UK fixed-line broadband performance, May 2011

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

Research Report

Publication date: 27 July 2011

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Background

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.

In the last decade internet access speeds across the UK have increased as consumers have migrated from narrowband 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 super-fast 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 they may not be able to make an informed choice about which broadband service is most suitable for them.

In order to understand the performance of UK fixed-line residential broadband connections, we commissioned research to identify the average actual download throughput speeds that they deliver, along with a number of other metrics, which determine the consumer experience of using broadband services.

This is the fifth report into fixed-line broadband speeds that Ofcom has published using data collected by research partner SamKnows Limited (SamKnows).[1] It sets out the findings from data collected during May 2011, during which 455 million tests were run across a panel of 1,767 UK residential broadband users. We believe that the integrity of our hardware-based technical methodology (see Annex 2), 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 available.

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

The analysis in this report is based on the actual speeds achieved by our panellists over the testing period of May 2011. In early July 2011 we published the separate Communications Infrastructure Report 2011[2] which contains analysis of modem sync speeds data provided to Ofcom by ISPs. Although this ISP data has allowed us to produce more granular geographical speed data in the Communications Infrastructure Report (which contains a UK map showing average download speeds by county), the technical methodology used in this report enables us to test connection parameters other than download speeds.

[1] http://www.samknows.com/broadband
[2] http://maps.ofcom.org.uk/broadband

Purpose of this report

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

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

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

- In the UK there are over 200 different fixed-line broadband internet service providers (ISPs) offering different packages to residential consumers, and we have not been able to report on the performance of each of these packages. We did gain sufficient panellists to be able to report the performance of those ISP packages which collectively represent around three-quarters of total residential broadband subscribers in the UK, and also to be able to report on the three largest 'super-fast' services in the UK – Virgin Media's 'up to' 30Mbit/s and 50Mbit/s cable packages and BT's 'up to' 40Mbit/s fibre-to-the-cabinet service. However, consumers should bear in mind that there are many other ISPs available, which may perform better or worse than those specifically featured in this report.

- Our research relates only to ADSL, fibre-to-the-cabinet (also known as FTTC or VDSL) 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 undertake separate research regarding mobile broadband performance, the first report from which was published in May 2011[3] and examines the drivers of variation in mobile broadband performance. Other broadband platforms such as fibre-to-the-home and satellite broadband are also not currently included in our analysis as these connections represent only a small proportion of the total broadband market in the UK.

- This research report presents information on the state of fixed-line residential broadband performance in the UK in May 2011. However, the broadband market continues to evolve rapidly, and the speeds and general performance results set out in this report are therefore liable to change.

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

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

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

Key terms used to describe broadband speeds

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

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

- The '**access line speed**' or '**modem synchronisation speed'** is the maximum download speed that a line is capable of supporting according to the way the line is configured by a customer's ISP.

- The '**average actual throughput**' speed, or '**average actual**' 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 throughput speed is referred to throughout this document as "**average speed**", unless specified otherwise.

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

Section 1

Executive summary

Ofcom's work on broadband speeds

1.1 The UK broadband market has been transformed in the period since Ofcom first researched fixed-line broadband speeds in 2008 and continues to change apace. The deployment and take-up of faster broadband services, the increasing popularity of mobile broadband and the greater use of internet applications and services using more bandwidth have all contributed to this transformation. Ofcom has taken a number of steps to ensure the market remains dynamic and competitive:

- Publishing this research bi-annually allowing consumers to see how broadband speeds vary across different providers, technologies and time periods and supplementing this with similar research on mobile broadband performance.[4]
- Introducing and updating the voluntary Code of Practice on broadband speeds[5] which ensures that consumers get clear information on the speeds available on their particular line.
- Advising consumers through new guides[6] on how to improve their broadband speeds and get the best deal on their broadband service.
- Creating a UK broadband map[7] which allows consumers to see at a glance how their region compares across a range of metrics with other areas.
- Ensuring a clear regulatory framework for the deployment of superfast broadband infrastructure.[8]

1.2 The UK fixed broadband market currently stands on the cusp between current generation broadband services and next generation services which offer much faster speeds. We estimate that by July 2011 superfast broadband (i.e. broadband with a headline speed of 30Mbit/s or higher) was available to around 57% of UK homes and continuing investment from providers means that availability continues to grow week-by-week. As this change progresses, Ofcom will continue to act to ensure that consumers have the information they need to make choices about the right broadband service for them.

UK broadband speeds increasing in 2011

1.3 The results of our latest research conducted in partnership with SamKnows show that in May 2011 average actual broadband speeds in the UK were 6.8Mbit/s, a 0.6Mbit/s (10%) increase since our last round of testing in November/December 2010.

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[4] http://stakeholders.ofcom.org.uk/market-data-research/telecoms-research/broadband-speeds/main/mobile-bb-10
[5] http://stakeholders.ofcom.org.uk/telecoms/codes-of-practice/broadband-speeds-cop/voluntary-codes-of-practice/
[6] http://consumers.ofcom.org.uk/guides/
[7] http://maps.ofcom.org.uk/broadband
[8] http://stakeholders.ofcom.org.uk/consultations/nga_future_broadband/statement/

1.4 This increase in average speeds is the result of consumers increasingly moving to faster broadband services: 47% of UK broadband connections had a headline speed above 10Mbit/s in May 2011, compared to 42% in November 2010, 24% in May 2010 and 8% in April 2009.

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

1.5 Over 75% of current UK residential broadband connections in the UK are delivered via ADSL, using the copper telephone line between the local telephone exchange and the customer's premises. A characteristic of ADSL broadband is that performance degrades due to signal loss over the length of the telephone line. This means that the speeds available to different customers vary significantly, with those with shorter line lengths (i.e. who live closer to the exchange) typically able to achieve higher speeds than those with longer line lengths.

1.6 Therefore, headline 'up to' speeds have little meaning for services delivered via ADSL. We found that the average download speed received for 'up to' 20Mbit/s or 24Mbit/s ADSL packages was 6.6Mbit/s, and 37% of customers had average speeds of 4Mbit/s or less.

1.7 It is therefore important that customers have information about the speed their line is actually capable of in order to inform their decision about which broadband service is right for them. In 2008 Ofcom and most of the UK's leading ISPs (collectively representing over 90% market share of residential connections) agreed a voluntary Code of Practice which requires signatories to provide an estimated line speed before a sale is completed; an update to this Code comes into force on 27 July 2011 which includes provision for customers to exit their contracts if actual speeds are significantly below the estimate provided.[9] In addition, some ADSL providers have moved away from advertising broadband on the basis of 'up to' speeds and now advertise their service on the basis that they will deliver the fastest speed that the line can support, promoting the fact that they will provide a line speed estimate to prospective customers.

1.8 Because of the wide range in performance, advertising guidelines are currently in place which restrict how theoretical speeds may be used in advertising, requiring for example that speeds are prefixed with 'up to' and that caveats are included which detail that actual performance varies with location. However, theoretical 'up to' speeds continue to be widely used in advertising and we consider that these have the potential to mislead customers. The CAP/BCAP committees of the Advertising Standards Agency are currently concluding a review into the use of 'up to' in advertising and are expected to announce their conclusions in late summer; Ofcom's public response to the consultation recommended that when speed is used in broadband advertising it should be based on a 'typical speed range' (TSR), which should have at least equal prominence to an 'up to' speed.[10]

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

[10] http://stakeholders.ofcom.org.uk/binaries/research/telecoms-research/bbspeeds2011/response-to-asa.pdf

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

1.9 Virgin Media's 'up to' 10Mbit/s cable service delivered average speeds of 9.5Mbit/s, 95% of advertised 'up to' speeds and significantly faster than the average speeds delivered by ADSL services with headline speeds of 'up to' 20Mbit/s or 24Mbit/s (Figure 1.1). Virgin Media's 'up to' 20Mbit/s cable service averaged 18.2Mbit/s (91% of advertised speeds), its 'up to' 30Mbit/s service 31.0Mbit/s (103% of the 'up to' speed) and its 'up to' 50Mbit/s service 48.4Mbit/s (97% of the advertised 'up to' speed).

1.10 We found that download speeds for BT's 'up to' 40Mbit/s FTTC service (which is currently available to around a fifth of UK homes) averaged 33.8Mbit/s (85% of the advertised 'up to' 40Mbit/s speed).

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

1.11 Download speeds can fall during peak periods as a result of capacity constraints on ISPs' networks (caused by simultaneous users sharing the same bandwidth). We found that in May 2011, speeds measured during the peak weekday hours of 8pm to 10pm (which on average were the hours in the week when speeds were slowest) were 90% of the maximum speeds delivered (typically during 'off-peak' hours such as 12am to 6am) and 98% of the average speeds delivered over a 24-hour period.

1.12 Among the 20Mbit/s and 24Mbit/s ADSL packages, O2/Be had the lowest average slowdown during peak periods, with speeds in the period 8pm to 10pm averaging 95% of the maximum speed. Karoo (the ISP of Kingston Communications, the incumbent in Kingston-upon-Hull) had the greatest slowdown, with download speeds in the peak period averaging 78% of maximum speeds.

1.13 There was little difference in levels of slowdown among the super-fast ISP packages covered in the research, although Virgin Media's 'up to' 30Mbit/s suffered the least slowdown, with speeds in the peak period being 96% of maximum speeds.

Metrics other than download speed also determine broadband performance

1.14 Download speed is typically the most important single metric in determining broadband performance and, along with price, continues to be the most important metric in the advertising of broadband. However, there are of course many other metrics that determine the overall performance of a broadband connection. As it is not always the case that the technologies and providers that deliver the best performance on download speeds always deliver the best performance on other metrics it is important that consumers understand the impact other metrics have on performance and choose the service that best meets their needs.

1.15 Upload speeds are particularly important for users looking to share large files, use real-time two-way video communications and for some games. As use of such services has increased, so too has the focus on upload speeds, which has become more of a source of differentiation in recent months, with BT's FTTC service offering advertised upload speeds of 'up to' 10Mbit/s (and 'up to' 2Mbit/s), and Virgin Media has increased the upload speeds associated with its cable services. Our results showed that BT's 'up to' 40Mbit/s download and 'up to' 10Mbit/s upload FTTC service

delivered average upload speeds of 8.8Mbit/s, significantly higher than any other service we measured. Virgin Media's 'up to' 50Mbit/s delivered average upload speeds of 4.1Mbit/s, with its 'up to' 30Mbit/s package averaging upload speeds of 2.7Mbit/s and its 'up to' 20Mbit/s package averaging upload speeds of just over 1.5Mbit/s. Among the ADSL services, O2's 'up to' 20Mbit/s package was significantly faster than the others with average upload speeds of just over 1Mbit/s.

1.16 Our research included measurements of the time it took to download an Ofcom test web page which was hosted on SamKnows' servers. In general, packages with faster download speeds were also quicker at downloading web pages – Virgin Media's cable services and the BT's FTTC service all delivered pages faster than any of the ADSL services, indicating that even for basic web internet functions there are benefits to higher speed services.

1.17 In this report we also look at how variations in various broadband connection metrics affect the end-user quality of experience (QoE) when undertaking a number of online activities. This shows that:

- For video streaming services, low data rates or high latency or packet loss lead to viewing 'glitches' that render the service annoying or unusable, although typical levels of jitter do not have an effect on these services as they are accommodated within data buffers.
- With download services and interactive websites the main observable effect with a decreased data rate or higher levels of latency and/or packet loss is that it takes longer to complete a task (again, typical jitter levels do not affect the QoE).
- With VoIP, performance varies gradually as data rates fall or latency and/or packet loss increases, however, although there are noticeable effects on sound quality, speech remains intelligible and typical jitter levels do not affect the QoE; and
- Massively Multiplayer Online Games (MMOG)s are sensitive to even the lowest levels of latency and packet loss, with users noticing reduced responsiveness and increases in jitter having a detrimental effect on the QoE.

Conclusion and next steps

1.18 This research report is a representative snapshot of the state of residential broadband performance in May 2011, 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. Our research programme continues, and we expect to publish our next report in early 2012.

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

1.20 Nevertheless, most broadband is still delivered via ADSL, over copper lines which were originally designed for phone services and which have been stretched to the

edge of their capability in order to provide broadband. An inescapable characteristic of ADSL broadband is that performance is constrained by the length and quality of the copper line.

1.21 It is therefore essential that consumers have accurate information on the speeds available on their line when they make their choice of broadband supplier. An update to the voluntary Code of Practice on Broadband Speeds comes into force on 27 July 2011 which requires that ISPs provide estimates to a common methodology in the form of a range, and gives consumers the right to exit the contract if actual speeds are significantly lower than the range. Most of the UK's largest ISPs are signatories to the Code, and a list is available on the Ofcom website.[11]

1.22 In addition, in our response to the Committee for Advertising Practice (CAP) and Broadcast Committee for Advertising Practice (BCAP)'s public consultation into the use of speed claims in advertising (which closed on 25 February 2011) we recommended the following:

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

1.23 Figure 1.1 shows Ofcom's estimates of the TSRs by technology and headline speed, based on data collected in May 2011.

Figure 1.1 Estimated typical speed ranges (25th to 75th percentile), by technology and headline speed

Current packages	Typical speed range
ADSL 'up to' 8Mbit/s	1Mbit/s to 5Mbit/s
ADSL 'up to' 20/24Mbit/s	3Mbit/s to 10Mbit/s
Cable 'up to' 10Mbit/s	9Mbit/s to 10Mbit/s
Cable 'up to' 20Mbit/s	18Mbit/s to 19Mbit/s
Cable 'up to' 30Mbit/s	31Mbit/s to 32Mbit/s
Cable 'up to' 50Mbit/s	49Mbit/s to 50Mbit/s
FTTC 'up to' 40Mbit/s	32Mbit/s to 37Mbit/s

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

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

1.24 Although average speeds are improving, our research, and the data we have collected from operators into line speeds across the UK[12], finds that for many consumers the speeds available to them via ADSL are not sufficient for a high-quality experience of high-bandwidth services such as internet TV, or for connecting multiple devices to the internet. The continuing investment by BT, Virgin Media and others into next-generation broadband is therefore essential to ensuring that UK consumers can participate fully in the communications and entertainment services enabled by higher speed broadband.

[12] Data collected from UK broadband providers finds that 14% were unable to receive fixed-line broadband speeds of higher than 2Mbit/s in December 2010: http://maps.ofcom.org.uk/broadband/downloads/ofcom-uk-broadband-speed-report-2011.pdf

Section 2

Introduction

Research objectives

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

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

2.2 Ofcom's primary duty under the 2003 Communications Act ('the Act') is to further the interests of UK citizens and consumers in carrying out our functions.[13] 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 services.[14] 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 UK.[15] We are also required to have regard to the interests of consumers in respect of price, choice, quality of service and value for money.[16] The Act requires us to make arrangements to find out about the experiences of consumers using electronic communications services and the way they are provided, and we do this by carrying out research into their experiences of these services.[17]. 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.[18]

Rationale for the report

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

[13] Section 3(1) of the Act.
[14] Section 3(2)(b).
[15] Section 3(4)(a) and (e).
[16] Section 3(5).
[17] Section 14.
[18] Section 15.

ensure that it is representative of residential broadband users, and also to apply appropriate statistical techniques to 'normalise' the data for ADSL broadband by distance from exchange. Normalisation ensures that the final results enable like-for-like comparison between ISP packages.

The scope of the research

2.4 We have commissioned broadband measurement company SamKnows to recruit a panel of UK residential broadband users who are also subscribers of certain ISP packages. This panel was assembled in spring 2010, but also included some of the same members of the panel that was used for data collection in the first phase of research (October 2009 to April 2010). Since then the panel has been updated to maintain and improve the quality of the sample and enable the inclusion of additional ISP packages which have launched or grown market share since the research was first conducted.

2.5 This report is the third report based on this panel performance data, and it presents performance data collected in the May 2011. We have opted to use multi-thread test results in this report as multiple-file download is increasingly being used to optimise delivery times, and, in particular, because multi-thread tests represent a better metric for the measurement of higher-speed services.

2.6 We examine average download speed and how this varies by a range of variables including geographical location, time of day, access technology and ISP package. Where appropriate, we also include data from November/December 2010 (as published in March 2011).

2.7 We also include analysis of other factors which determine the performance of a broadband connection: upload speeds, web-page loading time, latency, packet loss, DNS and jitter. However, the bulk of the analysis focuses on download speeds because this remains the main performance metric by which broadband is sold and because our research indicates that the variation in average performance of other indicators will have less impact on overall quality of experience, and average levels offered by all ISP packages is sufficient for most internet applications.

2.8 We include comparative data for those ISP packages for which we had large enough sample sizes to make the analysis statistically meaningful. This comprised the 'up to' 8Mbit/s ADSL packages from BT Retail and Plusnet; the 'up to' 20Mbit/s or 24Mbit/s ADSL packages from BT Retail, Karoo, O2/Be, Orange, Plusnet, Sky and TalkTalk; Virgin Media's 'up to' 10Mbit/s, 20Mbit/s, 30Mbit/s and 50Mbit/s cable packages; and BT's 'up to' 40Mbit/s FTTC package.

2.9 For those ISPs which offer services via local loop unbundling (LLU) and have different packages for consumers living within their LLU network footprint (on-net) and those who do not (off-net), we report only on the performance of on-net customers. This is because on-net services are typically offered as different packages with different prices and headline speeds, and consumers can readily identify whether a service is on-net or off-net. However, in order to ensure that ISP services are compared on a like-for-like basis, the comparative ISP data for ADSL services only includes broadband connections served by exchanges where at least one LLU operator is present (i.e. Ofcom's Geographic Markets 2 and 3).

Outside the scope of the research

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

2.11 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 2% 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).

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

2.13 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 published separate research regarding mobile broadband performance in May 2011.[19]

2.14 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.

2.15 Sections 4, 5, 6 and 7 of this report examine why download speeds are typically below headline speeds and look in particular at the influence of the following factors:

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

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

2.17 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:

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

- Bandwidth being shared by more than one PC using the same broadband connection simultaneously;
- The quality of the connection from the modem to the PC, for example the WiFi connection;[20] and
- The speed of the particular websites visited or applications used by the consumer.

Structure of this report

2.18 This report is structured as follows:

- **Section 3** 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 4** examines how broadband speeds vary by geographic location, including the choice of services available and the distance from exchange (for ADSL customers).
- **Section 5** 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 6** examines how broadband speeds vary by access technology, comparing the performance of ADSL, cable and FTTC broadband.
- **Section 7** looks in more detail at how ISPs and their packages vary in terms of download and upload speeds, and considers the reasons why this may be the case.
- **Section 8** looks at metrics other than download and upload speed which determine broadband performance. It considers how these metrics impact on the consumer experience of different internet applications and compares ISP package performance in terms of web browsing, latency, packet loss, DNS resolution and jitter.
- **Section 9** concludes the report with an overview of the implications of the findings for consumers and ISPs, and our proposed next steps.
- **Annex 1** contains a glossary explaining the technical terms used throughout the report.
- **Annex 2** explains our technical and research methodologies.

[20] Research by Epitiro found that use of WiFi results in average download speeds dropping by 30%, with other key performance indicators such as latency, packet loss and jitter also affected, http://www.epitiro.com/assets/files/WiFi_In_The_Home_Epitiro_V2.pdf

- **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.

