to 16.1	15.9 to 17.1
Virgin Media 'up to' 50Mbit/s	33.4 to 36.7	31.8 to 35.2	32.8 to 36.2	33.8 to 37.3	33.8 to 37.1

Figure 8.23 Summary of average download speed by ISP package, May 2010 (single-thread tests)

Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: Small sample size (<50)

Panel Base:1124

Notes: (1) Only includes DSL 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 DSL 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-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

8.28 As discussed above, distance from exchange is a major driver of variation for DSL broadband. Figure 8.24 below depicts the performance of higher speed packages when only panellists who live within 2km of the exchange are included. It shows that the average download speed for DSL packages were around 10- 20% higher than that including all panellists within 5km of the exchange.



Figure 8.24 Average download speeds for 'up to' 20Mbit/s and above connections within 2km of the exchange by ISP, overall and in the peak period, May 2010

Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Only includes DSL 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 DSL 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-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

- 8.29 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 8.25 and 8.26 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).
- 8.30 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 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.
- 8.31 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. There was little difference between the peak download and maximum download speeds of O2/Be and Sky's packages, meaning it is likely that their customers will typically receive consistent speeds throughout the day; by contrast peaks speeds for panellists on Orange's 'up to' 8Mbit/s package were between 60% and 70% of maximum speeds, indicating comparatively high levels of network contention.





Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: Small sample size (<50)

Notes: (1) Only includes DSL 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 DSL 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-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean





Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Only includes DSL 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 DSL 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-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

8.32 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.

8.33 Among the 'up to' 8 and 10Mbit/s DSL packages, we found that average download speeds were typically around half of advertised speeds. The primary cause of this is, as discussed above, DSL broadband speeds degrading over the length of the copper wire from exchange to premises. Unaffected by such constraints, Virgin Media's cable service delivered download speeds which were on average much closer to the headline speed (Figure 8.27).

Figure 8.27 Average download speeds (24 hours) as a proportion of headline speeds for 'up to' 8/10Mbit/s and above connections by ISP package, May 2010 (single-thread tests)



Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: Small sample size (<50)

Notes: (1) Only includes DSL 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 DSL 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-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

8.34 Among the 'up to' 20 or 24Mbit/s DSL services, actual download speeds delivered are only around 40% of advertised speeds (Figure 8.28). 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 exchange. Therefore, while the upgrade of services to ADSL2+ and 'up to' speeds of 20/24Mbit/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). Virgin Media's 'up to' 20Mbit/s and 'up to' 50Mbit/s cable services delivered a much higher proportion of advertised 'up to' download speeds, although, for these single-thread tests, the proportion was markedly lower than for its 'up to' 10Mbit/s cable service.





Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: Small sample size (<50)

Notes: (1) Only includes DSL 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 DSL 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-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

- 8.35 Multi-thread tests typically deliver faster speeds than single-thread tests (see section 8.37 below). Figures 8.29 and 8.30 show average download speeds as a proportion of advertised 'up to' speeds when multi-thread tests were run. We have data for these tests which allow us to examine the performance between 4am and 6am (off peak) and 8pm and 10pm weekdays (peak).
- 8.36 The improved performance for multi-thread tests compared to single-thread tests is most evident for the higher speed packages. Most notably, Virgin Media's 'up to' 20 and 'up to' 50Mbit/s services deliver on average around 90% of headline speeds in the off-peak hours of 4am to 6am; the 'up to' 50Mbit/s service maintains this performance in the peak weekday hours of 8pm to 10pm,and the average speed of the 'up to' 20Mbit/s cable service drops to around 80% during this peak hour (Figure 8.30)



Figure 8.29 Average download speeds (24 hours) as a proportion of headline speeds for 'up to' 8/10Mbit/s and above connections by ISP package, May 2010 (multi-thread tests)

Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: Small sample size (<50)

Notes: (1) Only includes DSL 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 DSL 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) Single-thread data collected between 8pm and 9pm and 4am and 5am, eseven days a week; multi-thread data collected between 8pm and 10pm and 4am and 6am, seven days a week; (6) The range shown represents a 95% confidence interval around the mean

Figure 8.30 Average download speeds (24 hours) as a proportion of headline speeds for 'up to' 20Mbit/s and above connections by ISP, May 2010 (single-thread tests)



Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Only includes DSL 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 DSL 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; (5) Single-thread data collected between 8pm and 9pm and 4am and 5am, eseven days a week; multi-thread data collected between 8pm and 10pm and 4am and 6am, seven days a week; (6) The range shown represents a 95% confidence interval around the mean

Differences between single-thread and multi-thread tests

- 8.37 Much of the analysis above shows the results from single-thread tests, i.e. testing the speed of download of a single file. An alternative download throughput test is a multi-thread test, which tests the speed when multiple files are downloaded simultaneously. 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.
- 8.38 We ran single-thread speeds tests every hour, and multi-thread tests (consisting of the simultaneous download of three files) twice a day for each panellist, one in the peak period between 8pm and 10pm, and another in the off-peak period between 4am and 6am (a consideration in limiting the number of multi-thread tests was the higher data requirements compared to single-thread tests, and thus the risk of impacting on the data usage caps of our volunteer panellists).
- 8.39 Among the 'up to' 8 and 10Mbit/s packages, multi-thread testing on average delivered speeds around 5% higher than single-thread tests for most ISP packages. This was consistent in both the peak period and the off-peak period (Figures 8.31 and 8.32)

Figure 8.31 Average download speeds for 'up to' 8/10Mbit/s connections by ISP, single and multi-thread test results, 4am to 6am, May 2010



Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: Small sample size (<50)

Notes: (1) Only includes DSL 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 DSL 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 8.32 Average download speeds for 'up to' 8/10Mbit/s connections by ISP, single and multi-thread test results, 8pm to 10pm, May 2010

Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: Small sample size (<50)

Notes: (1) Only includes DSL 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 DSL 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

8.39 Among the 'up to' 20 and 24Mbit/s and higher packages, multi-thread tests on average delivered speeds around 10% above those of the single-thread tests (Figures 8.33 and 8.34). However, for the Virgin Media 'up to' 50Mbit/s cable package, average download speeds for multi-thread tests were over 30% higher than for single-thread tests, an average difference of over 11Mbit/s.

Figure 8.33 Average download speeds for 'up to' 20Mbit/s and above connections by ISP, single and multi-thread test results, 4am to 6am, May 2010



Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Only includes DSL 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 DSL 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) Figures for single-thread tests are for 4-5am and 8-9pm; (6) The range shown represents a 95% confidence interval around the mean




Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Only includes DSL 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 DSL 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) Figures for single-thread tests are for 4-5am and 8-9pm; (6) The range shown represents a 95% confidence interval around the mean

	Average download throughput speed during period (Mbit/s)			
	Off-peak (4 to 6am)		Peak (8 to 10pm)	
	Multi-thread	Single-thread	Multi-thread	Single-thread
AOLbb 'up to' 8Mbit/s*	4.0 to 5.2	3.7 to 4.9	3.9 to 5.1	3.5 to 4.5
BT 'up to' 8Mbit/s	4.0 to 4.7	4.0 to 4.8	3.6 to 4.3	3.5 to 4.2
O2/Be 'up to' 8Mbit/s	4.6 to 5.4	4.3 to 5.0	4.5 to 5.4	4.2 to 5.0
Orange 'up to' 8Mbit/s*	4.1 to 5.3	3.8 to 4.9	3.4 to 4.5	2.7 to 3.5
Plusnet 'up to' 8Mbit/s	3.4 to 4.4	3.4 to 4.4	3.1 to 4.0	3.0 to 3.9
Sky 'up to' 10Mbit/s	4.1 to 5.2	3.9 to 4.9	4.1 to 5.2	3.8 to 4.9
TalkTalk 'up to' 8Mbit/s	3.8 to 4.7	3.7 to 4.4	3.7 to 4.6	3.4 to 4.1
Virgin Media 'up to' 10Mbit/s	9.1 to 9.5	9.0 to 9.4	8.2 to 8.8	7.6 to 8.2
BT 'up to' 20Mbit/s	6.4 to 8.1	6.3 to 7.8	5.9 to 7.4	5.8 to 7.1
O2/Be 'up to' 20/24Mbit/s	8.9 to 10.8	8.2 to 9.8	8.8 to 10.6	7.9 to 9.4
Sky 'up to' 20Mbit/s	7.5 to 9.3	7.0 to 8.6	7.4 to 9.2	6.9 to 8.5
TalkTalk 'up to' 24Mbit/s	7.3 to 9.7	6.7 to 8.7	7.0 to 9.3	6.0 to 7.7
Virgin Media 'up to' 20Mbit/s	17.5 to 19.0	16.3 to 17.5	15.7 to 17.3	13.8 to 15.3
Virgin Media 'up to' 50Mbit/s	45.9 to 47.4	33.9 to 37.2	44.4 to 46.5	32.5 to 35.9

Figure 8.35 Average off-peak and peak download throughput speeds by ISP package, single and multi-thread test results, May 2010

Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: Small sample size (<50)

Notes: (1) Only includes DSL 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 DSL 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-thread and multi-thread download speed tests; (5) Figures for single-thread tests are for 4-5am and 8-9pm (6) The range shown represents a 95% confidence interval around the mean;

LLU and non-LLU services

- 8.40 The comparisons of ISP packages above only include on-net panellists for LLU operators (LLU is where operators install their own equipment within the local telephone exchange and establish a backhaul connection between this equipment and its core network). However, most LLU operators also provide 'off-net' services to consumers who live in areas where they have not unbundled the local exchange.
- 8.41 Figure 8.36 shows that overall the speeds delivered to customers who receive DSL services via LLU are faster than those delivered to customers who receive services which are delivered via wholesale DSL (i.e. when operators do not have equipment within an exchange, but instead rent connections from wholesale providers).
- 8.42 These differences are likely to be caused by LLU operators typically having less contention in their own network, than when they rent backhaul from a wholesale provider (most commonly, BT Wholesale's *ADSL Max* product for 'up to' 8Mbit/s services, and *Wholesale Broadband Connect* (WBC) product for 'up to' 20/24Mbit/s services) and the fact that unbundled exchanged tend to be in urban areas where average line lengths are shorter. Higher levels of contention among non-LLU connections are indicated by a greater slowdown during the evening peak period of 8-10pm.

Figure 8.36	Average download speeds for LLU and non-LLU DSL services, May
2010	



Source: SamKnows measurement data for all panel members with a connection in May 2010, Notes: Data collected from single-thread download speed tests; (2) The range shown represents a 95% confidence interval around the mean

Section 9

Other metrics affecting performance

9.1 The performance of a broadband connection is not determined by download speeds alone. 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.

Variable	Definition and importance
Upload speed	The rate at which a connection can upload content to the wider internet
	Upload speeds matter to those looking to share large files, use real-time video
	communications and for some online games
Web browsing speed	The time taken to fetch the main HTML (text and basic code) from a website
	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
Packetloss	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 fail or operate slowly, web browsing and other activities suffer,
	and a DNS failure results in error messages such as "Host could not be found"
Jitter	Measures the 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.

Figure 9.1 Summary of additional metrics covered in the research

Source: Ofcom

Upload speeds

- 9.2 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.
- 9.3 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 0.4 to 0.6Mbit/s for all of the 'up to' 8 and 10Mbit/s ISP packages considered in our research with the exception of O2/Be's 'up to' 8Mbit/s service, which had an average upload speed of nearly 1Mbit/s, in part due to the fact that its 'up to' 8Mbit/s LLU service offers headline upload speeds of 'up to' 1.3Mbit/s, higher than those of comparable DSL packages. Despite delivering download speeds around twice as high as comparable DSL services, Virgin Media's 'up to' 10Mbit/s cable package delivered average upload speeds in line with those of most comparable DSL service, as were all of the other 'up to' 8/10Mbit/s ISP packages covered by our research (Figure 9.2).



Figure 9.2 Maximum, average and peak time upload speeds for 'up to' 8 and 10Mbit/s ISP packages, May 2010

Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: small sample size (<50),

Notes: (1) Only includes DSL 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 DSL 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

9.4 Upload speeds for ISPs' 'up to' 20/24Mbit/s DSL packages were all slightly higher than for their 'up to' 8/10Mbit/s services (Figure 9.3). O2/Be's 'up to' 20/24Mbit/s service also performed better than most other 'up to' 20 or 24Mbit/s packages, with its average upload speed of around 1.1Mbit/s being significantly higher than the 0.6 to 0.8Mbit/s recorded for other ISP 'up to' 20 or 24Mbit/s packages. Virgin Media's 'up to' 50Mbit/s service delivered the fastest upload speeds among the ISP packages considered in our research, with average upload speeds of around 1.7Mbit/s.

Figure 9.3 Maximum, average and peak time upload speeds for 'up to' 20Mbit/s and above ISP packages, May 2010



Source: SamKnows measurement data for all panel members with a connection in May 2010), Notes: (1) Only includes DSL 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 DSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean

Web browsing

- 9.5 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.
- 9.6 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 (i.e. text and basic code) from the home pages of three of the UK's most popular web sites. Note that tests were designed to ensure that pages were not cached.
- 9.7 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 section 9.9 below).
- 9.8 Robust web page download speed data was only available for four of the 'up to' 8/10Mbit/s ISP packages covered by our research, and among these the only statistically significant difference in performance was that Virgin Media's 'up to' 10Mbit/s cable service had faster web page loading times than BT's 'up to' 8Mbit/s service on average across the whole day. There were no significant variations in performance among the higher speed services for which we had data. (Note that in Figures 9.4 and 9.5 better performance is faster loading times, which are indicated by lower bars).

Figure 9.4 Average and peak time loading of web pages for 'up to' 8 and 10Mbit/s ISP packages, May 2010



Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Only includes DSL 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 DSL 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.

Milliseconds



Figure 9.5 Average and peak time loading of web pages for 'up to' 20Mbit/s and above ISP packages, May 2010

Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: small sample size (<50)Notes: (1) Only includes DSL 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 DSL 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

- 9.9 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.
- 9.10 There was a wide range of performance among the lower speed packages covered by our research. O2/Be's 'up to' 8Mbit/s service was significantly better in terms of latency than AOL Broadband, Orange, Sky and TalkTalk's 'up to' 8/10Mbit/s services over the 24-hour period and in the peak period. Among the higher ISP speed packagesO2/Be's 'up to' 20/24Mbit/s service also performed relatively well, and had lower levels of latency than BT, Sky and TalkTalk's 'up to' 20/24Mbit/s packages. (Note that in Figures 9.6 and 9.7 better performance is lower speeds, which are indicated by lower bars.)