Section 3

Overview of UK broadband speeds

Why broadband speeds matter

3.1 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 content has grown, and households increasingly use multiple devices to simultaneously connect to the internet. Indeed, some services are only possible at faster speeds; the BBC, for example, recommends a minimum speed of 500kbit/s to use its iPlayer, and 3.2Mbit/s for the high-definition iPlayer service. Details of the theoretical time taken to perform some of the most common online activities at downstream speeds are given in Figure 3.1 below.

Figure 3.1 Theoretical time taken to perform various online activities

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

Source: Ofcom

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

3.3 The demand for broadband services varies, and some households will require greater bandwidth than others. For example, households with multiple devices connected to the internet simultaneously will benefit from faster speeds more than those with only one, as will households who use services which require higher speeds such as high-definition video streaming. 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

3.4 Headline speeds have been central to the way in which broadband is marketed, with UK residential services being advertised according to their theoretical maximum download speed (for example, ‘up to’ 8Mbit/s or ‘up to’ 20Mbit/s). But there is some evidence that ISPs are changing the way in which they market their broadband services – in part, because they recognise that in many cases, consumers will not be

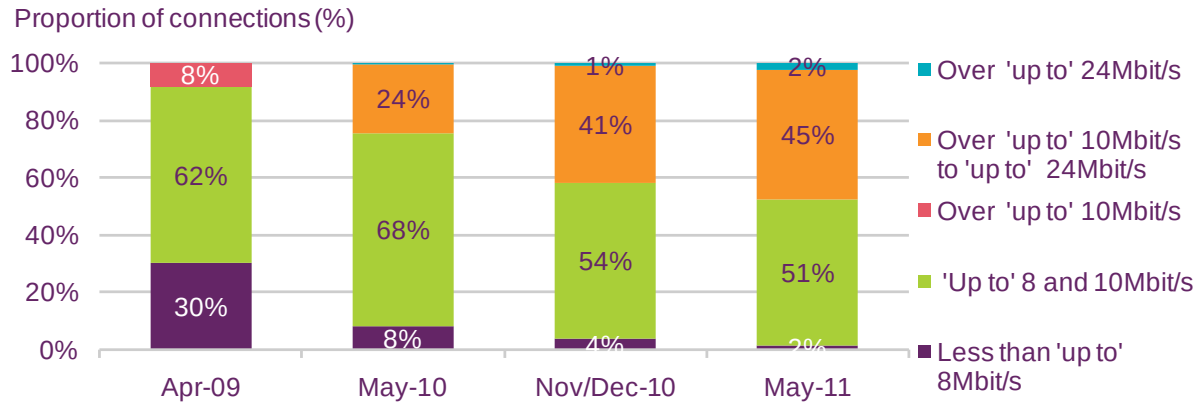
able to achieve the headline speeds of the package. For example, TalkTalk does not typically advertise its services on the basis of speeds but instead simply promotes them on the basis that they will provide the fastest speed that a customer's line is able to support.

3.5 Nevertheless, we have used the labels used by ISPs to describe their packages to illustrate how consumers have been increasingly taking up higher-speed broadband services. Over the last two years, the upgrade to faster ADSL2+ technology has meant that many ISPs offering ADSL-based services have been migrating customers on 'up to' 8Mbit/s and 10Mbit/s customer bases to 'up to' 20Mbit/s or 24Mbit/s services. In addition, BT has continued to roll out fibre services, including its fibre-to-the-cabinet (FTTC) product which offers download speeds of 'up to' 40Mbit/s and upload speeds of 'up to' 10Mbit/s (or 'up to' 2Mbit/s). BT has committed to making fibre-based services available to 40% of UK households by summer 2012 and 66% by 2015.

3.6 Figure 3.2 details the distribution of packages by headline speed based on data provided by the ISPs for which we include individual package data in this report (they have a combined market share of over 90%). It indicates a continuing shift in the market towards higher headline speeds during 2011. The average headline speed in May 2011 was 15.0Mbit/s, up from 13.8Mbit/s in November 2010.

3.7 We have presented the data in bands rather than detailing specific ISP packages in order to preserve the confidentiality of the 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 3.2 UK residential broadband connections by headline speed



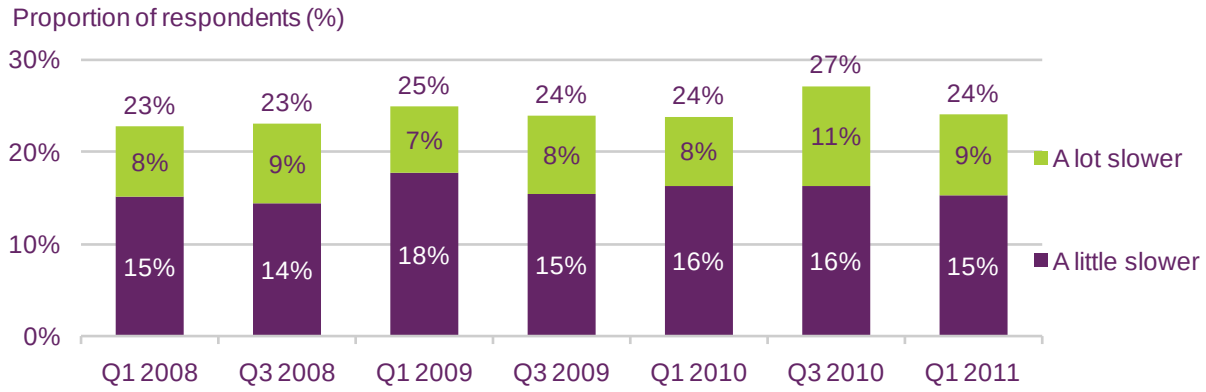
Source: Ofcom, based on data provided by the UK's largest ISPs by retail market share (representing over 90% of the total market)

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

3.8 Ofcom research shows that broadband speeds are a concern for a significant minority of consumers. Ofcom research conducted in the first quarter of 2011 showed that 24% of adults with a home broadband connection received slower connection speeds than they had expected when they first took their service, similar to reported levels over the previous three years. (Figure 3.3).

Figure 3.3 Perception of actual speeds compared to expected speeds

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



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

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

3.9 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.

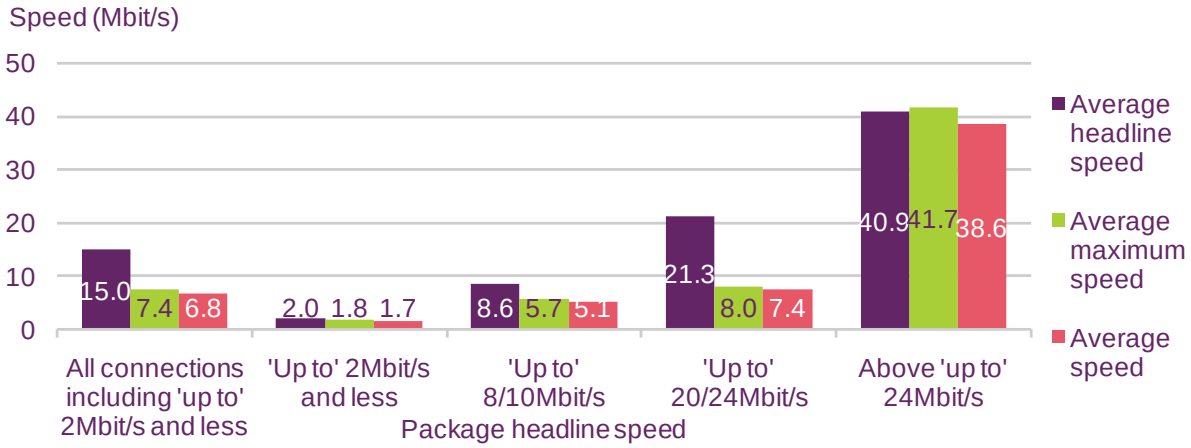
3.10 In practice, advertised headline 'up to' speeds are rarely delivered: our present research found that the overall average download speed delivered to UK residential consumers in May 2011 was 6.8Mbit/s, less than half (45%) of the average headline speed of 'up to' 15.0Mbit/s (Figure 3.4).

3.11 Maximum line speeds are a better indicator than headline speeds of the actual speeds that consumers can expect, and we found that average download speeds were 92% of maximum speeds in May 2011. It is in this context that Ofcom introduced the Voluntary Code of Practice on Broadband Speeds[21], implemented by ISP signatories in 2008, through which all signatories committed to notify consumers of the maximum speed their line is capable of supporting at the point of sale. An

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

updated Voluntary Code of Practice came into effect on 27 July 2011. This requires DSL ISPs who have signed up to the Code to provide speed estimates in the form of a range at the point of sale and gives consumers the right to exit a broadband contract without penalty if the actual speeds received are significantly below this estimate.

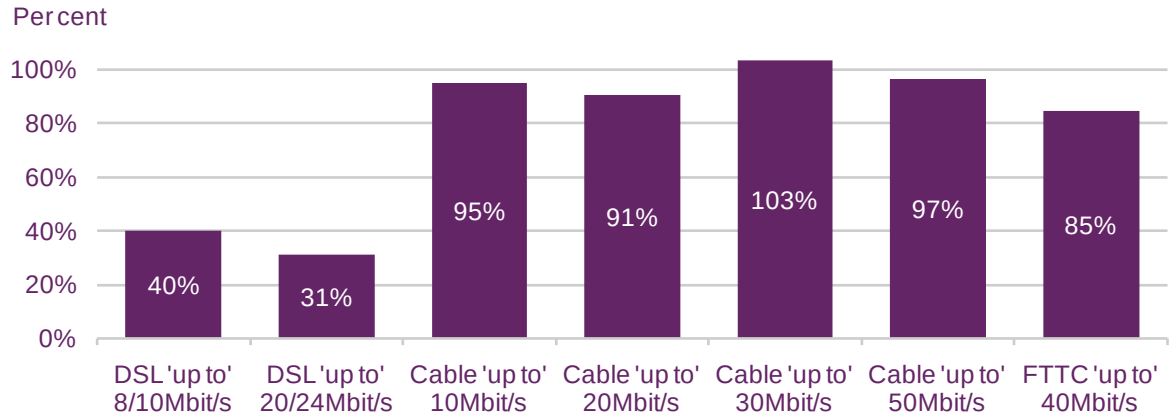
Figure 3.4 Average UK broadband speeds, May 2011



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

3.12 Cable and fibre services generally delivered average download speeds that were much closer to the advertised 'up to' speeds than ADSL services (Figure 3.5). On average, the actual speeds delivered to consumers on 'up to' 8Mbit/s ADSL packages were 40% of the advertised speed, while those on 'up to' 20 or 'up to' 24Mbit/s ADSL packages were 31% of the advertised 'up to' speed in May 2011. Cable services, on average, delivered between 91% and 103% of the advertised speeds, while BT's 'up to' 40Mbit/s FTTC service also performed better than ADSL services, on average delivering 85% of the headline download speed during the period.

Figure 3.5 Average download speeds (24 hours) as a proportion of headline speeds by connection headline speed and technology, May 2011



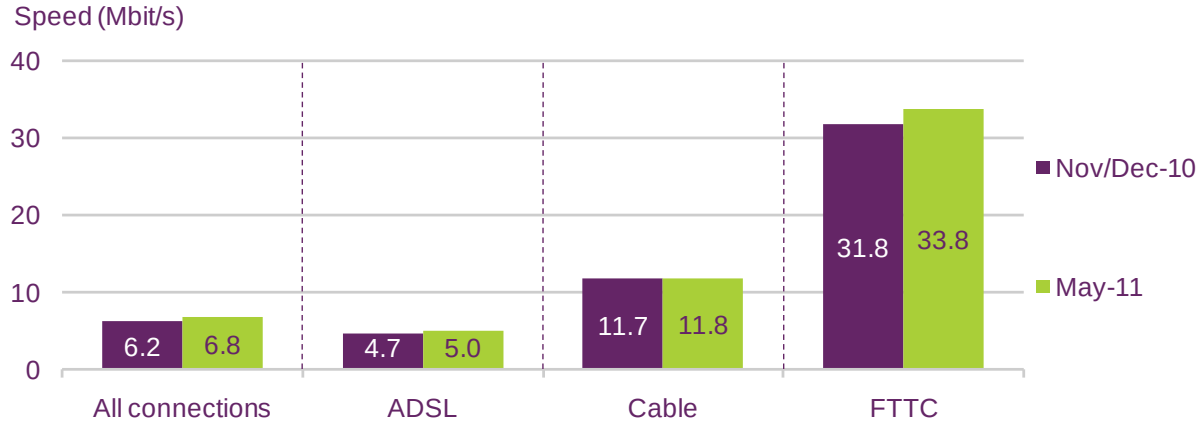
Source: SamKnows measurement data for all panel members with a connection in May 2011
Panel Base: 1325
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

Average UK broadband speeds increased by 5% between May and May 2011

3.13 Our research found that overall average UK download speeds were 6.8Mbit/s in May 2011, a 10% increase on the 6.2Mbit/s recorded on November/December 2010 (Figure 3.6). The average actual download speed for ADSL connections was 5.0Mbit/s, compared to 11.8Mbit/s for cable broadband services and 33.8Mbit/s for BT's 'up to' 40Mbit/s FTTC service.

3.14 It should be noted that these figures will to a large extent be defined by the mix of connections by headline speeds for each technology – for example the large majority of Virgin Media's cable customers currently take its lowest-price 'up to' 10Mbit/s service, meaning that the cable average is much closer to the average speed delivered for this package than for its legacy 'up to' 20Mbit/s service and its 'up to' 30Mbit/s and 'up to' 50Mbit/s packages.

Figure 3.6 Average download speeds for fixed broadband connections, all connections including 'up to' 2Mbit/s and less, by technology , May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011
Panel Base: 1325
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests.

Why actual broadband speeds vary from headline speeds

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

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

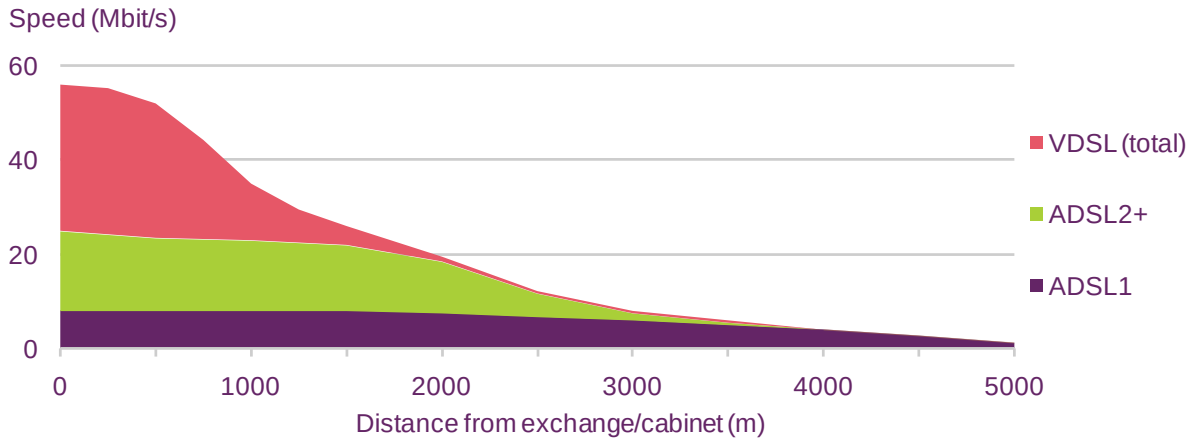
- Congestion on the wider internet causes individual web sites and applications to slow down. (Our research runs tests to multiple web sites and locations across the day in order to minimise the impact this has on our results).

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

3.16 As ADSL broadband is currently the only broadband technology that is available nationwide, the maximum speeds available to many consumers are defined by the length and quality of the copper wire between their home and the local telephone exchange. Figure 3.7 depicts the theoretical degradation of the maximum speeds achievable by ADSL and VDSL (FTTC) broadband as the length of line from the local telephone exchange to premises increases.

3.17 It shows that although second-generation ADSL services (ADSL2+) offer significantly faster speeds than first-generation ADSL speeds to customers with a short line length, beyond a distance of 3km from the exchange there is little difference between the two technologies. The chart also shows the degradation of speeds delivered by VDSL services as the distance between the street cabinet and the end-user's premises increases.

Figure 3.7 Theoretical maximum DSL speeds by length of line from exchange/cabinet to premises



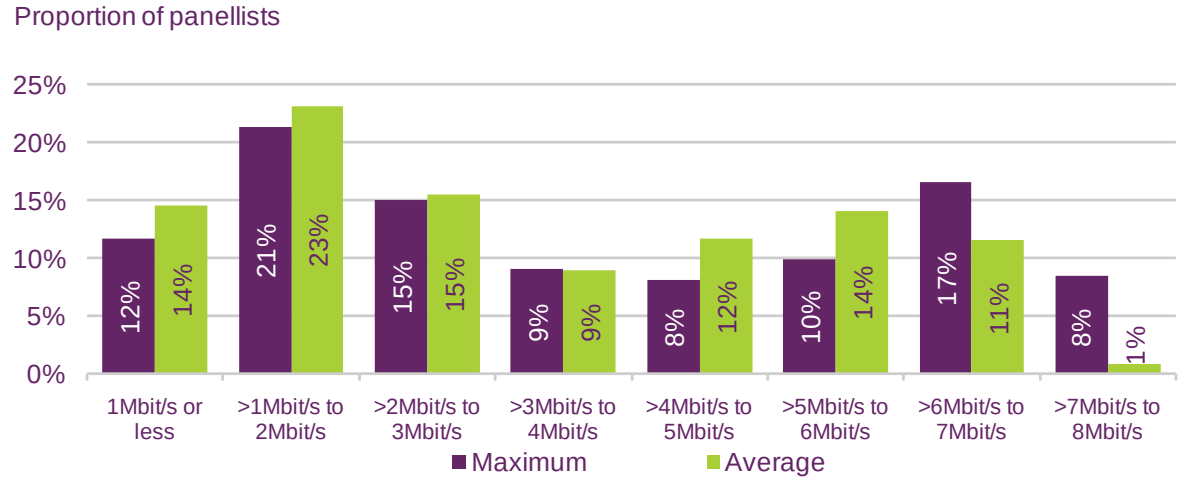
Source: Ofcom

The distribution of actual broadband speeds

3.18 Given the number of factors on which download speeds depend, it is not surprising that, for ADSL broadband, there is wide variation in the average download speeds received among consumers on packages with the same 'up to' headline speed. Figures 3.8 and 3.9 show the distribution of average download speeds received by panellists on 'up to' 8Mbit/s ADSL packages and 'up to' 20Mbit/s and 24Mbit/s ADSL packages.

3.19 In addition to the wide variation in performance, it is striking how few consumers on ADSL services received average download speeds which were close to headline speeds. For example, only 12% of our sample on 'up to' 8Mbit/s ADSL headline speed packages received average download speeds of over 6Mbit/s and 53% received 3Mbit/s or less (Figure 3.9). Similarly, 25% of our sample on 'up to' 8Mbit/s ADSL headline speed packages received maximum download speeds of over 6Mbit/s and 48% received maximum speeds of 3Mbit/s or less.