Figure 9.6 Latency for 'up to' 8 and 10Mbit/s ISP packages: average and peak times, May 2010

Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: small sample size (<50)

Notes: (1) Only includes DSL 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 DSL 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).





Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Only includes DSL 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 DSL 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

9.11 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).

9.12 Levels of packet loss were low among all of the ISP packages covered by our research, with none having loss of more than 2% (meaning that it is unlikely that users would experience any noticeable degradation of service). TalkTalk's 'up to' 8Mbit/s service had higher packet loss than all of the other 'up to' 8 and 10Mbit/s services covered by the research except Orange's, while its 'up to' 24Mbit/s services had higher packet loss than all of the other higher speed packages covered by our research. (Note that in Figures 9.8 and 9.9 better performance is lower packet loss, which is indicated by lower bars.)





Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: small sample size (<50)

Notes: (1) Only includes DSL 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 DSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Note that better performance is indicated by lower packet loss (i.e. lower values).



Figure 9.9 Average packet loss for 'up to' 20Mbit/s and above ISP packages, May 2010

Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Only includes DSL 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 DSL 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

- DNS (the domain name service) plays a crucial role in the internet. This protocol 9.13 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. A slow DNS time does not affect download speed, but can severely affect the responsiveness of the internet while browsing. 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".
- 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' 8 and 10Mbit/s packages most average resolution speeds fell within a range of 40 to 70ms, 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 9.10 and 9.11 better performance is faster resolution times, which are indicated by lower bars.)



Figure 9.10 Average and peak time DNS resolution time by ISP and package for 'up to' 8 and 10Mbit/s packages, May 2010

Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: small sample size (<50)

Notes: (1) Only includes DSL 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 DSL 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 Average DNS resolution times for the higher speed packages were broadly similar to those of the 'up to' 8Mbit/s and 10Mbit/s packages, and Virgin Media's 'up to' 20Mbit/s cable services performed better than all of the other 'up to' 20 and 24Mbit/s ISP packages covered by our research, both across the whole day and during the 8-10pm weekday peak period.

Figure 9.11 Average and peak time DNS resolution time by ISP and package for 'up to' 20Mbit/s and above packages, May 2010



Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Only includes DSL 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 DSL 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

- 9.16 '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).
- 9.17 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.
- 9.18 Both Virgin Media's 'up to' 10Mbit/s and 'up to' 20Mbit/s services had higher rates of jitter than the comparable DSL packages covered in this report. All of the DSL ISP packages covered by our research (both lower and higher speed) had similar levels of jitter, with 95% confidence ranges being under 2ms over the whole day and during the 8-10pm weekday period. (Note that in Figures 9.12 and 9.13 better performance is indicated by shorter times, which are indicated by lower bars.)

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



Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: small sample size (<50)

Notes: (1) Only includes DSL 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 DSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Note that better performance is indicated by shorter times (i.e. lower values).



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

Milliseconds

Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Only includes DSL 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 DSL 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

Conclusion and next steps

Implications for consumers

- 10.1 This research report is a representative snapshot of broadband performance of the ISP packages included in the research in May 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.
- 10.2 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.
- 10.3 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, and outside the scope of this research mobile broadband, satellite and fibre-to-the-home or fibre-to-the-cabinet). For DSL 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 premises and 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' 8/10Mbit/s to 'up to' 20/24Mbit/s is unlikely to make any difference to the actual speeds delivered.
- 10.4 The research data, and the evidence we have considered on access line speeds (see sections 4.19 to 4.25) shows that consumers are currently getting a very wide variety of access line and actual speeds. It also indicates that many consumers could significantly improve the speeds they obtain if they took some relatively simple steps, such as fitting an *iPlate*. We have separately published an updated consumer guide on how consumers can improve their broadband speeds and on factors we think consumers might wish to consider when buying broadband services.⁴⁷

Implications for ISPs

10.5 The research has 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 they are giving their customers sufficient information, which is clear and accurate, about the services they provide and the types of factors that may impact on the actual speed they will receive. This is important to help consumers make more informed choices, and to manage

⁴⁷ 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 will implement the new Code over the next year – some of them will have to make major systems changes as a result but all have committed to complying with the new Code within 12 months.
- 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 which 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. The Committee on Advertising Practice (CAP) are conducting a review of how broadband is currently advertised which may lead to new guidelines on how broadband is advertised.
- 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 continues to meet their needs, including through the deployment of superfast broadband services which increasing numbers of consumers may want to use in the future.

Next steps

- 10.6 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 current round of research into residential fixed-line broadband speeds is continuing and we plan to publish results every six months, with the next report due to be published in January 2011.
- 10.7 With around 15% of households now taking mobile broadband, and around half of these having it as their sole internet connection, it is important that similar research is available on mobile broadband performance. We have commissioned separate research into the performance of mobile broadband with data collection due to take place in autumn 2010 and a report scheduled for publication in early 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 July 2010 all of BT's nationally available 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 DSL 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 standard Linux tools (where possible) to perform the tests, such as *ping*, *dig*, *curl*, *iperf* and *tcpdump/*.

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 on broadband services of `up to' 10Mbit/s use a 1MB file on the download test. Units on broadband services of greater than 10Mbit/s use a 3MB file. The relatively small size of these files is compensated for by having a 100KB leadin 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 3 MB 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 webservers 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 for all units used 1MB file.

Single-thread download tests run once every hour and upload tests every 2 hours (alternating between odd and even hours on a daily basis). Multi-thread test run twice a day, once during the peak evening period and once in the early hours. Typically the download speeds achieved using the multi-thread test 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

This test utilises the *curl* utility to fetch the main HTML body of a website. Note that additional resources, such as images, embedded media, stylesheets and other external files are not fetched as a part of this test.

The time in milliseconds to receive the complete response from the webserver is recorded, as well as any failed attempts. A failed attempt is deemed to be one where the webserver cannot be reached, or where a HTTP status code of something other than 200 is encountered.

Three popular UK-based websites are used for the purposes of this test and tests are run every hour.

Testing ICMP latency and packet loss

Testing latency and packet loss is most commonly performed using the Unix utility ping and this solution is no different. In keeping with good practice, the first ping reply from any host is ignored (due to the delay in potentially having to ARP for the gateway) and an average of the following two is recorded as the result. This in keeping with how Cisco's IPSLA solution performs its ping tests.

Three external hosts were 'pinged' for the purposes of this test. The average round trip time of the tests as well as the number of packets lost was recorded.

Ping tests were performed 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.

Testing jitter

This test emulates the properties of a Voice over IP phone call in an attempt to determine how suitable the line is for VoIP purposes. Note that an actual VoIP call is not made – but the characteristics of it are emulated.

The test sends a 10 second burst of UDP traffic to one of three target servers residing on our network. Each UDP packet contains 160 bytes, and the traffic is sent at 64kbps. These characteristics match those of the G.711 [4] voice codec. Tests are run every hour.

Please note: This only tests upstream bandwidth. Due to NAT implementation issues on some volunteers' routers, downstream testing proved too unreliable.

Also note: Our test assumes a worst case jitter buffer of zero milliseconds. Most VoIP capable routers (those that natively support VoIP channels) incorporate a small ~20ms jitter buffer nowadays.