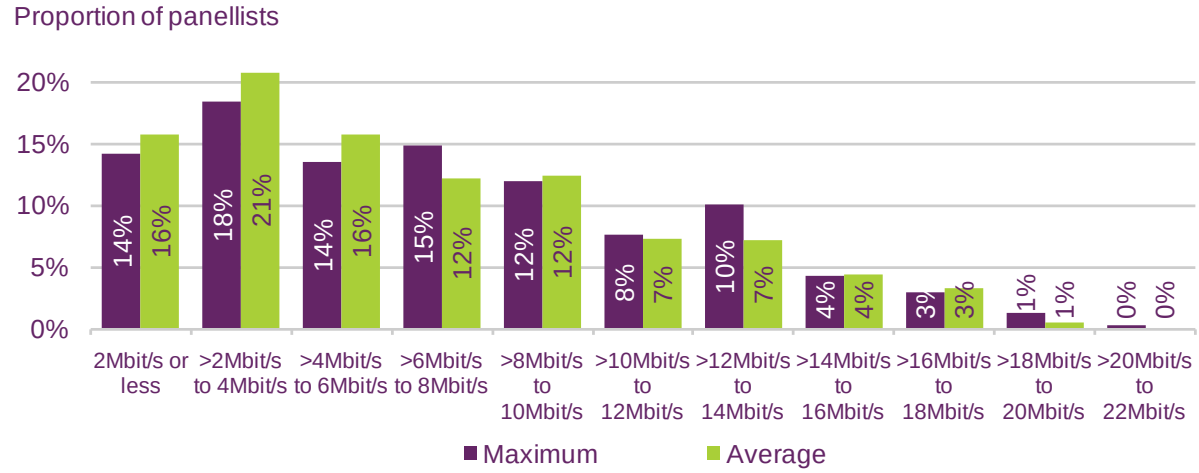
Figure 3.8 Distribution of maximum and average download speeds for consumers on 'up to' 8Mbit/s ADSL packages, May 2011



Source: SamKnows measurement data for panel members with a connection in May 2011.
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK ADSL 'up to' 8Mbit/s and 10Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

3.20 Similarly, very few customers on 'up to' 20Mbit/s or 24Mbit/s ADSL packages received speeds close to headline speeds, with just 16% receiving average download speeds in excess of 12Mbit/s, and 19% receiving average maximum speeds greater than 12Mbit/s (Figure 3.9). Meanwhile, 14% received average download speeds of 2Mbit/s or less and 46% average maximum speeds of 6Mbit/s or less.

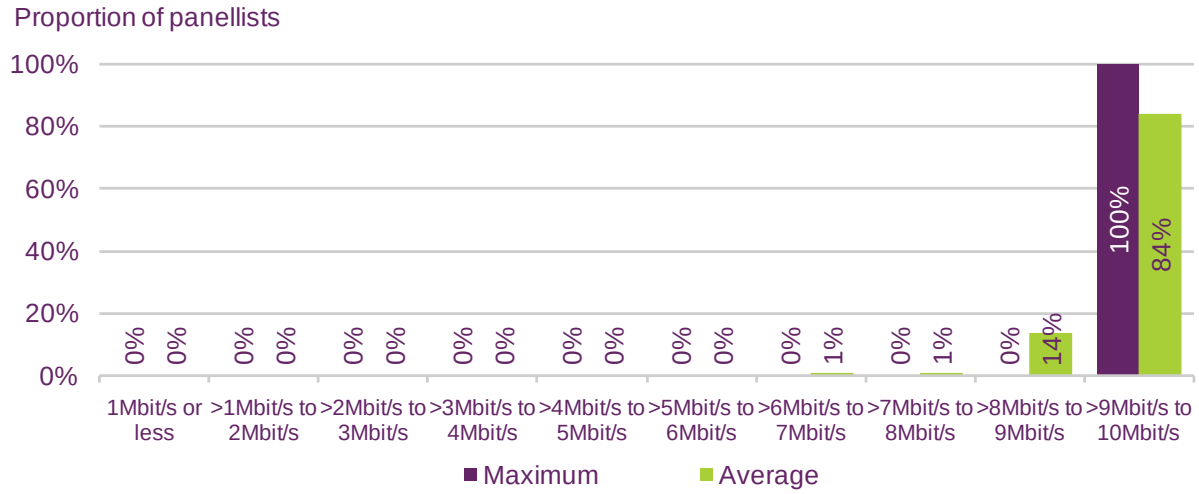
Figure 3.9 Distribution of maximum and average download speeds for consumers on 'up to' 20Mbit/s and 24Mbit/s ADSL packages, May 2011



Source: SamKnows measurement data for panel members with a connection in May 2011.
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK ADSL 'up to' 20Mbit/s and 24Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

3.21 There was significantly less variation in the average download speeds delivered to cable panellists, with all panellists on 'up to' 10Mbit/s cable packages receiving maximum speeds in excess of 9Mbit/s, and 84% having average speeds of over 9Mbit/s (Figure 3.10).

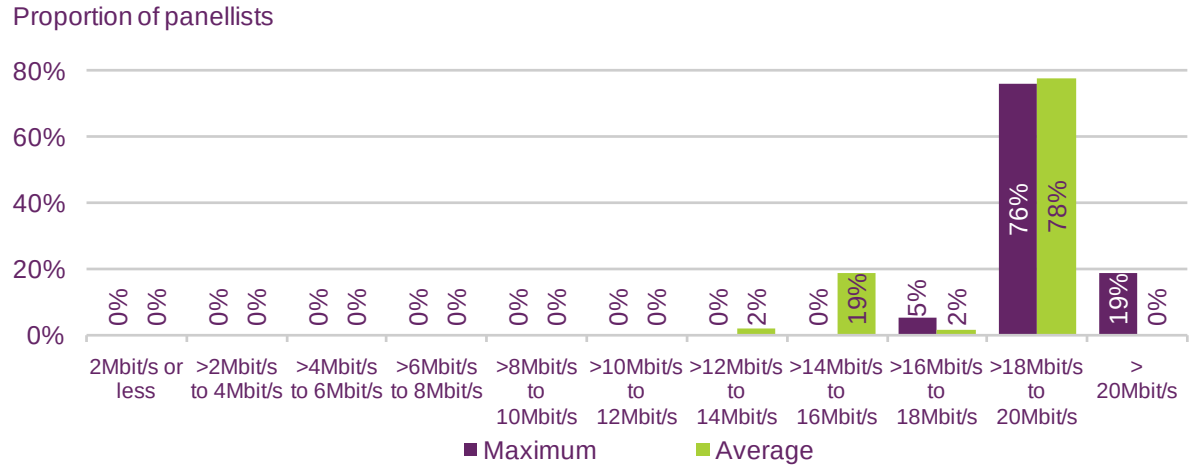
Figure 3.10 Distribution of maximum and average download speeds for consumers on 'up to' 10Mbit/s cable packages, May 2011



Source: SamKnows measurement data for panel members with a connection in May 2011.
Notes: (1) Data have been weighted to regional coverage to ensure that they are representative of UK cable 'up to' 20Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

3.22 Similarly, 95% of panellists on an 'up to' 20Mbit/s cable package received maximum speeds in excess of 18Mbit/s, and 78% had average speeds of over 18Mbit/s (Figure 3.11). It also notable that 19% of these connections received average maximum speeds in excess of the service's headline speed.

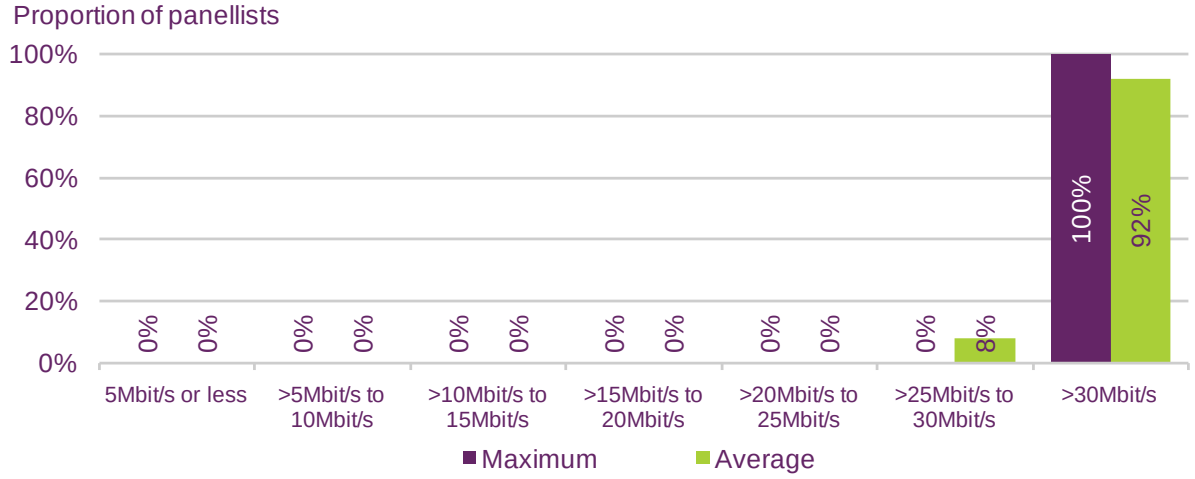
Figure 3.11 Distribution of maximum and average download speeds for consumers on 'up to' 20Mbit/s cable packages, May 2011



Source: SamKnows measurement data for panel members with a connection in May 2011.
Notes: (1) Data have been weighted to regional coverage to ensure that they are representative of UK cable 'up to' 20Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

3.23 In February 2011, Virgin Media stopped offering its 20Mbit/s service to new customers, and in its place launched a new 'up to' 30Mbit/s cable service. We found that all panellists with the new connection received maximum speeds in excess of 30Mbit/s, and 92% received average speeds higher than the connection's headline speed. (Figure 3.12).

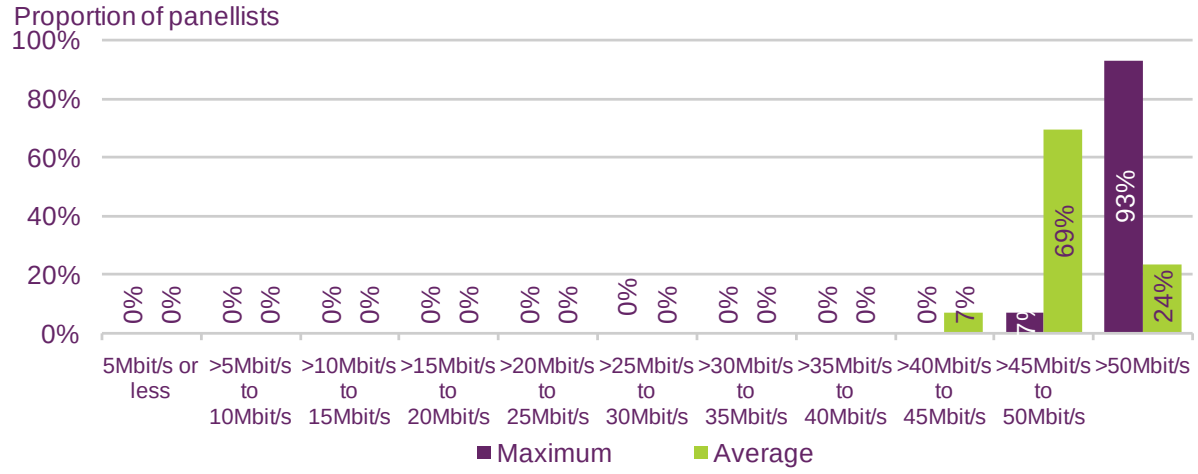
Figure 3.12 Distribution of maximum and average download speeds for consumers on 'up to' 30Mbit/s cable packages, May 2011



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

3.24 All panellists with an 'up to' 50Mbit/s cable package received maximum speeds in excess of 45Mbit/s, and 93% had average speeds of over 45Mbit/s (Figure 3.13). Again, some panellists received maximum and/or average speeds in excess of the headline speed, and 93% of panellists with an 'up to' 50Mbit/s cable package received average maximum download speeds greater than the connection headline speed. In December 2010 Virgin Media is started to offer an 'up to' 100Mbit/s cable service in some areas.

Figure 3.13 Distribution of maximum and average download speeds for consumers on 'up to' 50Mbit/s cable packages, May 2011

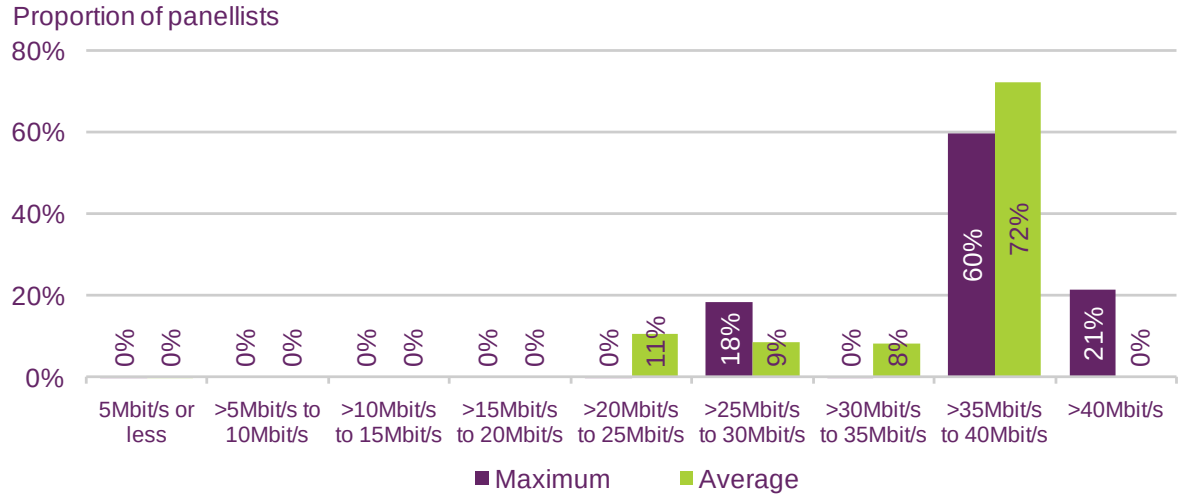


Source: SamKnows measurement data for panel members with a connection in May 2011.
Notes: (1) Data have been weighted to regional coverage to ensure that they are representative of UK cable 'up to' 50Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

3.25 Eighty-one per cent of panellists with a BT 'up to' 40Mbit/s FTTC connection had a average maximum connection speed greater than 35Mbit/s, while 72% had an

average download speed greater than 35Mbit/s. All panellists received average download speeds of more than 20Mbit/s (Figure 3.14).

Figure 3.14 Distribution of maximum and average download speeds for consumers on 'up to' 40Mbit/s FTTC packages, May 2011



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

Section 4

Variation of speeds by geographic location

Overview

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

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

- The availability of services varies by geography. Around 89% of UK homes have access to ADSL2+ services, offering theoretical speeds of 'up to' 20Mbit/s or 24Mbit/s, meaning that around 11% of UK homes only have access to ADSL1-based DSL services, offering a theoretical maximum speed of 'up to' 8Mbit/s. Currently around 48% of UK households have access to Virgin Media's cable services, which offer speeds of 'up to' 50Mbit/s (and 'up to' 100Mbit/s to around 15% of households) and we estimate that around a fifth of UK homes are able to receive FTTC services. BT has committed to making fibre services available to 40% of UK homes by the end of 2012, and 66% by the end of 2012, while Virgin Media is in the process of upgrading its whole network to offer speeds of 'up to' 100Mbit/s. We estimate that by July 2011 57% of UK homes were able to receive a super-fast cable or FTTC broadband service, i.e. one with a headline speed of 'up to' 30Mbit/s or more.

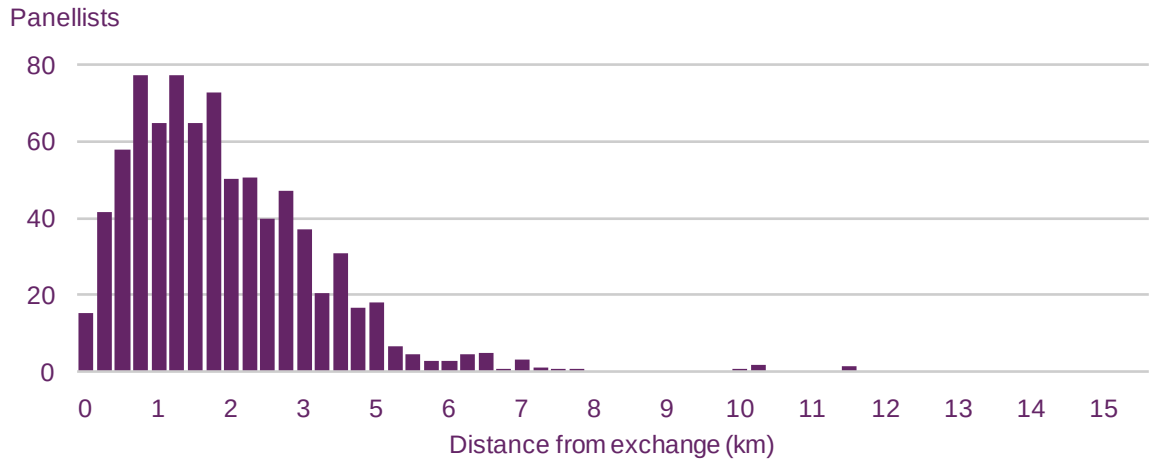
ADSL broadband speeds decline as distance from exchange increases

4.2 As detailed above, it is a characteristic of ADSL broadband that speeds degrade with the length of the copper wire between the exchange and the consumer's premises. We would therefore expect to see some relationship between the distance between a broadband connection and its local exchange and the speeds that are delivered through the connection. (See paragraph 3.16 onwards for a discussion of access line speeds and how they vary by length of line from exchange to premises).

4.3 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 4.1 illustrates, there was a wide range of distances from premises to exchange among our panellists, with an average of around 1.64km.