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.

Quotas were set by Geographic Market classification (see section 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 43% of the sample contributing less than 0.5 a response towards the UK average; this will increase over the course of the study as take-up of higher speed packages increases (many DSL operators are currently in the process of migrating 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 (8% of the total in May 2010, and which we expect to fall further during the course of the research). 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.

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 2,005 measurement units were despatched, and 1,660 of these were connected by participants between 19 April and 30 May 2010. Of these, 1,506 supplied data to the UK average, and 1,124 to the named ISP package comparisons.

Figure 1 Panellist numbers

Sample set	Number
Total number of boxes dispatched	
Total number of boxes connected	1,660
Excluded because of missing data, (i.e. measurements, packages, distance)	31
Excluded 'up to'2Mbit/s	38
Other Exclusions to improve UK sample weighting (i.e. distance, market classification, region, ISP)	85
Total participants included in UK Analysis	1,506
Total participants included in ISP Package Analysis	

Source: Ofcom

All measurement data was collated and stored for analysis purposes as a monthly average of the measurements obtained for each respondent for the relevant time interval (e.g. 24 hours, 8-10pm weekday, 9am-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. 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. 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 Orange did not achieve the minimum threshold of 50 against the specific criteria required, but are included in these findings with a warning regarding small sample size. Despite its relatively low number of subscribers, we were able to achieve more than 50 subscribers for Virgin Media's 'up to' 50Mbit/s cable package, which is included in ISP-specific results.

Sample panels

The results and analysis of the 1,506 panellists' measurement results were divided into two separate datasets, each weighted to targets.

• **National Panel** (over 'up to' 2Mbit/s packages): 1,506 panellists. All with at least five valid test measurements across all download tests, with a validated IP address, single measurement speed check and distance, region 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**: 1,124 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 minimum of 30 valid panellists (with those with less than 50 marked that, because of the small sample size, findings should be treated with caution).

Additional validation for the ISP Package Panel included a review of measured speed against straight line distance from the exchange to the panellist's premises, and an individual review of test measurement histories 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 each ISP's LLU (or Market 2 & 3) regional footprint and distance from exchange (those panellists with an unrecorded or straight-line distance to the exchange of more than 5km were excluded):
 - 'Up to' 8/10Mbit/s DSL 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' 20/24Mbit/s DSL 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

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 <u>www.samknows.com/broadband/signup/ofcom</u>) 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, headline speed, price and download limit (where they allowed identification of the correct ISP package) were used to assign participants to an ISP package. In order to be considered valid, at least two of package name, headline speed and price had to be consistent.
- 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, region and Geographic Market classification were added to the measurement data.
 - 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 DSL connection who were connected to an ADSL2+ enabled exchange were considered for the 20/24Mbit/s package allocation.
 - Any participant who received maximum speeds higher than the headline speed of the package they had stated they were on was reassigned to the next highest speed package offered by their ISP.
 - Statistical analysis of maximum speed and distance from exchange identified a feature consistent with a number of participants self assigned as 'up to' 8Mbit/s customers receiving speeds capped at 2Mbit/s or less. The following selection criteria were used to eliminate those participants from the 'up to' 8Mbit/s analysis, this affected 7% of the 'up to' 8Mbit/s DSL participants:
 - Participants with a DSL connection who lived closer than 1km to the local exchange and received maximum speeds of between 1.5Mbit/s and 2.5Mbit/s were assumed to be on headline packages of 'up to' 2Mbit/s for analysis purposes.
 - Statistical analysis of maximum speed and distance from exchange identified a feature consistent with a number of participants self assigned as 'up to' 20/24Mbit/s customers receiving speeds capped at 8/10Mbit/s or less. The following selection criteria were used to eliminate those participants from the 'up to' 20/24Mbit/s analysis, this affected 3% of the 'up to' 20/24Mbit/s DSL participants:
 - Participants with a DSL connection who lived closer than 1km to the local exchange and received maximum speeds of between 7 and 8Mbit/s were assumed to be on headline packages of 'up to' 8/10Mbit/s for analysis purposes.

Weighting to distance from exchange

As performance of DSL 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' 8/10Mbit/s and 20/24Mbit/s datasets.

National Panel

The average line lengths in the National (greater than 'up to' 2Mbit/s packages) sample were shorter than those observed in April 2009, as those panellists on the higher speed packages had on average shorter line lengths, and these formed a significantly higher proportion of the sample.

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. This was modelled as a Gamma distribution and the 'up to' 8/10Mbit/s DSL 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' 8/10Mbit/s packages and those on 'up to' 20/24Mbit/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' 20/24Mbit/s packages were instead normalised by weighting each to the aggregate distribution of line length among all 20/24Mbit/s panellists.

Aggregate 20/24 Mbit/s line length distribution: Gamma a=2.170 b=619

O2/Be panellists on 'up to' 20/24Mbit/s packages had significantly fewer line lengths over 2km from the exchange, average 1,097m, when compared against the aggregate 'up to' 20/24 Mbit/s distribution of 1,380 m, and an average line length after normalisation of 1,283m. This could have occurred by random sampling, as a reflection of an underlying sales strategy, or a combination of both. The normalisation is not as effective, and the results should be treated with caution.

Comparative data only showing performance among subscribers less than 2km from the exchange, reduces the difference between DSL providers, but does not alter the statistical significance of the observed differences.

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 addition to LLU regional footprint and distance from exchange.
- TalkTalk and Tiscali are reported combined as a single ISP package entity, but the performance of legacy Tiscali connections are statistically different from TalkTalk connections. The **TalkTalk 'up to' 8Mbit/s package** and **TalkTalk 'up to' 24Mbit/s** package was therefore weighted in addition to legacy 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' 8/10Mbit/s packages, and one for ISP 'up to' 20/24Mbit/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.

ISP package panellists were recruited in line with regional (10 regions) coverage of broadband take-up across the UK. The interaction between regional coverage and distance, led to the aggregation of regions to just four categories, when weighting ISP packages to LLU footprint and distance from exchange: South, North, East/Midlands, Nations (other than England)

Weighting Efficiency

Overall, against the entire weight frame, the National Panel achieved a weighting efficiency of 50.1%. 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 regional and market shortfall and distance from exchange.

Figure 2 National Panel range of weights

Range	Count	Column N%
Less than 0.5	640	42.5%
0.5 to 2	722	47.9%
2 to 4	121	8.0%
4 to 6	22	1.5%
over6	1	0.1%

Source: Ofcom

Figure 3 National Panel weight extremes by reported category

		Excluding LLU and Market classification		
		Minimum	Maximum	% of sample weights in the range 0.5-2
Technology	Non-LLU DSL	.004020	10.329694	44.1
	LLUDSL	.016854	5.821198	45.0
	Cable	.028403	4.640284	54.4
Urban / rural	Urban	.008937	10.329694	49.1
	Rural	.004020	5.829155	36.1
Market classification	Market 1	.004020	5.829155	39.4
	Market2	.005271	4.518613	48.8
	Market3	.007178	10.329694	47.1

Source: Ofcom

Overall, against the entire weight frame, the ISP Package Panel achieved a weighting efficiency of 78%. The under 0.5s are primarily driven by shorter line lengths on the high speed packages and regional over representation in London and the South East, the over 2's primarily from the small sample size of some ISP Packages in the panel currently.

Figure 4 ISP Package Panel range of weights

Weights	Count	Column N %
Less than 0.5	127	11.3%
0.5 to 2	943	83.8%
2 to 4	48	4.3%
4 to 6	6	0.5%
over6	1	0.1%

Source: Ofcom

ISP package	Weighting efficiency
AOL Broadband 'up to' 8Mbit/s	58%
BT 'up to' 8Mbit/s	91%
O2/Be 'up to' 8Mbit/s	50%
Orange 'up to' 8Mbit/s	69%
Plusnet 'up to' 8Mbit/s	75%
Sky 'up to' 10Mbit/s	87%
TalkTalk 'up to' 8Mbit/s	59%
Virgin Media 'up to' 10Mbit/s	84%
BT 'up to' 20Mbit/s	94%
O2/Be 'up to' 20/24Mbit/s	80%
Sky 'up to' 20Mbit/s	96%
TalkTalk 'up to' 24Mbit/s	83%
Virgin Media 'up to' 20Mbit/s	91%
Virgin Media 'up to' 50Mbit/s	89%

Figure 5 Weighting Efficiency by ISP package

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' 8/10Mbit/s connections by ISP, 24 hours, weighted and unweighted figures, May 2010



Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: small sample size (<50)

Notes: (1) Only includes DSL 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 DSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange, weighted data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from single-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.



Figure 7Average download speed for 'up to' 20Mbit/s and above connectionsby ISP, 24 hours, weighted and unweighted figures, May 2010

Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Only includes DSL 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 DSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange, weighted data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from single-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' 8/10Mbit/s connections by ISP, 24 hours, weighted and unweighted figures, May 2010



Source: SamKnows measurement data for all panel members with a connection in May 2010 *Caution: small sample size (<50)

Notes: (1) Only includes DSL 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 DSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange, weighted data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from single-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, May 2010

Source: SamKnows measurement data for all panel members with a connection in May 2010 Notes: (1) Only includes DSL 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 DSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange, weighted data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from single-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 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 download speeds between ISP packages

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

ISP package	Is slower than	Is faster than
AOLbb 'up to' 8Mbit/s*	Virgin Media	
BT 'up to' 8Mbit/s	Virgin Media	
O2/Be 'up to' 8Mbit/s	Virgin Media	
Orange 'up to' 8Mbit/s*	Virgin Media	
Plusnet 'up to' 8Mbit/s	Virgin Media	
Sky 'up to' 10Mbit/s	Virgin Media	
TalkTalk 'up to' 8Mbit/s	Virgin Media	
Virgin Media 'up to' 10Mbit/s		AOL bb, BT, O2/Be, Orange, Plusnet, Sky and TalkTalk

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 'up to' 24Mbit/s connections, 24 hours, May 2010

ISP package	Is slower than	Is faster than
BT 'up to' 20Mbit/s	O2/Be and Virgin Media	
O2/Be 'up to' 20/24Mbit/s	Virgin Media	BT
Sky 'up to' 20Mbit/s	Virgin Media	
TalkTalk 'up to' 24Mbit/s	Virgin Media	
Virgin Media 'up to' 20Mbit/s		BT, O2/Be, Sky and TalkTalk

Source: Ofcom

Figure 3 Significant differences to a 99% level of confidence between average speeds on 'up to' 8Mbit/s and 'up to' 10Mbit/s connections within 2km of the exchange, 24 hours, May 2010

ISP package	Is slower than	Is faster than
AOLbb 'up to' 8Mbit/s*	Virgin Media	
BT 'up to' 8Mbit/s	Virgin Media	
O2/Be 'up to' 8Mbit/s	Virgin Media	
Orange 'up to' 8Mbit/s*	Virgin Media	
Plusnet 'up to' 8Mbit/s	Virgin Media	
Sky 'up to' 10Mbit/s	Virgin Media	
TalkTalk 'up to' 8Mbit/s	Virgin Media	
Virgin Media 'up to' 10Mbit/s		AOL bb, BT, O2/Be, Orange, Plusnet, Sky and TalkTalk

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 'up to' 24Mbit/s connections within 2km of the exchange, 24 hours, May 2010

ISP package	Is slower than	Is faster than
BT 'up to' 20Mbit/s	Virgin Media	
O2/Be 'up to' 20/24Mbit/s	Virgin Media	
Sky 'up to' 20Mbit/s	Virgin Media	
TalkTalk 'up to' 24Mbit/s	Virgin Media	
Virgin Media 'up to' 20Mbit/s		BT, O2/Be, Sky and TalkTalk

Source: Ofcom

Figure 5 Significant differences to a 99% level of confidence between average speeds on 'up to' 8Mbit/s and 'up to' 10Mbit/s connections, 8-10pm weekdays, May 2010

ISP package	Is slower than	Is faster than
AOLbb 'up to' 8Mbit/s*	Virgin Media	
BT 'up to' 8Mbit/s	Virgin Media	
O2/Be 'up to' 8Mbit/s	Virgin Media	Orange and Plusnet
Orange 'up to' 8Mbit/s*	O2/Be, Sky and Virgin Media	
Plusnet 'up to' 8Mbit/s	O2/Be and Virgin Media	
Sky 'up to' 10Mbit/s	Virgin Media	Orange
TalkTalk 'up to' 8Mbit/s	Virgin Media	
Virgin Media 'up to' 10Mbit/s		AOL bb, BT, O2/Be, Orange, Plusnet, Sky and TalkTalk

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 speeds on 'up to' 20Mbit/s and 'up to' 24Mbit/s connections, 8-10pm weekdays, May 2010

ISP package	Is slower than	Is faster than
BT 'up to' 20Mbit/s	O2/Be and Virgin Media	
O2/Be 'up to' 20/24Mbit/s	Virgin Media	BT
Sky 'up to' 20Mbit/s	Virgin Media	
TalkTalk 'up to' 24Mbit/s	Virgin Media	
Virgin Media 'up to' 20Mbit/s		BT, O2/Be, Sky and TalkTalk

Source: Ofcom

Figure 7 Significant differences to a 99% level of confidence between average speeds on 'up to' 8Mbit/s and 'up to' 10Mbit/s connections, 9am to 5pm weekdays, May 2010

ISP package	Is slower than	Is faster than
AOLbb 'up to' 8Mbit/s*	Virgin Media	
BT 'up to' 8Mbit/s	Virgin Media	
O2/Be 'up to' 8Mbit/s	Virgin Media	
Orange 'up to' 8Mbit/s*	Virgin Media	
Plusnet 'up to' 8Mbit/s	Virgin Media	
Sky 'up to' 10Mbit/s	Virgin Media	
TalkTalk 'up to' 8Mbit/s	Virgin Media	
Virgin Media 'up to' 10Mbit/s		AOL bb, BT, O2/Be, Orange, Plusnet, Sky and TalkTalk

Source: Ofcom

*Caution: small sample size

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

Figure 8 Significant differences to a 99% level of confidence between average speeds on 'up to' 20Mbit/s and 'up to' 24Mbit/s connections, 9am to 5pm weekdays, May 2010

ISP package	Is slower than	Is faster than
BT 'up to' 20Mbit/s	O2/Be and Virgin Media	
O2/Be 'up to' 20/24Mbit/s	Virgin Media	BT
Sky 'up to' 20Mbit/s	Virgin Media	
TalkTalk 'up to' 24Mbit/s	Virgin Media	
Virgin Media 'up to' 20Mbit/s		BT, O2/Be, Sky and TalkTalk