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

Figure 4.1 Distribution of panellists, by distance from exchange

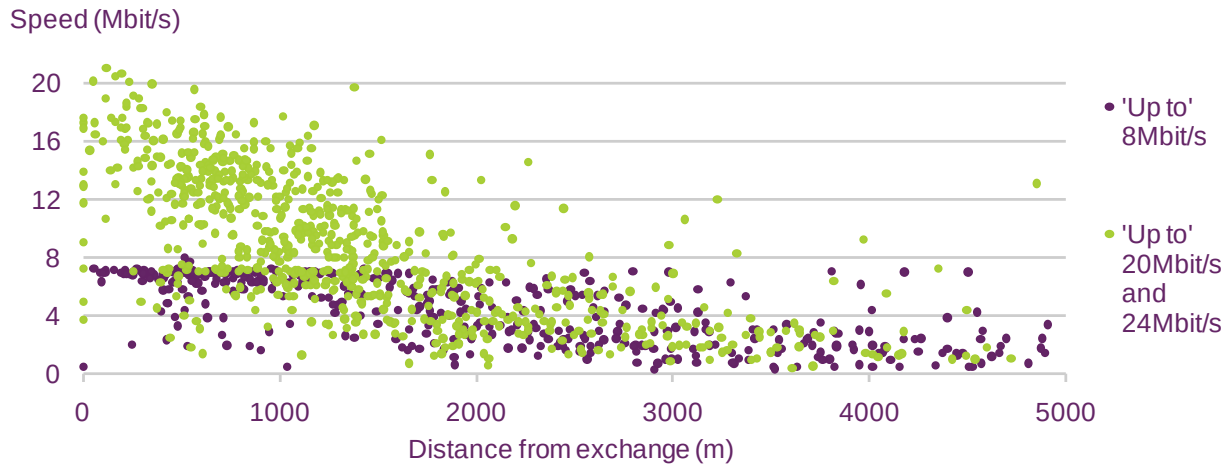


Source: Ofcom using data supplied by SamKnows

4.5 Figure 4.2 shows a plot of line length against maximum download speed. These show that none of our panellists on 'up to' 20 or 'up to' 24Mbit/s ADSL packages ever received average maximum download speeds of more than 21Mbit/s, and few ever received average maximum speeds of more than 18Mbit/s. It also shows that there was a cluster of 'up to' 8Mbit/s customers who received maximum speeds of around 7Mbit/s. This indicates consumers whose line is likely to support a faster speed, but who are being constrained by the limitations of ADSL1 technology (compared to ADSL2+ which support theoretical speeds of up to 24Mbit/s), or are being throttled at around 7Mbit/s as they have signed up for an 'up to' 8Mbit/s package.

4.6 It is also clear that there is a relationship between the maximum download speed delivered and the length of the line (as illustrated in Figure 3.8 previously), although it is also evident that there is a big variation between the speeds delivered to consumers with similar line lengths. This may be explained by a number of factors, including the fact that line length is not an exact proxy of signal loss, the varying quality of in-house wiring, microfilters not being connected, as well as differences between the 'as the crow flies' distance and the actual length of the wire connection.

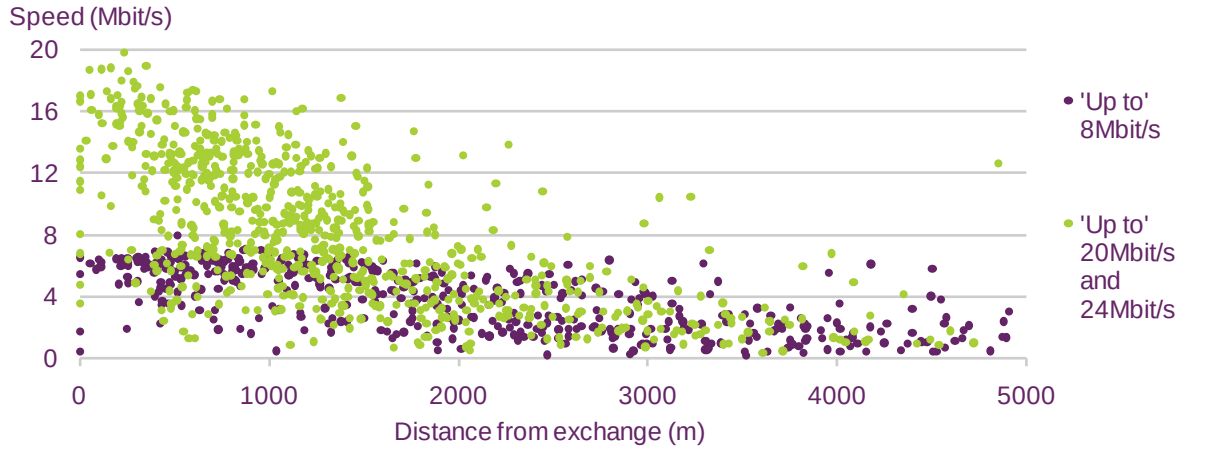
Figure 4.2 Distance from exchange and maximum download speeds achieved by panellists on 'up to' 8Mbit/s and 'up to' 20Mbit/s and 24Mbit/s ADSL packages, May 2011



Source: SamKnows measurement data for all panellists with a ADSL connection in May 2011.
Note: Data are unadjusted so are not directly comparable with data elsewhere in this report, which have been weighted for line length.

4.7 As might be expected, there is also a relationship between distance from exchange and the average download speeds delivered (Figure 4.3). The pattern is similar to that of maximum download speeds, but average speeds are lower, with only six panellists receiving average speeds of more than 18Mbit/s. The difference between maximum and average speeds is primarily due to download speeds being constrained by contention within ISPs' networks.

Figure 4.3 Distance from exchange and average download speeds achieved by panellists on 'up to' 8Mbit/s and 'up to' 20Mbit/s and 24Mbit/s ADSL packages, May 2011



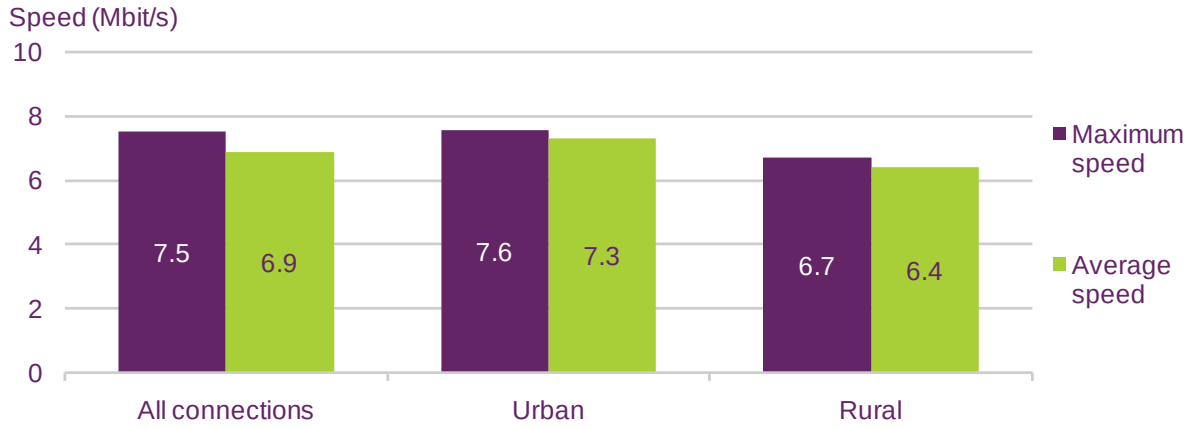
Source: SamKnows measurement data for all panellists with a ADSL connection in May 2011.
Note: Data are unadjusted so are not directly comparable with data elsewhere in this report, which have been weighted for line length.

Rural versus urban location

4.8 Urban consumers typically have a wider choice of broadband provider than their rural counterparts, and are more likely to have a choice of higher-speed services. This greater availability of higher-speed services means that average download speeds

delivered to urban consumers are higher than the average speeds delivered to rural consumers. We estimate that, overall, including DSL, cable and FTTC connections, the average maximum speed delivered to residential fixed-line broadband consumers in rural areas (6.7Mbit/s) was 11% lower than the average maximum 7.6Mbit/s delivered to urban consumers (Figure 4.4). Similarly, average download speeds in rural areas averaged 6.4Mbit/s, 12% lower than half the 7.3Mbit/s average in urban areas.

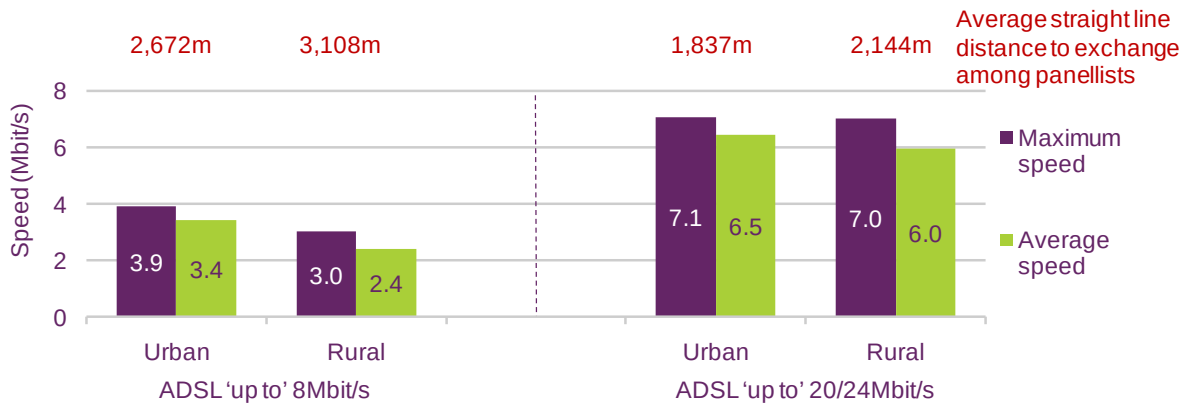
Figure 4.4 Estimated average and maximum download speeds for broadband connections in rural & urban areas, May 2011



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

4.9 Among our ADSL panellists, the average line length for rural consumers was 2,424m, compared to an average of 2,226m for urban consumers, meaning that on average rural ADSL consumers received much slower speeds than those living in urban areas. Figure 4.5 indicates that both maximum and average download speeds were slower for ADSL consumers in rural areas on 'up to' 8Mbit/s packages, and on 'up to' 20Mbit/s or 24Mbit/s packages. In addition to having typically shorter line lengths, the greater availability of ADSL2+ services in urban areas is also likely to be a factor.

Figure 4.5 Average and maximum download speeds for ADSL broadband connections in rural & urban areas, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011, Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) Data collected from multi-thread download speed tests

Geographic market situation

4.10 Different areas of the country have different ranges of providers. In some locations it is only possible to obtain broadband services using lines operated by BT Wholesale. In other parts of the country, there is a wider range of providers, including cable and ADSL services delivered by operators who have taken over BT lines using local-loop unbundling (LLU). We wanted to see how download speeds varied between these different areas.[22]

4.11 Ofcom considers three separate geographic markets for wholesale broadband provision (see Annex 2 for more details)[23]:

- Market 1 – Those geographic areas covered by exchanges where BT is the only operator (i.e. there has been no LLU);
- Market 2 – Those geographic areas covered exchanges where two Principal Operators[24] are present or forecast AND exchanges where three Principal Operators are present or forecast but where BT's share is greater than or equal to 50 per cent; and

[22] It should be noted that the Market definitions and local exchange designations used in the analysis contained in this report were updated in December 2010, and therefore differ to those used in previous Broadband Speeds reports.

[23] A fourth area is the Hull area, consisting of those geographic areas covered by exchanges where KCom is the only operator (representing 14 exchanges and covering 0.7% of the population). Ofcom, *Review of the wholesale broadband access markets: Statement on market definition, market power determinations and remedies*, December 2010 available at http://stakeholders.ofcom.org.uk/binaries/consultations/wba/statement/wbastatement.pdf

[24] The operators classed as Principal Operators are BT, Cable & Wireless Worldwide, O2, Orange, Sky, TalkTalk and, in local exchange areas where cable coverage exceeded 65 per cent of premises, Virgin Media.

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

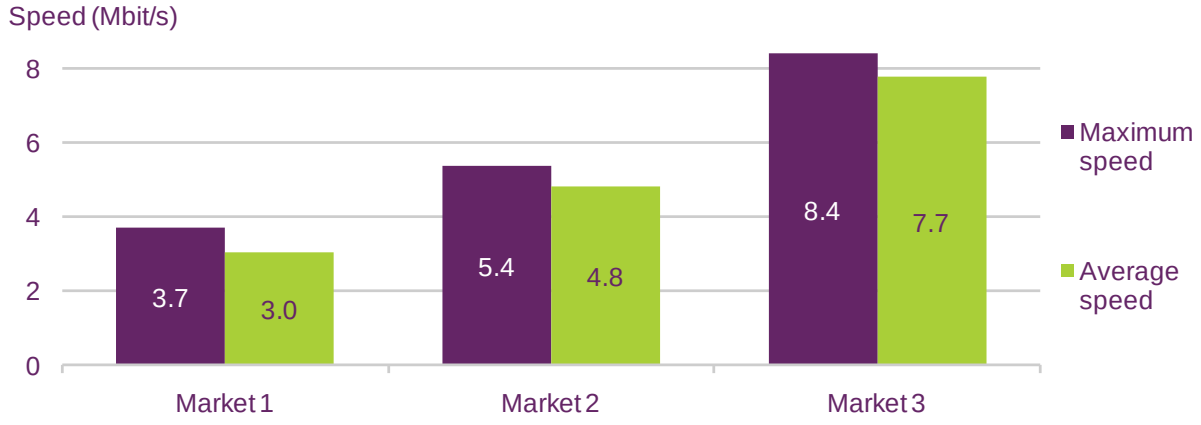
4.12 In general, exchanges in Market 1 tend to serve rural areas, and those in Market 3 tend to service the most densely populated areas. Therefore, comparing performance by these markets provides an indication of how broadband performance varies with demography.

4.13 Consumers living in areas designated as Market 1 on average received download speeds significantly slower than those in areas designated as Markets 2 or 3. (Figure 4.6). Average broadband download speeds in Market 1 areas were just 3.0Mbit/s compared to 4.8Mbit/s in Market 2 areas and 7.7Mbit/s in Market 3 areas[25].

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

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

Figure 4.6 Average and maximum download speeds by geographic market, May 2011



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

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

4.15 Figure 4.7 below shows our estimates of average speeds by UK nation, which were derived from applying the average speeds of connections in each of the three markets to the split of connections in each nation.

4.16 This analysis suggests that among the UK nations maximum and average speeds were highest in England (at 7.6Mbit/s and 6.9Mbit/s respectively) - around 15% higher than in Northern Ireland, where both maximum and average speeds were lowest. It must be noted that these are estimates and that the method of calculation means that these figures are not comparable with the UK averages published elsewhere in this report.

Figure 4.7 Estimated average and maximum download speeds by UK nation, May 2011

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

Section 5

Variation of speeds by time of day

Download speeds typically slow down during peak periods

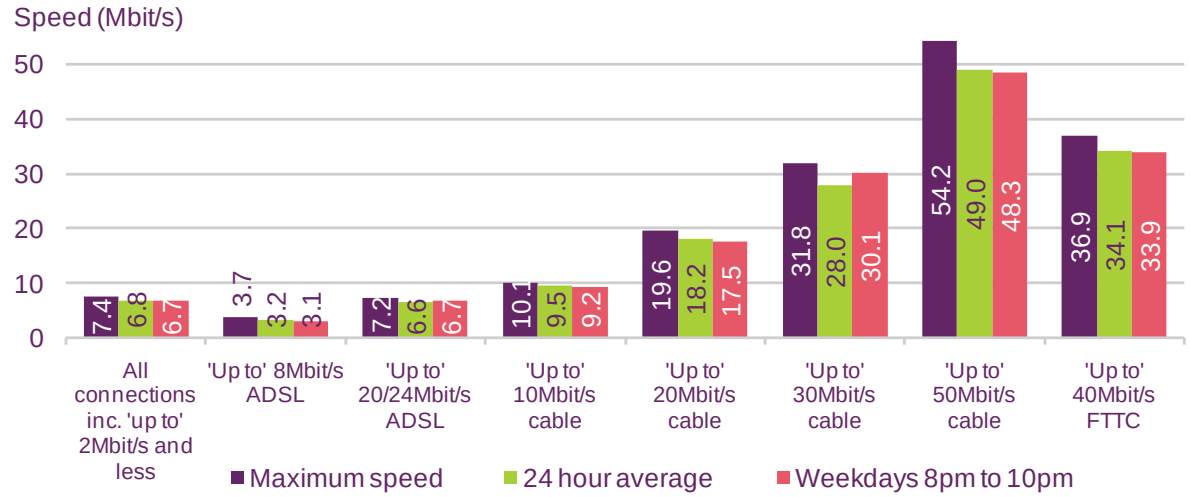
5.1 In addition to geographic factors, another driver of variation in broadband performance is contention in the ISP's network, when speeds are degraded as multiple users share the same bandwidth. It is primarily for this reason that in May 2011 average download speeds during the peak weekday evening period of 8pm to 10pm were, on average across all panellists, around 90% of the maximum download speed recorded (which was typically during an off-peak hour when there was very little contention in the network).

5.2 Figure 5.1 indicates that there was similar pattern across all types of ADSL and cable services. It should be noted, however, that there is some variation between ADSL providers in terms of peak-time performance (see section 7 below).

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

5.4 It should also be noted that our tests have been designed to measure the performance delivered by ISPs to the consumer's router. 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 5.1 Variations in download speed by time of day, May 2011



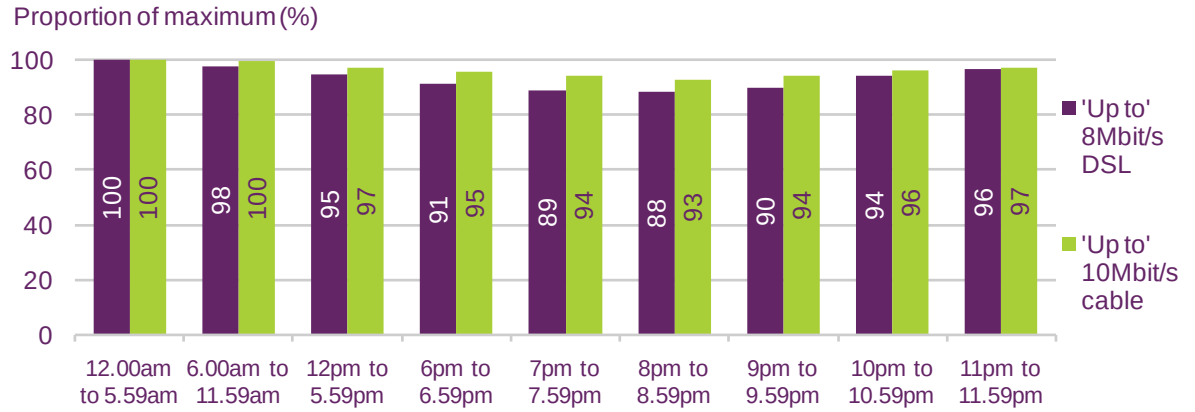
Source: SamKnows measurement data for all panel members with a connection in May 2011. Panel Base: 1325
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK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

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

5.5 Figure 5.2 shows the average download speeds delivered to panellists on 'up to' 8Mbit/s ADSL packages and 'up to' 10Mbit/s cable packages as a proportion of the average maximum for each type of connection by time of day. It indicates that speeds were fastest in the early morning for each connection type, and slowed down during the 'peak' evening period.

5.6 For 'up to' 8Mbit/s ADSL packages, average download speeds in the slowest period of 8pm to 9pm (3.1Mbit/s) were 12% slower than the 3.5Mbit/s average maximum recorded between 12am and 6am. For 'up to' 10Mbit/s cable services the difference between the slowest speed recorded (9.1Mbit/s at 8pm to 9pm) and the highest (9.8Mbit/s at 12am to 6am) was lower, with the slowest speed being 7% lower than the highest one.