Source: Ofcom

Figure 9 Significant differences to a 99% level of confidence between average speeds on 'up to' 8Mbit/s and 'up to' 10Mbit/s connections, 10am to 10pm weekends, May 2010

ISP package	Is slower than	Is faster than
AOLbb 'up to' 8Mbit/s*	Virgin Media	
BT 'up to' 8Mbit/s	Virgin Media	
O2/Be 'up to' 8Mbit/s	Virgin Media	
Orange 'up to' 8Mbit/s*	Virgin Media	
Plusnet 'up to' 8Mbit/s	Virgin Media	
Sky 'up to' 10Mbit/s	Virgin Media	
TalkTalk 'up to' 8Mbit/s	Virgin Media	
Virgin Media 'up to' 10Mbit/s		AOL bb, BT, O2/Be, Orange, Plusnet, Sky and TalkTalk

Source: Ofcom

*Caution: small sample size

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

Figure 10 Significant differences to a 99% level of confidence between average speeds on 'up to' 20Mbit/s and 'up to' 24Mbit/s connections, 10am to 10pm weekends, May 2010

ISP package	Is slower than	Is faster than
BT 'up to' 20Mbit/s	O2/Be and Virgin Media	
O2/Be 'up to' 20/24Mbit/s	Virgin Media	BT
Sky 'up to' 20Mbit/s	Virgin Media	
TalkTalk 'up to' 24Mbit/s	Virgin Media	
Virgin Media 'up to' 20Mbit/s		BT, O2/Be, Sky and TalkTalk

Source: Ofcom

3. Significant differences in other performance measures between ISP packages

To a 95% level of confidence

Figure 11 Significant differences to a 95% level of confidence between average, peak time and maximum upload speeds on 'up to' 8Mbit/s and 'up to' 10Mbit/s connections, May 2010

	24 ho	ours	8-10pm v	veekday	Maxi	mum
ISP package	ls slower than	ls faster than	ls slower than	ls faster than	ls slower than	ls faster than
AOLbb 'up to' 8Mbit/s*	O2/Be and Sky		O2/Be		O2/Be and Sky	
BT 'up to' 8Mbit/s	O2/Be, Orange, Sky and Virgin		O2/Be, Orange and Sky		O2/Be, Orange, Sky, TalkTalk and Virgin	
O2/Be 'up to' 8Mbit/s		AOLbb, BT, Orange, Plusnet, Sky, TalkTalk and Virgin		AOL bb, BT, Orange, Plusnet, Sky, TalkTalk and Virgin		AOLbb, BT, Orange, Plusnet, Sky, TalkTalk and Virgin
Orange 'up to' 8Mbit/s*	O2/Be	BT and Plusnet	O2/Be	BT and Plusnet	O2/Be	BT and Plusnet
Plusnet 'up to' 8Mbit/s	O2/Be, Orange, Sky and Virgin		O2/Be, Orange and Sky		O2/Be, Orange, Sky, TalkTalk and Virgin	
Sky 'up to' 10Mbit/s	O2/Be	AOLbb, BT, Plusnet and TalkTalk	O2/Be	BT, Plusnet and and Virgin	O2/Be	AOLbb, BT, Plusnet and Virgin
TalkTalk 'up to' 8Mbit/s	O2/Be and Sky		O2/Be		O2/Be	BT and Plusnet
Virgin Media 'up to' 10Mbit/s	O2/Be	BT and Plusnet	O2/Be and Sky		O2/Be and Sky	BT and Plusnet

Source: Ofcom

*Caution: small sample size
Figure 12 Significant differences to a 95% level of confidence between average, peak time and maximum upload speeds on 'up to' 20Mbit/s and 'up to' 24Mbit/s connections, May 2010

	24 hours		8-10pm weekday		Maxi	mum
ISP package	ls slower than	ls faster than	ls slower than	ls faster than	ls slower than	ls faster than
BT 'up to' 20Mbit/s	O2/Be, Sky and TalkTalk		O2/Be, Sky and TalkTalk		O2/Be, Sky, TalkTalk and Virgin	
O2/Be 'up to' 20/24Mbit/s		BT, Sky, TalkTalk and Virgin		BT, Sky, TalkTalk and Virgin		BT, Sky, TalkTalk and Virgin
Sky 'up to' 20Mbit/s	O2/Be	BT	O2/Be	BT	O2/Be	BT
TalkTalk 'up to' 24Mbit/s	O2/Be	BT	O2/Be	BT	O2/Be	BT
Virgin Media 'up to' 20Mbit/s	O2/Be		O2/Be		O2/Be	BT

Figure 13 Significant differences to a 95% level of confidence between average and peak time to load web pages by ISP and package for 'up to' 8 and 10Mbit/s ISP connections, May 2010

	24 hc	ours	8-10pm weekday		
ISP package	Is slower than	Is faster than	Is slower than	Is faster than	
BT 'up to' 8Mbit/s	Virgin				
O2/Be 'up to' 8Mbit/s					
Sky 'up to' 10Mbit/s					
Virgin Media 'up to' 10Mbit/s		BT			

Source: Ofcom *Caution: small sample size

Figure 14 Significant differences to a 95% level of confidence between average and peak time to load web pages by ISP and package for 'up to' 20 and 24Mbit/s ISP connections, May 2010

	24 hours		8-10pm weekday		
ISP package	Is slower than	ls faster than	Is slower than	Is faster than	
BT 'up to' 20Mbit/s					
O2/Be 'up to'					
20/24Mbit/s					
Sky 'up to'					
20Mbit/s					
Virgin Media 'up					

Note: There are no significant variations between ISP packages Source: Ofcom

Figure 15 Significant differences to a 95% level of confidence between average and peak time latency by ISP and package for 'up to' 8 and 10Mbit/s connections, average and peak times, May 2010

	24 hc	ours	8-10pm weekday	
ISP package	Is slower than	Is faster than	Is slower than	Is faster than
AOLbb 'up to' 8Mbit/s*	O2/Be	TalkTalk		
BT 'up to' 8Mbit/s		Sky and TalkTalk		TalkTalk
O2/Be 'up to' 8Mbit/s		AOLbb, Orange, Sky, TalkTalk and Virgin		Sky, TalkTalk and Virgin
Orange 'up to' 8Mbit/s*	O2/Be and Plusnet	TalkTalk		
Plusnet 'up to' 8Mbit/s		Orange, Sky and TalkTalk		TalkTalk
Sky 'up to' 10Mbit/s	BT, O2/Be, Plusnet and Virgin		O2/Be	
TalkTalk 'up to' 8Mbit/s	AOLbb, BT, O2/Be, Orange, Plusnet and Virgin		BT, O2/Be, Plusnet and Virgin	
Virgin Media 'up to' 10Mbit/s	O2/Be	TalkTalk and Virgin	O2/Be	TalkTalk

Source: Ofcom

*Caution: small sample size

Note: Better performance is indicated by lower speeds (i.e. faster)

Figure 16 Significant differences to a 95% level of confidence between average and peak time latency by ISP and package for 'up to' 20 and 24Mbit/s connections, average and peak times, May 2010