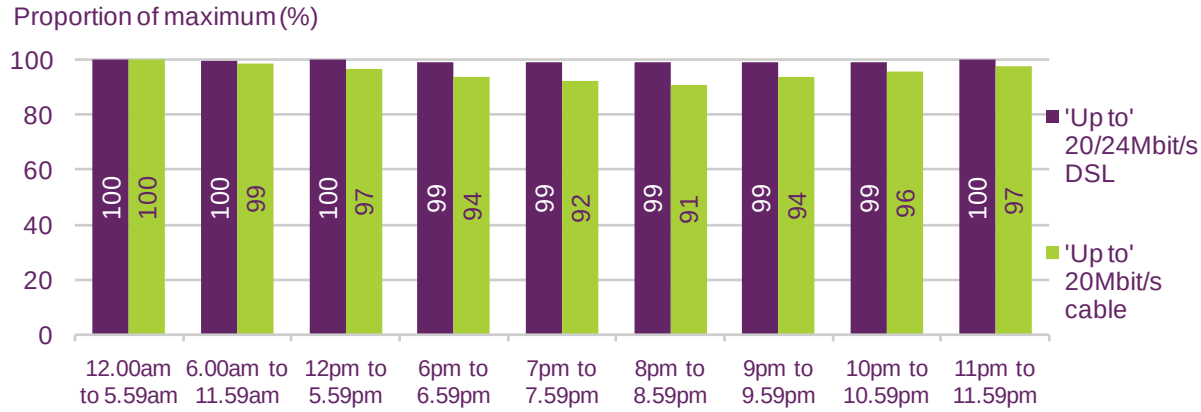
Figure 5.2 Average download speed as a proportion of maximum speed by time of day for panellists 'up to' to 8Mbit/s and 10Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK 'up to' 8Mbit/s and 10Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

5.7 The difference was even greater when comparing the highest and lowest recorded hourly average download speeds for 'up to' 20Mbit/s or 24Mbit/s ADSL packages and 'up to' 20bit/s cable connections (Figure 5.3). Although cable customers on 'up to' 20Mbit/s packages receive significantly higher speeds than customers on 'up to' 20Mbit/s and 24Mbit/s ADSL services, the decrease in speeds in peak periods was greater for cable connections, with speeds in the slowest hour of 8pm to 9pm (17.3Mbit/s) being 9% lower than those in the fastest hour of 12am to 6am (19.0Mbit/s), compared to a 1% difference between the lowest (6.7Mbit/s at 7pm to 8pm) and highest (6.7Mbit/s at 12am to 6am) values for 'up to' 20Mbit/s or 24Mbit/s ADSL packages.

Figure 5.3 Average download speed as a proportion of maximum speed by time of day for panellists 'up to' to 20Mbit/s and 24Mbit/s packages, May 2011

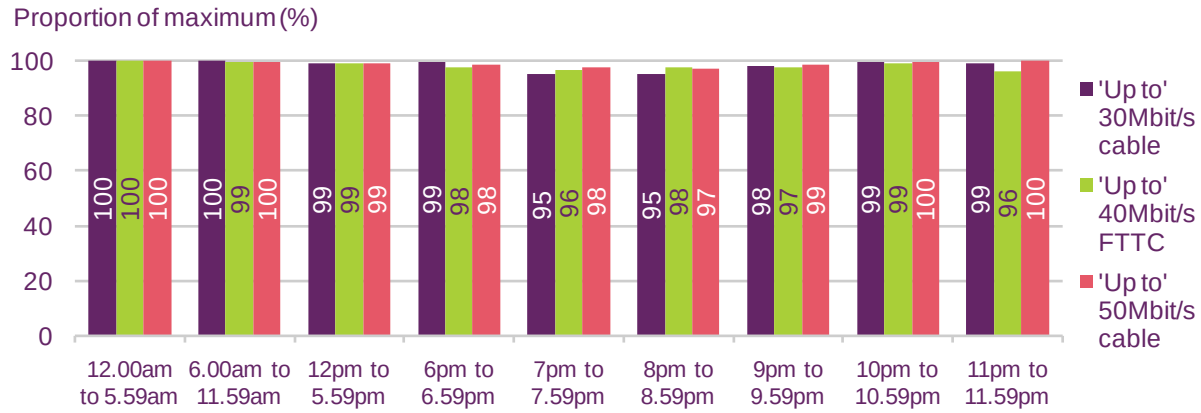


Source: SamKnows measurement data for all panel members with a connection in May 2011.
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK 'up to' 20Mbit/s and 24Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

5.8 The super-fast ISP packages included in our research (i.e. those with a headline speed of 30Mbit/s or above) all suffered from similar levels of connection slowdown during busy times, with the slowest recorded average speeds of each being around 4% lower than the average maximums (Figure 5.4).

5.9 Average download speeds for BT's 'up to' 40Mbit/s service in the slowest period of 11pm to 12am (33.5Mbit/s) were 4% slower than the fastest recorded speeds of 34.8Mbit/s between 12am and 6am). Virgin Media's 'up to' 30Mbit/s services also recorded its fastest average speeds between 12am and 6am (at 31.5Mbit/s) compared to a slowest average recorded speeds of 29.9Mbit/s between 7pm and 8pm, a slowdown of 5%. Virgin Media's 'up to' 50Mbit/s service's slowest average speed (48.0Mbit/s between 8pm and 9pm) was 3% slower than the highest average recorded speeds (49.6Mbit/s between 11pm and 12am).

Figure 5.4 Average download speeds as a proportion of maximum speed by time of day for panellists 'up to' 30Mbit/s to 50Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK 'up to' 30Mbit/s, 40Mbit/s and 50Mbit/s residential customers as a whole; (2) Data collected from multi-thread download speed tests.

Section 6

Variation of speeds by access technology

A range of different broadband technologies are available in the UK

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

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

6.3 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 published research into mobile broadband performance in May 2011.[26]

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

- **ADSL** (sometimes referred to as ADSL1) was the first generation of ADSL technology and can currently deliver broadband speeds up to a theoretical maximum of 8Mbit/s. However, speeds of 8Mbit/s are not achieved by most customers because ADSL broadband degrades as the length of the line from the exchange gets longer. Indeed, ISPs typically cap speeds at less than 8Mbit/s in order to ensure connections are stable. (For example, BT Wholesale's Broadband Remote Access Server (BRAS) system sets a maximum speed of 7.2Mbit/s for ADSL1 broadband – its ADSL Max product). BT Wholesale is currently upgrading its exchanges to enable it to offer the higher speed (ADSL2+) *Wholesale Broadband Connect* (WBC) product in addition to ADSL Max. As a consequence, BT Retail, and other ISPs who purchase services from BT Wholesale, has 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 3.8 above, the speed of ADSL2+ broadband degrades more quickly than ADSL1 over the length of the copper wire from exchange to premises, meaning that at a distance of more than 3km there is little difference between the two technologies. ADSL2+ has been widely rolled out in the UK since 2006 by LLU providers such as Sky, Orange and O2/Be. BT Wholesale has launched its WBC ADLS2+ service, and is currently upgrading its exchanges to

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

this standard, while LLU-based ADSL2+ services are already available to 89% of UK homes.

6.5 Over 20% of broadband connections in the UK are made via cable, and Virgin Media's cable services are available to just under half of UK homes, delivering broadband via its hybrid fibre and co-axial cable network. Unlike ADSL, cable broadband does not degrade with distance from the exchange, although it is subject to the same constraints of limited network capacity (contention). In 2008 and 2009 Virgin Media upgraded its network to the DOCSIS 3.0 standard which has allowed it to offer services of 'up to' 100Mbit/s in some parts of the UK (around 4 million homes – 15% of all homes in the UK – by May 2011).

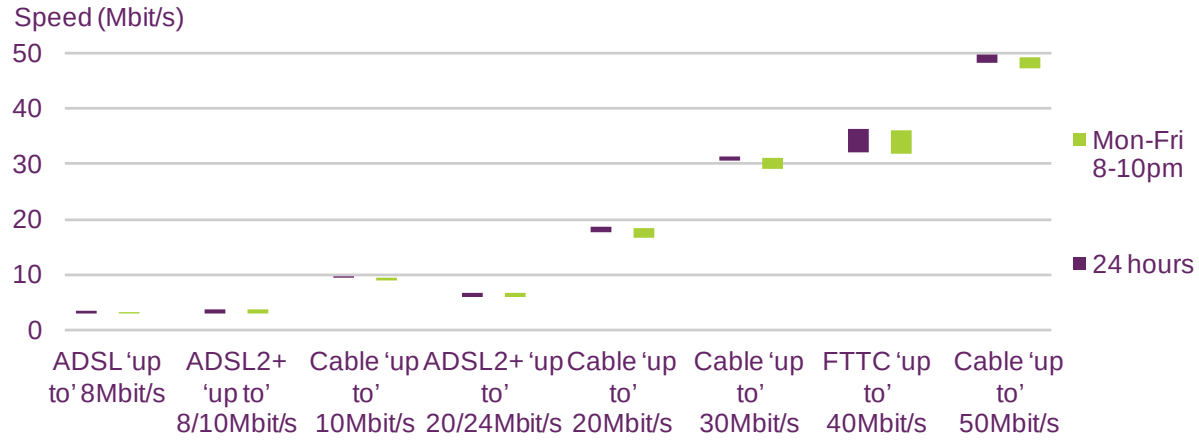
Cable broadband services were significantly faster than ADSL services

6.6 Our results demonstrated significant differences in performance between different broadband technologies. Figure 6.1 below compares the average download speeds delivered to panellists in May 2011 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 weekday 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.

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

6.8 The difference between cable and ADSL was also repeated for higher-speed packages. Cable customers on a headline speed of 20Mbit/s on average received speeds more than twice as fast as ADSL2+ packages at 'up to' 20Mbit/s or 24Mbit/s. 'Up to' 30Mbit/s and 50Mbit/s cable connections delivered average speeds closer to the headline speeds than BT's 'up to' 40Mbit/s FTTC service.

Figure 6.1 Average download speeds by technology and headline speed, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011. Panel Base: 1325
Notes: (1) Data have been weighted by ISP package and LLU/non-LLU connections, Rural/Urban, Geographic Market classification and distance from exchange to ensure that they are representative of UK residential broadband consumers as a whole; (2) As sufficient sample sizes were not available for consumers on packages of 'up to' 2Mbit/s or less, data collected for these packages in April 2009 has been factored in, in proportion to share of all connections in May 2011; (3) Data collected from multi-thread download speed tests; (4)The range shown represents a 95% confidence interval around the mean.

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

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

6.10 A consumer's location not only determines the length of their connection to the local exchange, it also determines what services are available as ADSL2+ service offering speeds of 'up to' 20Mbit/s or 24Mbit/s and cable broadband services are only available in some parts of the country. 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.[27] A more detailed set

[27] 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.

of factors on what should be considered when purchasing broadband is available in Ofcom's consumer guide to buying broadband[28].

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

Section 7

Variation of speeds by internet service provider (ISP) package

7.1 The results described in the previous sections indicate that in addition to the geographic location of consumers (particularly in terms of line length for ADSL consumers), there are two main reasons why broadband performance may vary: the technology used by the ISP serving the consumer and the capacity per user of their network (often described as level of contention). In this section we examine the effects of these factors on individual ISP packages' performance, firstly on download speeds and then on upload speeds. ISP performance on other metrics (web browsing, latency, DSN, packet loss and jitter) is included in Section 8.

ISP packages for which we had a representative sample

7.2 Our ability to robustly compare the performance of specific ISP packages was dependent on achieving sufficient sample sizes necessary to allow meaningful statistical analysis. We were able to achieve this for the following packages (listed in alphabetical order):

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

7.3 We were able to generate statistically reliable results only for ISP packages for which we were able to recruit sufficient test recruits; these accounted for 74% of UK residential broadband connections in May 2011. However, there are many other ISPs available, many of which may match or better the performance of some of the ISP packages included in the report. See paragraph 2.12 onwards.

7.4 As in the March 2011 report, for comparisons of ISP package performance outside the Kingston-upon-Hull area we only used panellists who live within geographic Markets 2 and 3 in the present research. This means that all panellists outside Kingston-upon-Hull area 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. Additionally, we also include Karoo ADSL broadband connections in the Kingston-upon-Hull area for the first time in this report.

7.5 For those ADSL 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 O2/Be, Sky and TalkTalk.

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

Methodological considerations

7.7 As in the March 2011 Ofcom Broadband Speeds report, the analysis in this section shows the results from multi-thread tests, which test the speed when multiple files are downloaded simultaneously (previous reports had concentrated on the results from single-thread tests which test the speed of download of a single file). While a single-thread test replicates the consumer experience of downloading a small file such as an MP3 track, multi-thread testing replicates web page downloads, peer-to-peer configurations, or multiple PCs simultaneously downloading files using the same broadband connection. Multi-thread tests typically deliver slightly faster speeds than single-thread tests.

7.8 In the last 18 months, most ISPs have changed their ADSL package offerings. Whereas previously they all offered 'up to' 8Mbit/s packages as standard, BT Retail, Sky and Orange now offer 'up to' 20Mbit/s as the standard on all ADSL packages, and TalkTalk offer 'up to' 24Mbit/s (marketed as the fastest speed the line can provide) as the standard on all its products. However, in May 2011 many providers still had customers on legacy products, where maximum speeds are still capped at 'up to' 8Mbit/s (or, for a small proportion of customers, at 'up to' 2Mbit/s or less).

7.9 As such, it was a challenge to allocate panellists taking part in the research to the most appropriate package. It was necessary to do this in order to ensure that valid comparisons were made – we consider that it would not be appropriate to consider, for example, all BT Retail customers as if they were on an 'up to' 20Mbit/s package, when a large proportion of its subscription base had purchased and were still receiving an 'up to' 8Mbit/s ADSL1-based service. The method we applied to allocate panellists to the most appropriate package are detailed in Annex 3.

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

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

ADSL broadband is that performance degrades over the length of the copper wire.)

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

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

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

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

7.11 We consider that the data set out below represent an accurate assessment of the comparative download speeds achieved by the ISP packages included in the research during May 2011. However, caution should be applied in drawing conclusions from this research given its limitations. In particular, we highlight the following constraints:

- The data represent a 'snapshot' of the market in May 2011. 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 2011) or future performance.

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

- Traffic management policies are also relevant to the user experience and are not generally captured in the data below. These may include policies which limit peer-to-peer traffic and which slow down the download speeds available to heavy broadband users. Under Ofcom's Voluntary Code of Practice on Broadband

Speeds, ISP signatories have committed to advise consumers of these policies if they use them.[29]

- We have only included selected ISP packages within our analysis. We are keen to include additional ISP packages in future research. Relevant considerations include the ability to obtain a representative sample of consumers on a particular ISP package and the ease of recruitment of panel members.

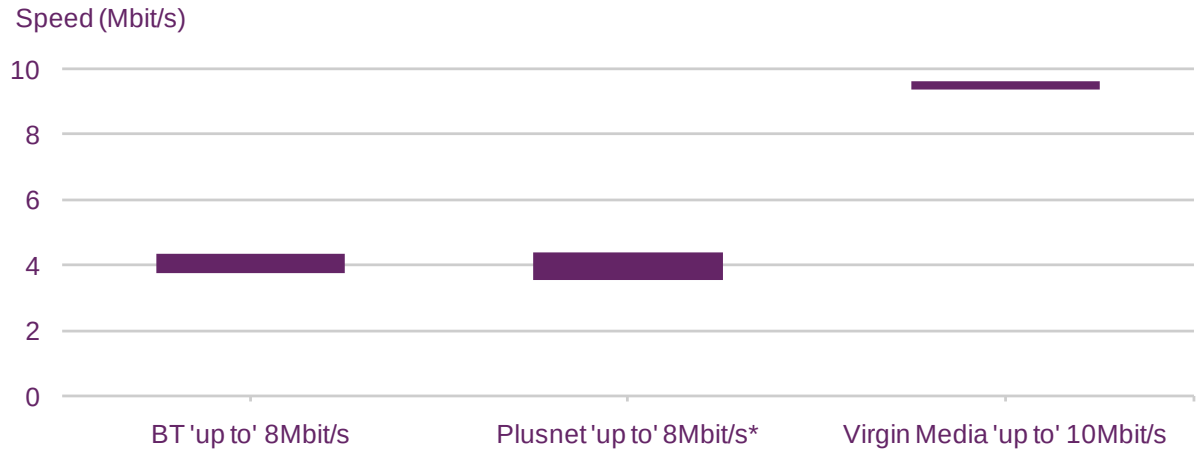
Results over the 24-hour period

7.12 Figures 7.1 and 7.2 illustrate the differences among ISP packages of 'up to' 8Mbit/s or 10Mbit/s for the average of all download speed tests run 24 hours a day, during the May 2011 testing period. As with the results by technology set out earlier, they are presented in terms of bars showing the 95% confidence interval – this means that there is a 95% probability that the actual average speed for all customers (i.e. not just customers within our sample) falls within the range shown.

7.13 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.

7.14 Our research found that the average actual download speeds received by Virgin Media cable customers on 'up to' 10Mbit/s (9.3 to 9.6Mbit/s) were significantly higher than those delivered by both of the 'up to' 8Mbit/s ADSL packages included in this research.

Figure 7.1 Average download speeds for 'up to' 8Mbit/s and 10Mbit/s ISP packages, 24 hours, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: Small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's

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

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 7.2 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 2011

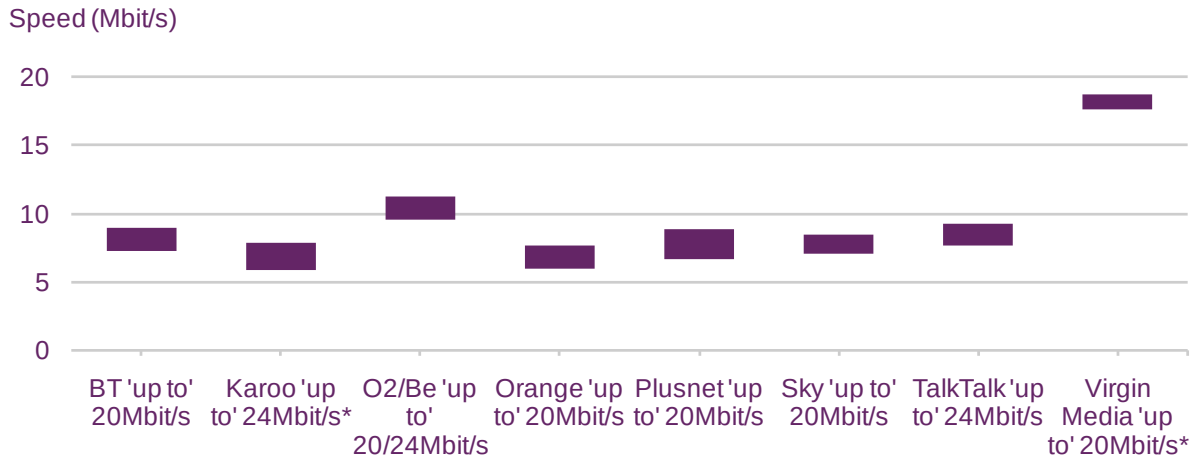
ISP package	Is faster than...
Virgin Media	BT and Plusnet

Source: Ofcom

7.15 Figures 7.3 and 7.4 apply the same analysis to 'up to' 20Mbit/s and 24Mbit/s ISP packages. Again, it finds that Virgin Media's cable service delivered significantly faster download speeds than the ADSL equivalents, with average download speeds of 17.6 to 18.7Mbit/s on its 'up to' 20Mbit/s service compared to average download speeds of 5.6 to 11.7Mbit/s delivered by ADSL providers' 'up to' 20Mbit/s or 24Mbit/s packages.