	24 hc	ours	8-10pm weekday		
ISP package	Is slower than	Is faster than	Is slower than	Is faster than	
BT 'up to' 20Mbit/s	O2/Be and Virgin		O2/Be		
O2/Be 'up to' 20/24Mbit/s		BT, Sky and TalkTalk		BT, Sky and TalkTalk	
Sky 'up to' 20Mbit/s	O2/Be and Virgin	TalkTalk	O2/Be	TalkTalk	
TalkTalk 'up to' 24Mbit/s	O2/Be, Sky and Virgin		O2/Be, Sky and Virgin		
Virgin Media 'up to' 20Mbit/s		BT, Sky and TalkTalk		TalkTalk	

Source: Ofcom

Figure 17 Significant differences to a 95% level of confidence between average packet loss by ISP and package for 'up to' 8 and 10Mbit/s connections, May 2010

	24 h	ours
ISP package	Is worse than	Is better than
AOLbb 'up to' 8Mbit/s*		TalkTalk
BT 'up to' 8Mbit/s		TalkTalk
O2/Be 'up to' 8Mbit/s		Orange and TalkTalk
Orange 'up to' 8Mbit/s*	O2/Be	
Plusnet 'up to' 8Mbit/s		TalkTalk
Sky 'up to' 10Mbit/s		TalkTalk
TalkTalk 'up to' 8Mbit/s	AOLbb, BT, O2/Be, Plusnet, Sky and Virgin	
Virgin Media 'up to' 10Mbit/s		TalkTalk

Source: Ofcom

*Caution: small sample size

Figure 18 Significant differences to a 95% level of confidence between average packet loss by ISP and package for 'up to' 20 and 24Mbit/s connections, May 2010

ISP package	Is worse than	Is better than
BT 'up to' 20Mbit/s		TalkTalk
O2/Be 'up to' 20/24Mbit/s		TalkTalk
Sky 'up to' 20Mbit/s		TalkTalk
TalkTalk 'up to' 24Mbit/s	BT, O2/Be Sky and Virgin	
Virgin Media 'up to' 20Mbit/s		TalkTalk

Figure 19 Significant differences to a 95% level of confidence between DNS resolution time by ISP and package for 'up to' 8 and 10Mbit/s connections, May 2010

	24 h	ours	8-10pm weekday		
ISP package	Is slower than	Is faster than	Is slower than	ls faster than	
BT 'up to' 8Mbit/s	Virgin	O2/Be, Orange		O2/Be	
O2/Be 'up to' 8Mbit/s	BT, Plusnet, Sky and Virgin		BT, Plusnet and Virgin		
Orange 'up to' 8Mbit/s*	BT, Plusnet, TalkTalk and Virgin		Virgin		
Plusnet 'up to' 8Mbit/s	Virgin	O2/Be and Orange		O2/Be	
Sky 'up to' 10Mbit/s	Virgin	O2/Be			
TalkTalk 'up to' 8Mbit/s	Virgin	O2/Be			
Virgin Media 'up to' 10Mbit/s		BT, O2/Be, Orange, Plusnet, Sky and TalkTalk		O2/Be and Orange	

Source: Ofcom

*Caution: small sample size

Note: Better performance is indicated by lower speeds (i.e. faster)

Figure 20 Significant differences to a 95% level of confidence between DNS resolution time by ISP and package for 'up to' 20 and 24Mbit/s connections, May 2010

	24 h	ours	8-10pm weekday		
ISP package	Is slower than	Is faster than	Is slower than	Is faster than	
BT 'up to' 20Mbit/s	Virgin	O2/Be	Virgin	O2/Be	
O2/Be 'up to' 20/24Mbit/s	BT, Sky, TalkTalk and Virgin		BT, Sky, TalkTalk and Virgin		
Sky 'up to' 20Mbit/s	Virgin	O2/Be	Virgin	O2/Be	
TalkTalk 'up to' 24Mbit/s	Virgin	O2/Be	Virgin	O2/Be	
Virgin Media 'up to' 20Mbit/s		BT, O2/Be, Sky and TalkTalk		BT, O2/Be, Sky and TalkTalk	

Source: Ofcom

Figure 21 Significant differences to a 95% level of confidence between average and peak time jitter by ISP and package for 'up to' 8 and 10Mbit/s connections, May 2010

	24 hours			8-10pm weekday		
ISP package	Is worse than	Is better than	Is worse than	Is better than		
AOLbb 'up to' 8Mbit/s*		Virgin		Virgin		
BT 'up to' 8Mbit/s		Virgin		Virgin		
O2/Be 'up to' 8Mbit/s		Virgin		Virgin		
Orange 'up to' 8Mbit/s*		Virgin		Virgin		
Plusnet 'up to' 8Mbit/s		Virgin		Virgin		
Sky 'up to' 10Mbit/s		Virgin		Virgin		
TalkTalk 'up to' 8Mbit/s		Virgin		Virgin		
Virgin Media 'up to' 10Mbit/s	AOLbb, BT, O2/Be, Orange, Plusnet, Sky and TalkTalk		AOL bb, BT, O2/Be, Orange, Plusnet, Sky and TalkTalk			

Source: Ofcom

*Caution: small sample size

Figure 22 Significant differences to a 95% level of confidence between average and peak time jitter by ISP and package for 'up to' 20 and 24Mbit/s connections, May 2010

ISP package	Is worse than	Is better than	Is worse than	Is better than
BT 'up to' 20Mbit/s		Virgin		Virgin
O2/Be 'up to' 20/24Mbit/s		Virgin		Virgin
Sky 'up to' 20Mbit/s		Virgin		Virgin
TalkTalk 'up to' 24Mbit/s		Virgin		Virgin
Virgin Media 'up to' 20Mbit/s	BT, O2/Be, Sky and TalkTalk		BT, O2/Be, Sky and TalkTalk	

To a 99% level of confidence

Figure 23 Significant differences to a 99% level of confidence between average, peak time and maximum upload speeds on 'up to' 8Mbit/s and 'up to' 10Mbit/s connections, May 2010

	24 hours		8-10pm v	weekday	Maxi	mum
ISP package	ls slower than	ls faster than	ls slower than	ls faster than	Is slower than	ls faster than
AOLbb 'up to' 8Mbit/s*	O2/Be		O2/Be		O2/Be and Sky	
BT 'up to' 8Mbit/s	O2/Be, Orange and Sky		O2/Be and Sky		O2/Be, Sky, TalkTalk and Virgin	
O2/Be 'up to' 8Mbit/s		AOLbb, BT, Orange, Plusnet, Sky, TalkTalk and Virgin		AOLbb, BT, Orange, Plusnet, Sky, TalkTalk and Virgin		AOLbb, BT, Orange, Plusnet, Sky, TalkTalk and Virgin
Orange 'up to' 8Mbit/s*	O2/Be	BT and Plusnet	O2/Be		O2/Be	
Plusnet 'up to' 8Mbit/s	O2/Be, Orange and Sky		O2/Be, Orange and Sky		O2/Be, Sky, TalkTalk and Virgin	
Sky 'up to' 10Mbit/s	O2/Be	BT and Plusnet	O2/Be	BT and Plusnet	O2/Be	AOLbb, BT and Plusnet
TalkTalk 'up to' 8Mbit/s	O2/Be		O2/Be		O2/Be	BT and Plusnet
Virgin Media 'up to' 10Mbit/s	O2/Be		O2/Be		O2/Be	BT and Plusnet