7.16 In terms of statistical significance, among the ADSL operators, the average download speeds delivered by O2/Be were significantly faster than those delivered by BT Retail, Karoo, Orange, Plusnet, Sky and TalkTalk over the 24-hour period.

Figure 7.3 Average download speeds for 'up to' 20Mbit/s and 24Mbit/s packages, 24 hours, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: Small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

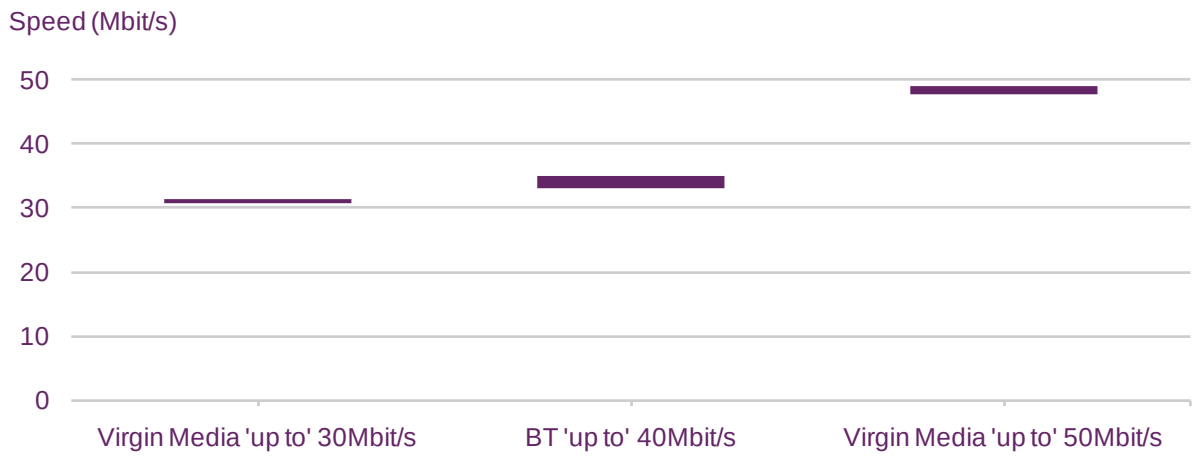
Figure 7.4 Significant differences to a 95% level of confidence between average download speeds for 'up to' 20Mbit/s and 24Mbit/s packages, 24 hours, May 2011

ISP package	Is faster than...
Virgin Media	BT, Karoo, O2/Be, Orange, Plusnet, Sky and TalkTalk
O2/Be	BT*, Karoo, Orange, Plusnet, Sky and TalkTalk*

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

7.17 Figures 7.5 and 7.6 show the performance of the ISP packages with a headline speed above 'up to' 24Mbit/s that were included in our research. Virgin Media's 'up to' 50Mbit/s service delivered average speeds between 47.7Mbit/s and 49.0Mbit/s, while BT's 'up to' 40Mbit/s FTTC service delivered, on average, speeds between 32.9Mbit/s and 34.8Mbit/s. This was faster than Virgin Media's 'up to' 30Mbit/s service which delivered average speeds above the service's headline speed (30.7Mbit/s and 31.3Mbit/s).

Figure 7.5 Average download speeds for above 'up to' 24Mbit/s packages, 24 hours, May 2011



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

Figure 7.6 Significant differences to a 95% level of confidence between average download speeds for above 'up to' 24Mbit/s packages, 24 hours, May 2011

ISP package	Is faster than...
Virgin Media 50	BT and Virgin Media 30
BT	Virgin Media 30

Source: Ofcom

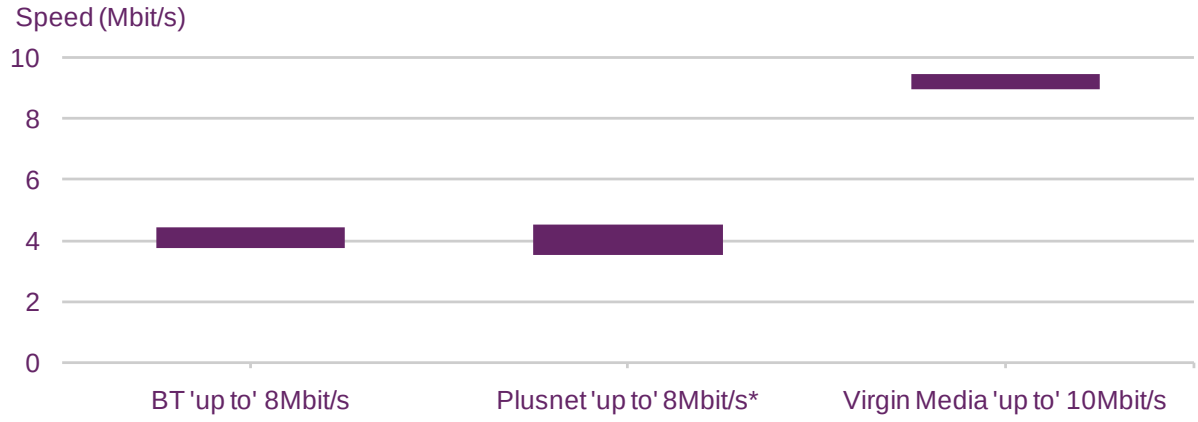
Results during peak periods

7.18 The effect of contention in ISPs' networks is shown in Figures 7.7 to 7.12 which look specifically at performance during the peak period between 8pm and 10pm on weekdays[30]. In aggregate, performance in this peak period is around 2% slower than over the 24-hour period.

7.19 Figure 7.7 indicates that during these peak hours, Virgin Media's 'up to' 10Mbit/s cable service remained significantly faster than any ADSL operator's 'up to' 8Mbit/s package, delivering average download speeds of 9.0 to 9.5Mbit/s, compared to ADSL package performance from 3.3 to 4.1Mbit/s.

7.20 There were no significant differences between the performance of the two 'up to' 8Mbit/s ADSL ISP packages, either in terms of average download speeds delivered during the peak period or the difference between average 24 hour download speeds and peak-period download speeds. This is unsurprising given that BT and Plusnet, to a large extent, use the same network infrastructure.

Figure 7.7 Average download throughput speeds for 'up to' 8Mbit/s and 10Mbit/s packages, 8 to 10pm weekdays, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011
**Caution: Small sample size (<50).*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 7.8 Significant differences to a 95% level of confidence between average speeds on 'up to' 8Mbit/s and 10Mbit/s packages, 8 to 10pm weekdays, May 2011 (multi-thread tests)

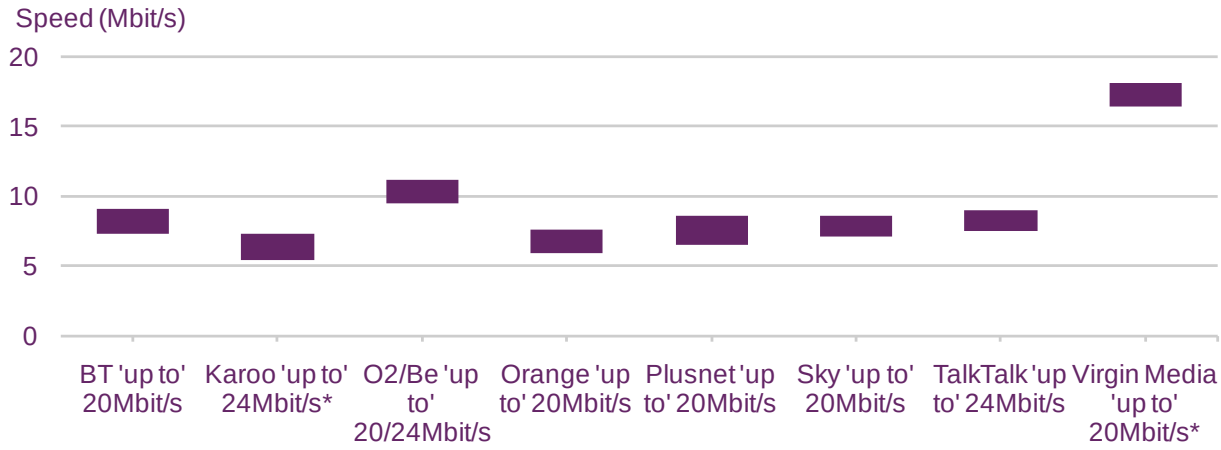
ISP package	Is faster than...
Virgin Media	BT and Plusnet

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

Source: Ofcom

7.21 As shown in Figures 7.9 and 7.10, among the 'up to' 20Mbit/s and 24Mbit/s packages, Virgin Media's cable service delivered significantly faster peak-time download speeds than comparable ADSL packages (16.4 to 18.1Mbit/s compared to the range of ADSL package performance of 5.2 to 11.6Mbit/s). O2/Be delivered significantly faster download speeds than the other 'up to' 20Mbit/s and 'up to' 24Mbit/s ADSL services.

Figure 7.9 Average download throughput speeds for 'up to' 20Mbit/s and 24Mbit/s packages, 8 to 10pm weekdays, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: Small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

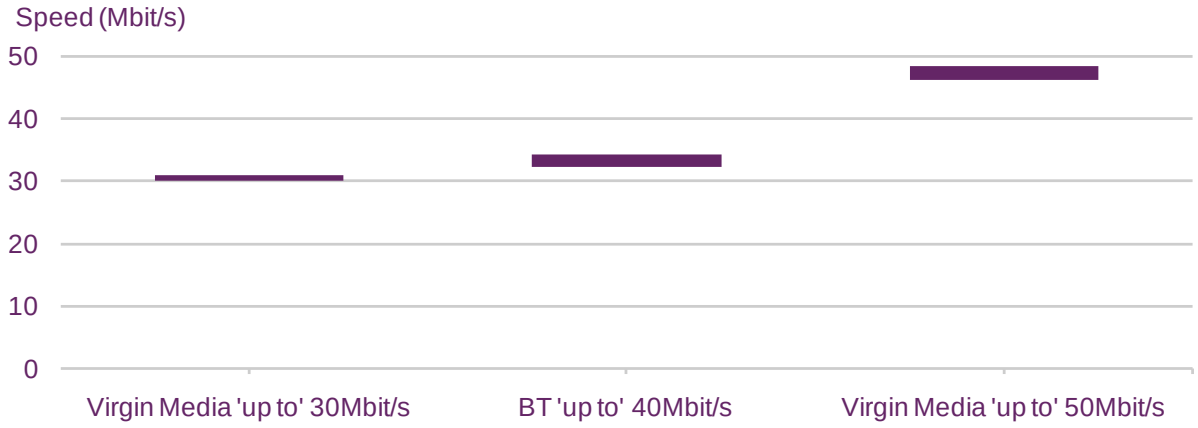
Figure 7.10 Significant differences to a 95% level of confidence between average download throughput speeds for 'up to' 20Mbit/s and 24Mbit/s packages, 8 to 10pm weekdays, May 2011

ISP package	Is faster than...
Virgin Media	BT, Karoo, O2/Be, Orange, Plusnet, Sky and TalkTalk
O2/Be	BT*, Karoo, Orange, Plusnet, Sky* and TalkTalk*

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

7.22 As was the case over the 24 hour period, Virgin Media's 'up to' 50Mbit/s cable service delivered the highest average download speeds among the super-fast services included in this reports during the 8 to 10pm weekday peak period at 46.3Mbit/s to 48.4Mbit/s (Figure 7.11). Again, BT's 'up to' 40Mbit/s service delivered average speeds faster that Virgin Media's 'up to' 30Mbit/s service (at 32.1Mbit/s to 34.1Mbit/s compared 30.1Mbit/s to 30.9Mbit/s). It is notable Virgin Media's 'up to' 30Mbit/s delivered average speeds higher than the packages headline speed, even during the peak period when speeds are generally lowest.

Figure 7.11 Average download throughput speeds for above 'up to' 24Mbit/s packages, 8 to 10pm weekdays, May 2011



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

Figure 7.12 Significant differences to a 95% level of confidence between average download throughput speeds for above 'up to' 24Mbit/s packages, 8 to 10pm weekdays, May 2011

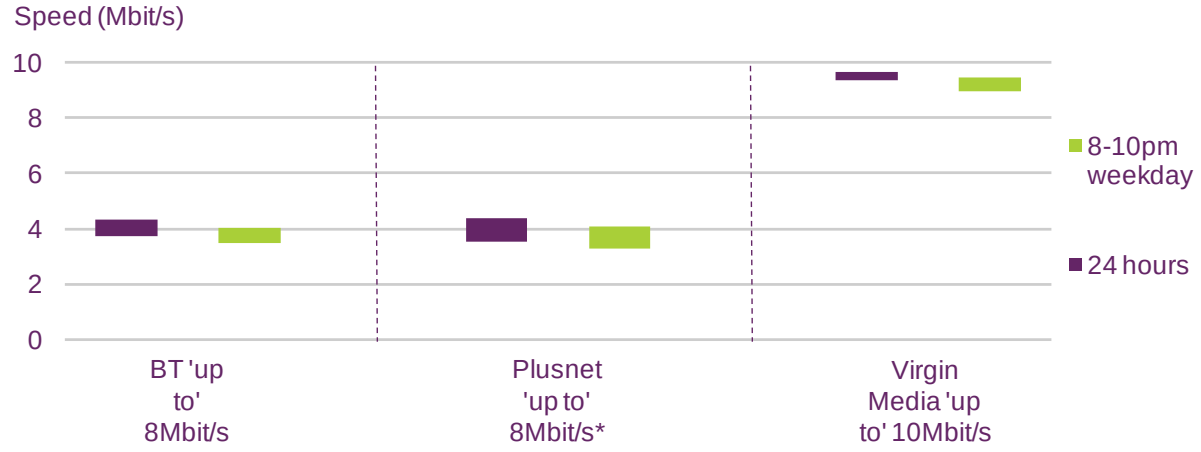
ISP package	Is faster than...
Virgin Media 50	BT and Virgin Media 30
BT	Virgin Media 30

Source: Ofcom

Summary of results

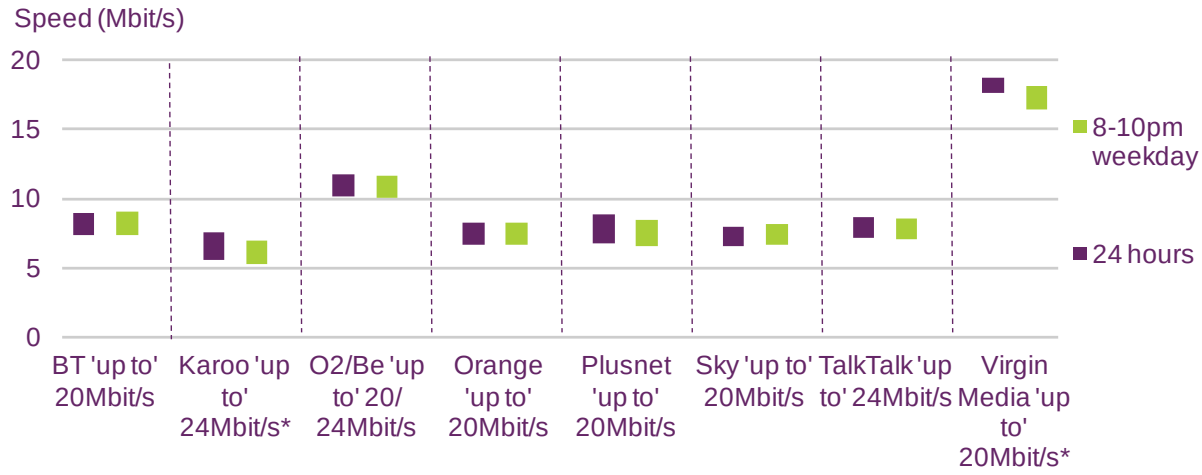
7.23 Figures 7.13 to 7.15 depict the average performance by ISP packages in May 2011 over a 24-hour period and in the peak period of 8pm to 10pm weekdays to a 95% confidence interval around the mean.

Figure 7.13 Average download speeds for 'up to' 8Mbit/s and 10Mbit/s connections by package, overall and in the peak period, May 2011



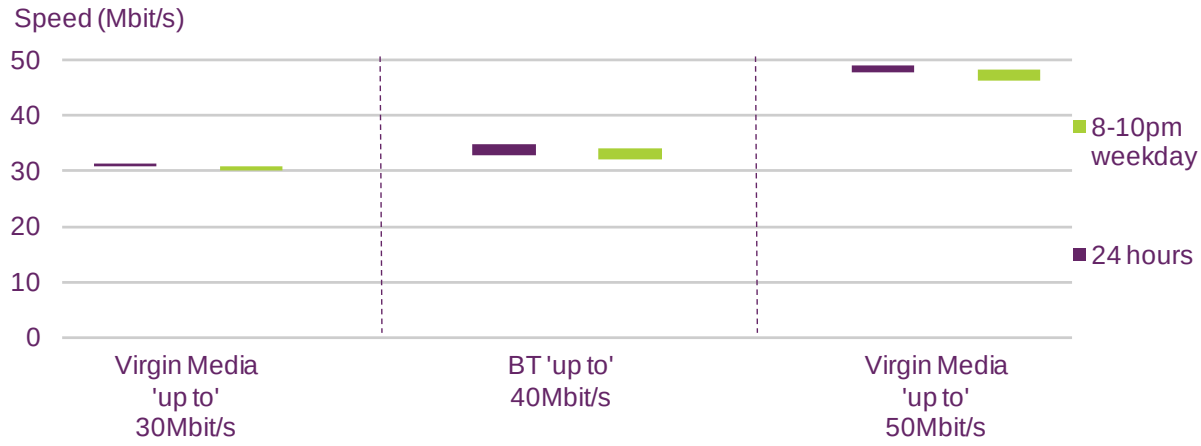
Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: Small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 7.14 Average download speeds for 'up to' 20Mbit/s and 24Mbit/s connections by package, overall and in the peak period, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: Small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 7.15 Average download speeds for above 'up to' 24Mbit/s connections by package, overall and in the peak period, May 2011



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

7.24 Figure 7.16 summarises the speeds achieved by all ISPs on average and in the peak evening period. As with the charts above, performance is detailed in the form of a range which represents a 95% confidence interval around the mean; we do this in order to acknowledge the limited statistical accuracy of the research - a 95% confidence interval means that if we repeated the research again with a different sample assembled in the same way there would be a 95% probability that the mean value would be in the range shown. As a rule of thumb, where the range of two operators overlaps, differences in performance between the operators are not statistically different at a 95% level of confidence.