Source: Ofcom *Caution: small sample size

Figure 24 Significant differences to a 99% level of confidence between average, peak time and maximum upload speeds on 'up to' 20Mbit/s and 'up to' 24Mbit/s connections, May 2010

	24 ho	24 hours 8-10pm weekday		Maximum		
ISP package	ls slower than	ls faster than	ls slower than	ls faster than	ls slower than	ls faster than
BT 'up to' 20Mbit/s	O2/Be and Sky		O2/Be and Sky		O2/Be and Sky	
O2/Be 'up to' 20/24Mbit/s		BT, Sky, TalkTalk and Virgin		BT, Sky, TalkTalk and Virgin		BT, Sky, TalkTalk and Virgin
Sky 'up to' 20Mbit/s	O2/Be	ВТ	O2/Be	BT	O2/Be	BT
TalkTalk 'up to' 24Mbit/s	O2/Be		O2/Be		O2/Be	
Virgin Media 'up to' 20Mbit/s	O2/Be		O2/Be		O2/Be	

Figure 25 Significant differences to a 99% level of confidence between average and peak time to load web pages by ISP and package for 'up to' 8 and 10Mbit/s connections, May 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				
O2/Be 'up to' 8Mbit/s				
Sky 'up to' 10Mbit/s				
Virgin Media 'up to' 10Mbit/s				

Source: Ofcom *Caution: small sample size

Figure 26 Significant differences to a 99% level of confidence between average and peak time to load web pages by ISP and package for 'up to' 20 and 24Mbit/s connections, May 2010

	24 hours		8-10pm weekday	
ISP package	Is slower than	Is faster than	Is slower than	Is faster than
BT 'up to' 20Mbit/s				
O2/Be 'up to'				
20/24Mbit/s				
Sky 'up to'				
20Mbit/s				
Virgin Media 'up to' 20Mbit/s				

Figure 27 Significant differences to a 99% level of confidence between average and peak time latency by ISP and package for 'up to' 8 and 10Mbit/s connections, average and peak times, May 2010

	24 hc	ours	8-10pm weekday	
ISP package	Is slower than	ls faster than	Is slower than	ls faster than
AOLbb 'up to' 8Mbit/s*		TalkTalk		
BT 'up to' 8Mbit/s		Sky and TalkTalk		TalkTalk
O2/Be 'up to' 8Mbit/s		Orange, Sky, TalkTalk		Sky, TalkTalk and Virgin
Orange 'up to' 8Mbit/s*	O2/Be	TalkTalk		
Plusnet 'up to' 8Mbit/s		Sky and TalkTalk		TalkTalk
Sky 'up to' 10Mbit/s	BT, O2/Be, Plusnet and Virgin		O2/Be	
TalkTalk 'up to' 8Mbit/s	AOLbb, BT, O2/Be, Orange, Plusnet and Virgin		BT, O2/Be, Plusnet and Virgin	
Virgin Media 'up to' 10Mbit/s		TalkTalk and Sky	O2/Be	TalkTalk

Source: Ofcom

*Caution: small sample size

Note: Better performance is indicated by lower speeds (i.e. faster)

Figure 28 Significant differences to a 99% level of confidence between average and peak time latency by ISP and package for 'up to' 20 and 24Mbit/s connections, average and peak times, May 2010

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

Source: Ofcom

Figure 29 Significant differences to a 99% level of confidence between average packet loss by ISP and package for 'up to' 8 and 10Mbit/s connections, May 2010

	24 ho	ours
ISP package	Is worse than	Is better than
AOLbb 'up to' 8Mbit/s*		TalkTalk
BT 'up to' 8Mbit/s		TalkTalk
O2/Be 'up to' 8Mbit/s		TalkTalk
Orange 'up to' 8Mbit/s*		TalkTalk
Plusnet 'up to' 8Mbit/s		TalkTalk
Sky 'up to' 10Mbit/s		TalkTalk
TalkTalk 'up to' 8Mbit/s	AOLbb, BT, O2/Be, Orange, Plusnet, Sky and Virgin	
Virgin Media 'up to' 10Mbit/s		TalkTalk

Source: Ofcom

*Caution: small sample size

Figure 30 Significant differences to a 99% level of confidence between average packet loss by ISP and package for 'up to' 20 and 24Mbit/s connections, May 2010

ISP package	Is worse than	Is better than
BT 'up to' 20Mbit/s		TalkTalk
O2/Be 'up to' 20/24Mbit/s		TalkTalk
Sky 'up to' 20Mbit/s		TalkTalk
TalkTalk 'up to' 24Mbit/s	BT, O2/Be Sky and Virgin	
Virgin Media 'up to' 20Mbit/s		TalkTalk

Figure 31 Significant differences to a 99% level of confidence between DNS resolution time by ISP and package for 'up to' 8 and 10Mbit/s connections, May 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	O2/Be, Orange		O2/Be
O2/Be 'up to' 8Mbit/s	BT, Plusnet, Sky, TalkTalk and Virgin		BT, Plusnet and Virgin	
Orange 'up to' 8Mbit/s*	BT, Plusnet and Virgin		Virgin	
Plusnet 'up to' 8Mbit/s		O2/Be and Orange		O2/Be
Sky 'up to' 10Mbit/s	Virgin	O2/Be		
TalkTalk 'up to' 8Mbit/s	Virgin	O2/Be		
Virgin Media 'up to' 10Mbit/s		BT, O2/Be, Orange, Sky and TalkTalk		O2/Be and Orange

Source: Ofcom

*Caution: small sample size

Note: Better performance is indicated by lower speeds (i.e. faster)

Figure 32 Significant differences to a 99% level of confidence between DNS resolution time by ISP and package for 'up to' 20 and 24Mbit/s connections, May 2010

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

Source: Ofcom

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

	24 hours		8-10pm weekday	
ISP package	Is worse than	Is better than	Is worse than	Is better than
AOLbb 'up to' 8Mbit/s*		Virgin		Virgin
BT 'up to' 8Mbit/s		Virgin		Virgin
O2/Be 'up to' 8Mbit/s		Virgin		Virgin
Orange 'up to' 8Mbit/s*		Virgin		Virgin
Plusnet 'up to' 8Mbit/s		Virgin		Virgin
Sky 'up to' 10Mbit/s		Virgin		Virgin
TalkTalk 'up to' 8Mbit/s		Virgin		Virgin
Virgin Media 'up to' 10Mbit/s	AOLbb, BT, O2/Be, Orange, Plusnet, Sky and TalkTalk		AOLbb, BT, O2/Be, Orange, Plusnet, Sky and TalkTalk	

Source: Ofcom

*Caution: small sample size

Figure 34 Significant differences to a 99% level of confidence between average and peak time jitter by ISP and package for 'up to' 20 and 24Mbit/s connections, May 2010

ISP package	Is worse than	Is better than	Is worse than	Is better than
BT 'up to' 20Mbit/s		Virgin		Virgin
O2/Be 'up to' 20/24Mbit/s		Virgin		Virgin
Sky 'up to' 20Mbit/s		Virgin		Virgin
TalkTalk 'up to' 24Mbit/s		Virgin		Virgin
Virgin Media 'up to' 20Mbit/s	BT, O2/Be, Sky and TalkTalk		BT, O2/Be, Sky and TalkTalk	