Figure 7.16 Summary of average download speed by ISP package, May 2011

	Average download throughput speed during period	
	24 hours	8 to 10pm weekdays
BT 'up to' 8Mbit/s	3.8 to 4.3Mbit/s	3.5 to 4.0Mbit/s
Plusnet 'up to' 8Mbit/s*	3.5 to 4.4Mbit/s	3.3 to 4.1Mbit/s
Virgin Media 'up to' 10Mbit/s	9.3 to 9.6Mbit/s	9.0 to 9.5Mbit/s
BT 'up to' 20Mbit/s	7.3 to 9.0Mbit/s	7.4 to 9.0Mbit/s
Karoo 'up to' 24Mbit/s*	5.6 to 7.6Mbit/s	5.2 to 7.0Mbit/s
O2/Be 'up to' 20/24Mbit/s	10.1 to 11.7Mbit/s	10.1 to 11.6Mbit/s
Orange 'up to' 20Mbit/s	6.7 to 8.3Mbit/s	6.6 to 8.3Mbit/s
Plusnet 'up to' 20Mbit/s	6.8 to 8.9Mbit/s	6.6 to 8.5Mbit/s
Sky 'up to' 20Mbit/s	6.6 to 8.0Mbit/s	6.7 to 8.1Mbit/s
TalkTalk 'up to' 24Mbit/s	7.1 to 8.7Mbit/s	7.1 to 8.5Mbit/s
Virgin Media 'up to' 20Mbit/s*	17.6 to 18.7Mbit/s	16.4 to 18.1Mbit/s
Virgin Media 'up to' 30Mbit/s	30.7 to 31.3Mbit/s	30.1 to 30.9Mbit/s
BT 'up to' 40Mbit/s	32.9 to 34.8Mbit/s	32.1 to 34.1Mbit/s
Virgin Media 'up to' 50Mbit/s	47.7 to 49.0Mbit/s	46.3 to 48.4Mbit/s

Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: Small sample size (<50)*
Panel Base:1081
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

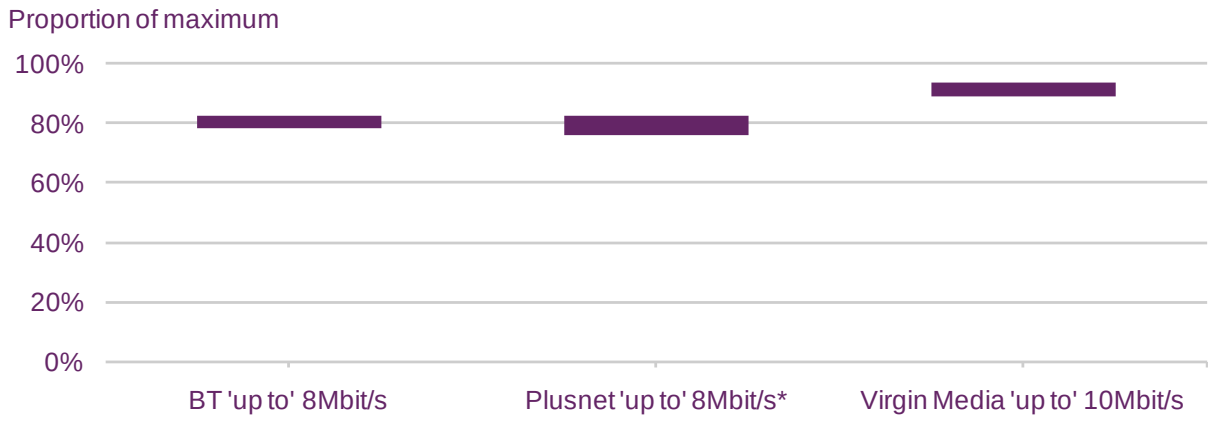
Peak download speeds as a proportion of maximum line speeds

7.25 As discussed above, there are two key drivers of variation between ISP performance; (1) the backhaul capacity available (which determines the level of contention in the network); and (2) the access technology used (which is the main factor defining the maximum line speed available). Figures 7.17 to 7.19 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).

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

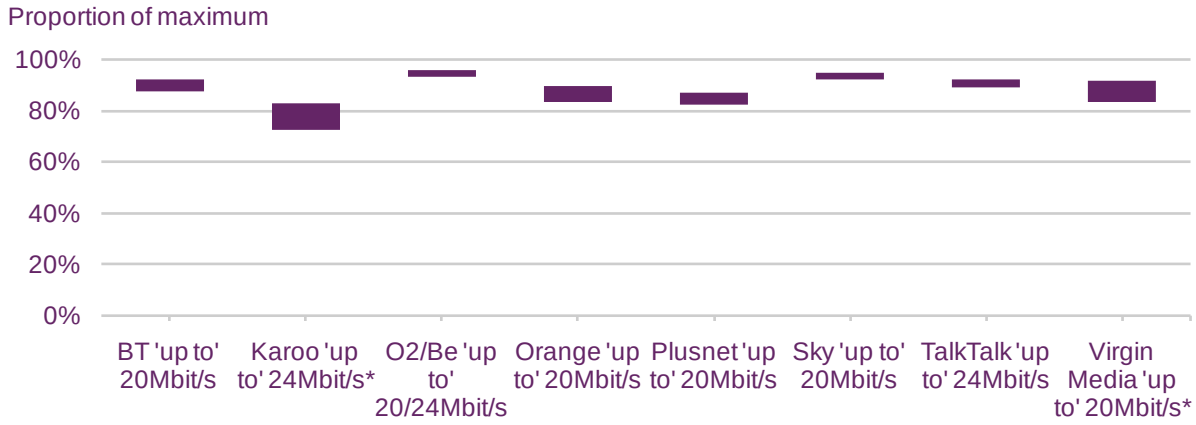
7.27 The analysis shows that there are some differences between operators, indicating that contention in the network is a bigger issue for some ISPs than for others. Virgin Media's 'up to' 30Mbit/s cable service delivered the most consistent speeds, with average speeds in the peak period being 96% of maximum speeds. By contrast, average peak speeds for panellists on Karoo's 'up to' 8Mbit/s package were 78% of maximum speeds, indicating comparatively high levels of network contention.

Figure 7.17 Peak (8 to 10pm weekday) speeds as a proportion of maximum speeds for 'up to' 8Mbit/s and 10Mbit/s connections by package, May 2011



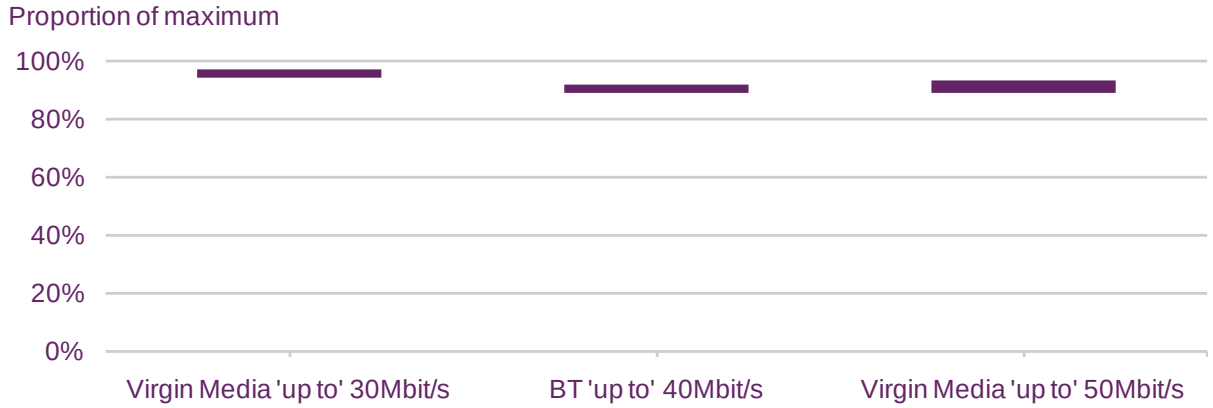
Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: Small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 7.18 Peak (8 to 10pm weekday) speeds as a proportion of maximum speeds for 'up to' 20Mbit/s and 24Mbit/s connections by package, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: Small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 7.19 Peak (8 to 10pm weekday) speeds as a proportion of maximum speeds for above 'up to' 24Mbit/s connections by package, May 2011



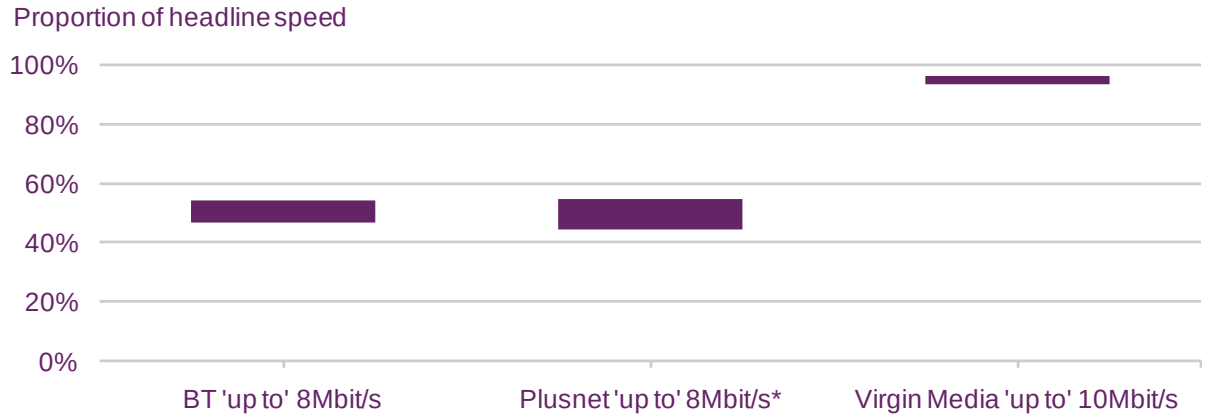
Source: SamKnows measurement data for all panel members with a connection in May 2011.
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional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

Average download speeds as a proportion of headline speeds

7.28 As broadband is often 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.

7.29 Among the two 'up to' 8Mbit/s ADSL packages, we found that average download speeds were typically around 40-60% of advertised speeds. The primary cause of this is, as discussed previously, ADSL broadband speeds degrade over the length of the copper wire from exchange to premises meaning that there is great variation in the speeds delivered to customers. Unaffected by such constraints, Virgin Media's cable service delivered download speeds which were on average much closer to the headline speed (Figure 7.20).

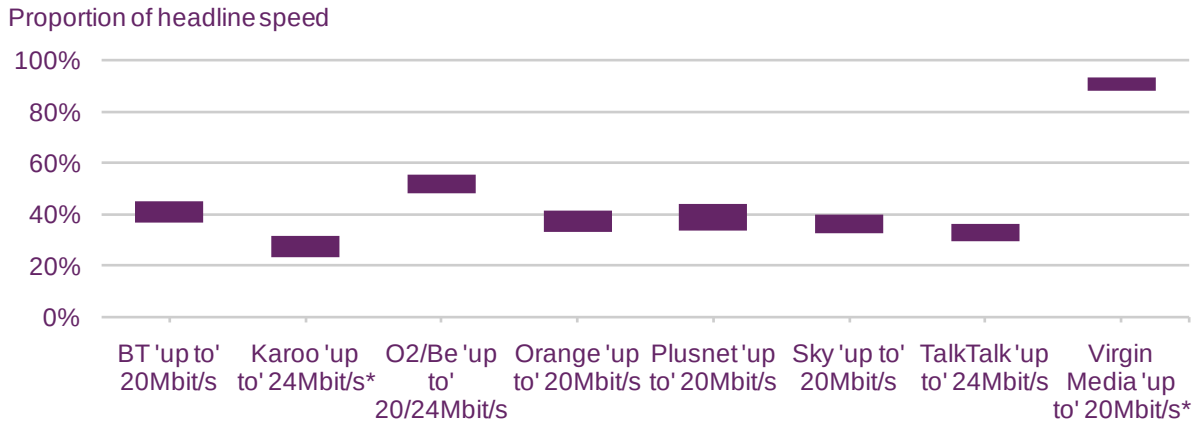
Figure 7.20 Average download speeds (24 hours) as a proportion of headline speeds for 'up to' 8Mbit/s and 10Mbit/s connections by package, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011
**Caution: Small sample size (<50).*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

7.30 Among the 'up to' 20Mbit/s or 24Mbit/s ADSL services, most actual download speeds delivered are only around 30-50% of advertised speeds (Figure 7.21). This is to be expected as although the ADSL2+ technology associated with these packages can typically deliver faster speeds to consumers who live within 3km of the exchange than the ADSL1 technology associated with many 'up to' 8Mbit/s connections, speeds degrade more quickly with distance from the exchange. Therefore, while the upgrade of services to ADSL2+ and 'up to' speeds of 20Mbit/s and 24Mbit/s represents a step change in advertised speeds, the improvement in performance is less dramatic (and is likely to be negligible for consumers who live more than 3km from the exchange).

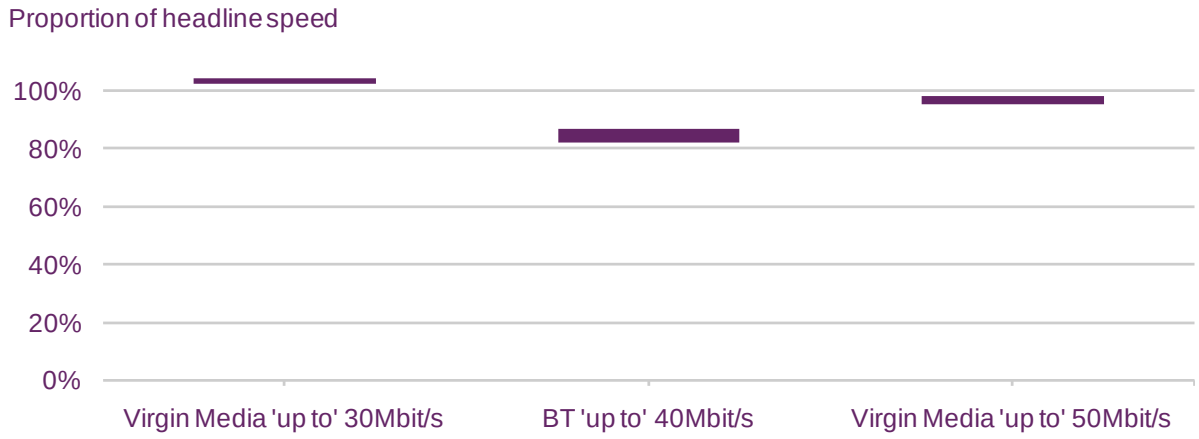
Figure 7.21 Average download speeds (24 hours) as a proportion of headline speeds for 'up to' 20Mbit/s and 24Mbit/s connections by package, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011
**Caution: Small sample size (<50).*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

7.31 Virgin Media's four cable packages and BT's 'up to' 40Mbit/s FTTC service all delivered a much higher proportion of advertised 'up to' download speeds than did ADSL1 and ADSL2+-based connections. For cable services the proportion averaged between 91% and 103%, while for BT's 'up to' 40Mbit/s FTTC service it was 85%.

Figure 7.22 Average download speeds (24 hours) as a proportion of headline speeds for above 'up to' 24Mbit/s connections by package, May 2011



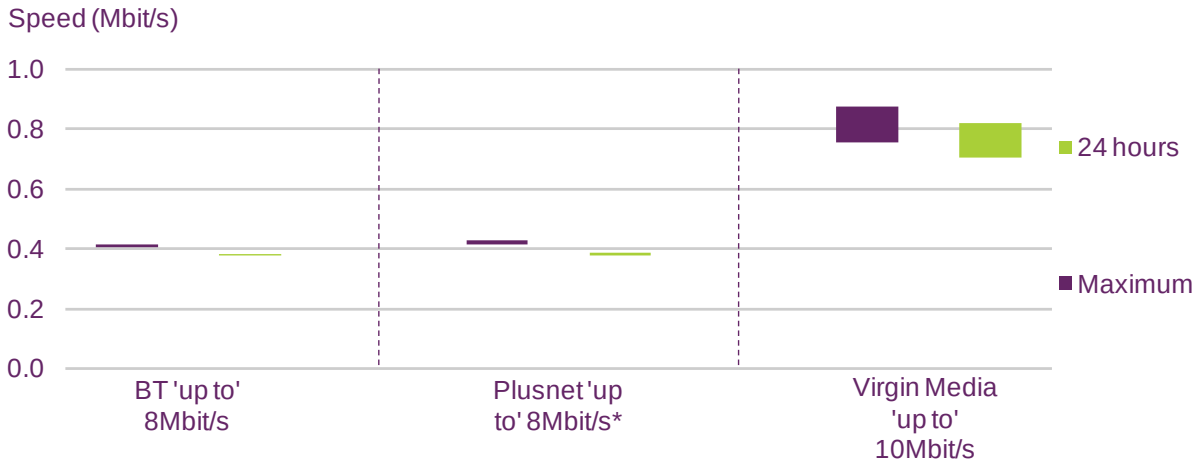
Source: SamKnows measurement data for all panel members with a connection in May 2011.
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional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

Upload speeds

7.32 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 important for most consumer applications, upload speeds matter to those looking to share large files, use real-time two-way video communications and for some online games.

7.33 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 across the 24-hour period were around 0.4Mbit/s for the two 'up to' 8Mbit/s ADSL ISP packages considered in our research, half the average of 0.8Mbit/s for Virgin Media's 'up to' 10Mbit/s cable service (Figure 7.23). During 2011 Virgin Media has upgraded its cable packages to offer 'up to' upload speeds that are 10% of each package's headline download speeds.

Figure 7.23 Maximum and average upload speeds for 'up to' 8Mbit/s and 10Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: small sample size (<50),*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 7.24 Significant differences to a 95% level of confidence between maximum and average upload speeds for 'up to' 8Mbit/s and 10Mbit/s packages, May 2011

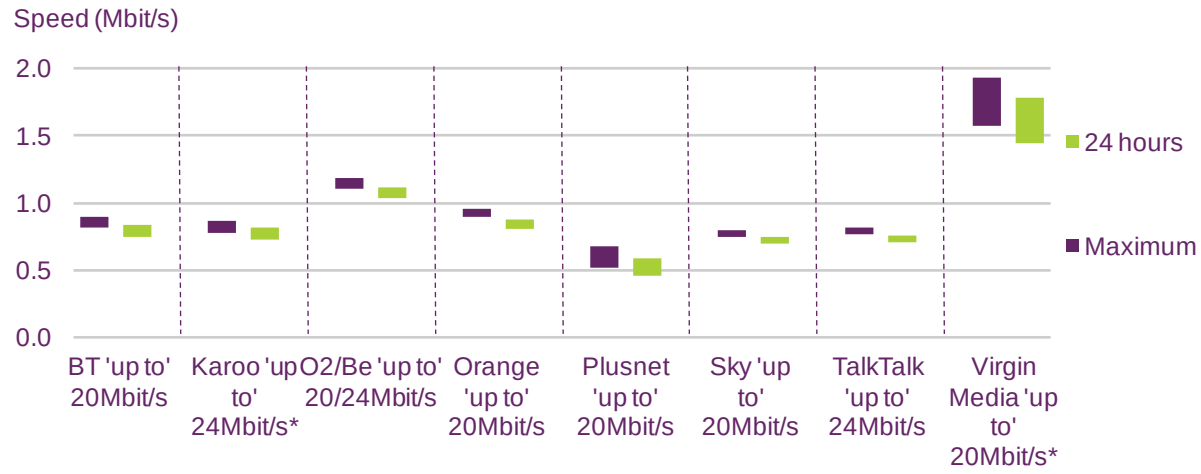
	24 hours	Maximum
ISP package	**Is faster than...**	**Is faster than...**
Virgin Media	BT and Plusnet	BT and Plusnet

Source: Ofcom

7.34 Upload speeds for ISPs' 'up to' 20Mbit/s and 24Mbit/s ADSL packages were generally higher than for their 'up to' 8Mbit/s and 10Mbit/s services, averaging around 0.8Mbit/s over the 24-hour period (Figure 7.25). Among the 'up to' 20Mbit/s and 24Mbit/s ADSL services O2/Be's 'up to' 20/24Mbit/s services delivered significantly

faster upload speeds than other 'up to' 20Mbit/s and 24Mbit/s ADSL services, averaging 1.1Mbit/s, while the upload speeds delivered by Plusnet's 'up to' 20Mbit/s service were slower than the other 'up to' 20Mbit/s and 24Mbit/s services at around 0.5Mbit/s. Again, Virgin Media's 'up to' 20Mbit/s cable service had average upload speeds above those of comparable ADSL ISP packages at around 1.6Mbit/s.

Figure 7.25 Maximum and average upload speeds for 'up to' 20Mbit/s and 24Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: Small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 7.26 Significant differences to a 95% level of confidence between maximum and average upload speeds for 'up to' 20Mbit/s and 24Mbit/s packages, May 2011

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

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

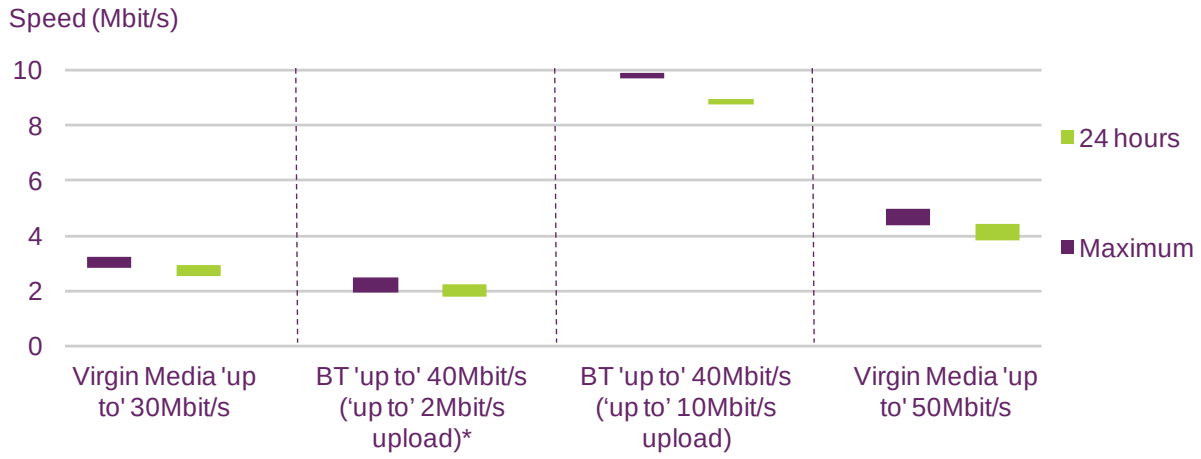
7.35 While the rest of this report combines test results for all BT 'up to' 40Mbit/s FTTC panellists, there are actually two different service packages, one of which offers upload speeds of 'up to' 10Mbit/s (and unlimited usage), while the other offers upload

speeds of 'up to' 2Mbit/s upload speeds (and a 40GB usage cap). In this section we consider them separately.

7.36 BT's 'up to' 40Mbit/s FTTC download and 'up to' 10Mbit/s upload product delivered considerably faster upload speeds than any other ISP package within our research over the 24-hour period, its average upload speeds being around 8.8Mbit/s. Virgin Media's 'up to' 50Mbit/s service delivered average upload speeds of 4.1Mbit/s, while its 'up to' 30Mbit/s service had an average upload speed of 2.7Mbit/s (Figure 7.27).

7.37 BT's 'up to' 40Mbit/s FTTC download and 'up to' 2Mbit/s upload service delivered average upload speeds of 2.0Mbit/s. This figure is only based on the test results from seven hardware units (as most of the FTTC panellists taking part in our research were on the higher BT tariff), however, there was a high level of consistency in the results recorded over the May 2011 testing period suggesting that these are representative of speeds delivered to customers on this package.

Figure 7.27 Maximum and average upload speeds for above 'up to' 24Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011).
**Caution: small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 7.28 Significant differences to a 95% level of confidence between maximum and average upload speeds for above 'up to' 24Mbit/s packages, May 2011

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

Source: Ofcom

Section 8

Other metrics affecting performance

8.1 Although download and upload throughput speeds may be the most significant determinants of the overall performance of a broadband connection, other factors also have an impact and may be more important for some applications. This section of the report discusses the impact of other key factors on the consumer experience and compares the performance of ISP packages included in the research on that basis. These are summarised in Figure 8.1 below.

Figure 8.1 Summary of additional metrics covered in the research

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

Source: Ofcom

Web browsing

8.2 In order to assess the basic web browsing performance of packages with different headline speeds, we measured the time in milliseconds to fetch the main HTML and assets (i.e. text, basic code and content files) from an Ofcom test page hosted on a SamKnows server. Note that tests were designed to ensure that pages were not cached.

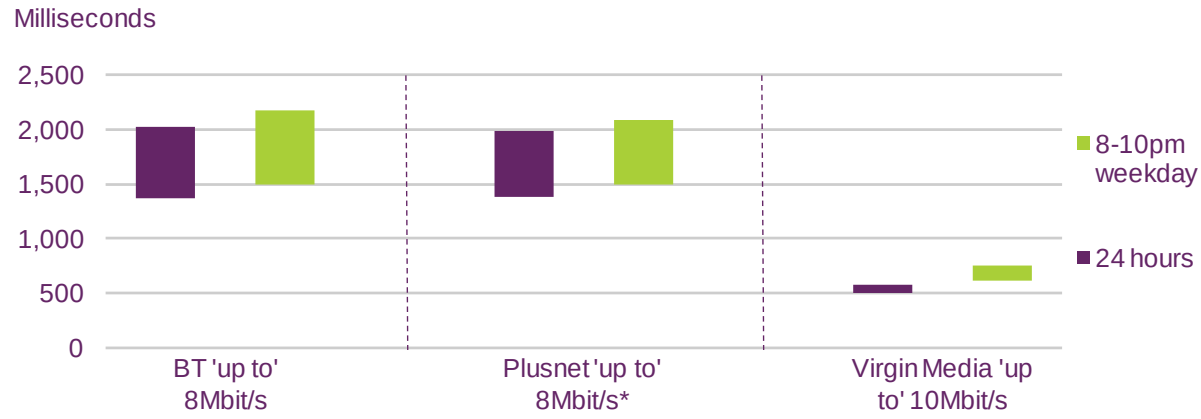
8.3 Download speeds are of limited importance for web browsing, where file sizes are typically small (less than 100KB). A broadband connection's latency and DNS resolution time are equally important (both are discussed in more detail below), and combine with server-side factors (for example the bandwidth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

8.4 Due to the relatively small sizes of most web pages there comes a point when increasing the raw download speed of the connection yields no tangible increase in the browsing performance. Latency becomes the limiting factor in determining webpage load times on very fast connections (see paragraph 8.8 onwards). Note that

in Figures 8.2, 8.4 and 8.6 better performance is faster loading times, which are indicated by lower bars.

8.5 Among the 'up to' 8Mbit/s and 10Mbit/s ISP packages covered by our research, Virgin Media had the fastest web page loading time averaged across the whole day and during the 8 to 10pm weekday peak period (Figure 8.2).

Figure 8.2 Average and peak time loading of web pages for 'up to' 8Mbit/s and 10Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data for AOL Broadband, Orange, Plusnet and TalkTalk were excluded as the measurement values had a large variance, and their sample was insufficient (5) Data collected from multi-thread download speed tests; (6) The range shown represents a 95% confidence interval around the mean; (7*) Better performance is indicated by a faster loading time, i.e. lower values.*

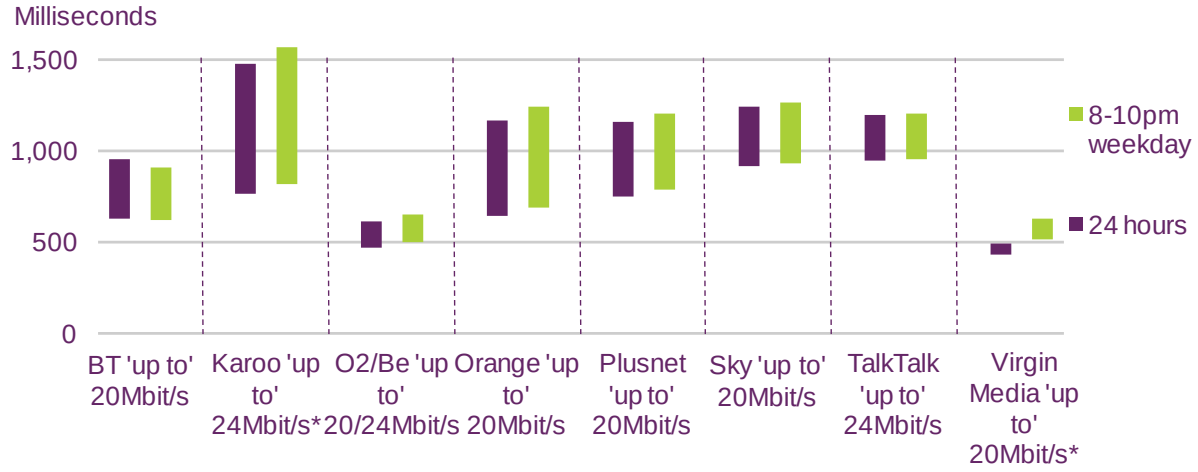
Figure 8.3 Significant differences to a 95% level of confidence between average and peak time to load web pages for 'up to' 8Mbit/s and 10Mbit/s packages, May 2011

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

Source: Ofcom

8.6 Virgin Media and O2/Be had the fastest web page loading times among the 'up to' 20Mbit/s and 24Mbit/s services covered in this report, again both over the 24-hour and during peak periods, while BT also performed comparatively well (Figure 8.4). Again, in this chart better performance is faster loading times, which are indicated by lower bars.

Figure 8.4 Average and peak time loading of web pages for 'up to' 20Mbit/s and 24Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

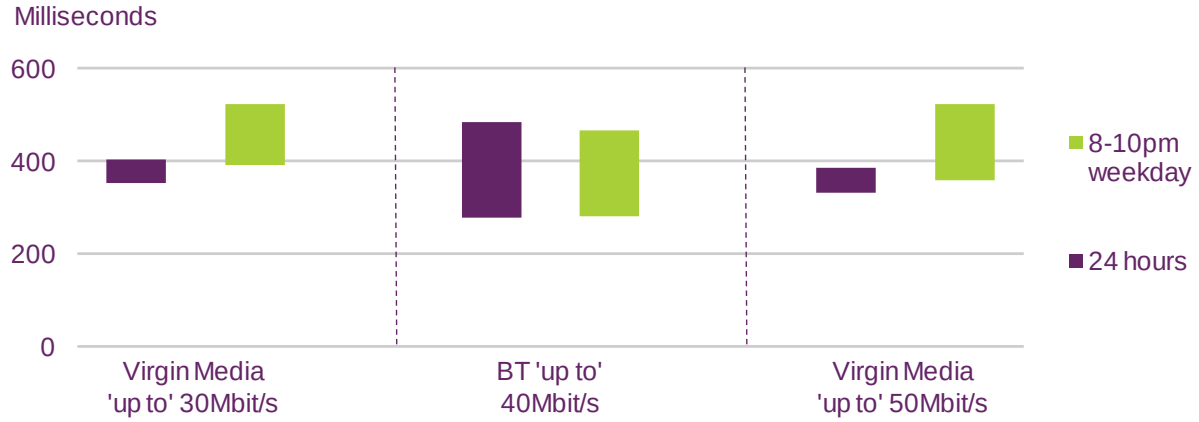
Figure 8.5 Significant differences to a 95% level of confidence between average and peak time to load web pages for 'up to' 20Mbit/s and 24Mbit/s packages, May 2011

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

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

8.7 Among the super-fast services there were no differences in web page loading times, either across the whole day or during the 8 to 10pm weekday peak periods (Figure 8.6). Again, in this chart better performance is faster loading times, which are indicated by lower bars.

Figure 8.6 Average and peak time loading of web pages for above 'up to' 24Mbit/s packages, May 2011



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

Figure 8.7 Significant differences to a 95% level of confidence between average and peak time to load web pages for above 'up to' 24Mbit/s and above packages, May 2011

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

Source: Ofcom

8.8 While the impact on the consumer experience of differences in download or upload speeds and web page loading time are generally self-evident, it is more difficult to define the impact on the consumer experience of difference in other broadband performance metrics, such as latency, packet loss and jitter, and to understand the relationship between different metrics: for example, download speed, packet loss and latency all combine to affect the overall quality of a video stream.

8.9 In order to gain insight into this, in 2009 Ofcom commissioned media research agency Sagentia to undertake research into how variations in various broadband connection metrics affect the end-user quality of experience (QoE) when undertaking various commonplace online activities.[31] Although there may have been changes to the underlying technologies used to deliver these services subsequent to the report having been produced, it is likely that these will only have improved the QoE of the online activities covered for any set of broadband connection metrics. In addition, it should be noted that many of the test bandwidths used in the research were far below those which are commonplace in 2011, and connections with higher throughput speeds are likely to reduce the impact of packet loss and latency on QoE.

[31] http://stakeholders.ofcom.org.uk/binaries/research/technology-research/NetworkQoE.pdf

8.10 For BBC iPlayer and YouTube, the research found that low data rates or high latency or packet loss led to viewing 'glitches' that rendered the service annoying or unusable. With no packet loss and very low levels of latency iPlayer Live and YouTube required 800kbit/s bandwidth, while iPlayer SD required 650kbit/s and the HD version 3.5Mbit/s. Packet loss of 0.25%, combined with latency at more than 50ms had a significant impact on the standard definition iPlayer when streamed at 0.7Mbit/s; when streamed at 1.7Mbit/s it was much more tolerant of higher levels of latency and packet loss (at this speed the average levels of latency and packet loss for all ISP packages measured – see Section 8.15 and following and 8.19 and following below - would have no impact on QoE, even at peak times). Typical levels of jitter (i.e. less than 10ms upstream and 10ms downstream jitter - as were the average of all ISP packages measured, see Section 8.26 and following below) did not have much effect on the QoE as it is accommodated within data buffers.

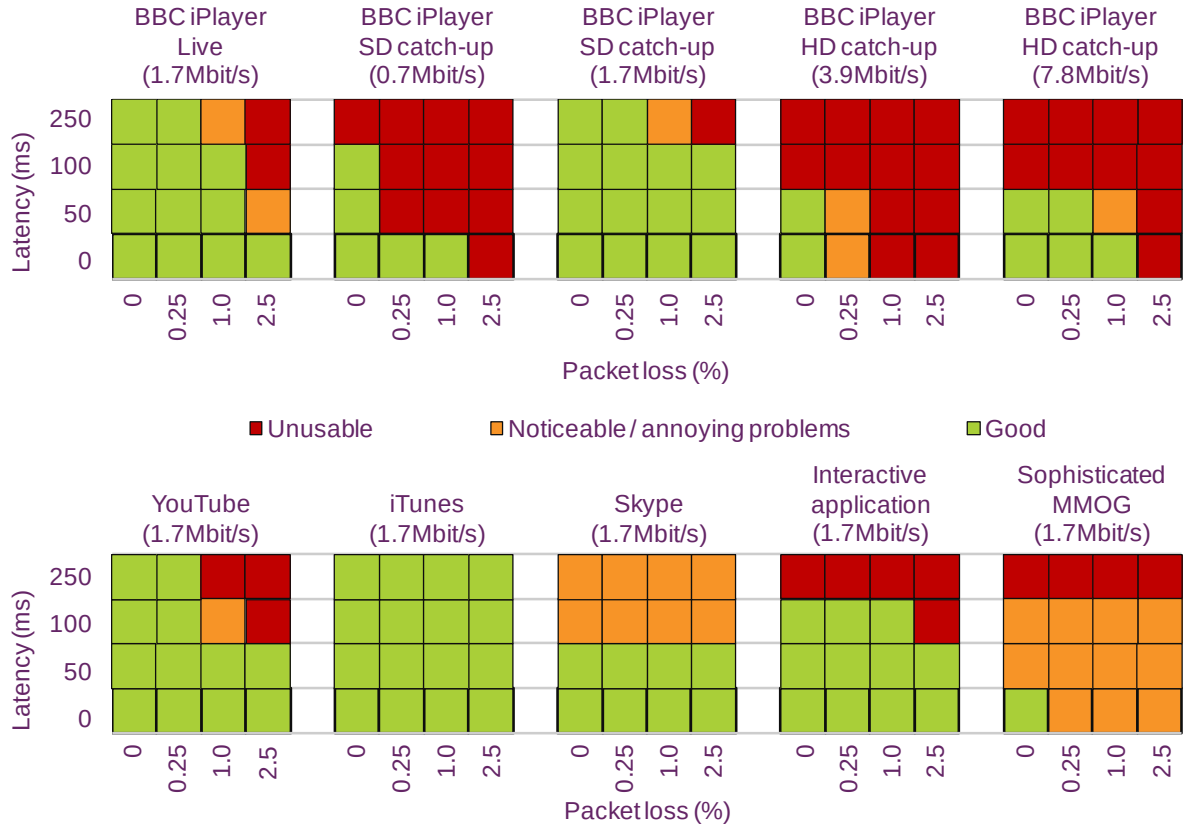
8.11 For iTunes and interactive websites the main observable effect was that as the data rate decreased or latency or packet loss increased it took longer to complete a task. Average levels of latency, packet loss and jitter for all ISP packages measured would have no discernible impact on consumer experience at a download speed of 1.7Mbit/s.

8.12 The VoIP service Skype was found to vary its performance gradually, and although there were noticeable effects on sound quality, speech remained intelligible. Differing expectations of sound degradation made the analysis of results difficult and, again, average levels of latency, packet loss and jitter for all ISP packages measured would have no discernible impact on consumer experience at a download speed of 1.7Mbit/s.

8.13 Massively Multiplayer Online Games (MMOG)s were very sensitive to even the lowest levels of latency and packet loss, with users noticing subtle delays between their actions and the onscreen response. Similarly, even low levels of jitter did seem to have an effect on the QoE. This indicates that the average levels of latency, packet loss and jitter measured for ISP packages would potentially have an impact on the QoE.

8.14 Figure 8.8 summarises a selection of the report's findings. Again, it should be highlighted that most of the tests were performed on connections with low levels of throughput, and that connections with higher throughput may help to reduce the impact of packet loss and latency.

Figure 8.8 Effects of latency and packet loss on the user QoE for various online activities



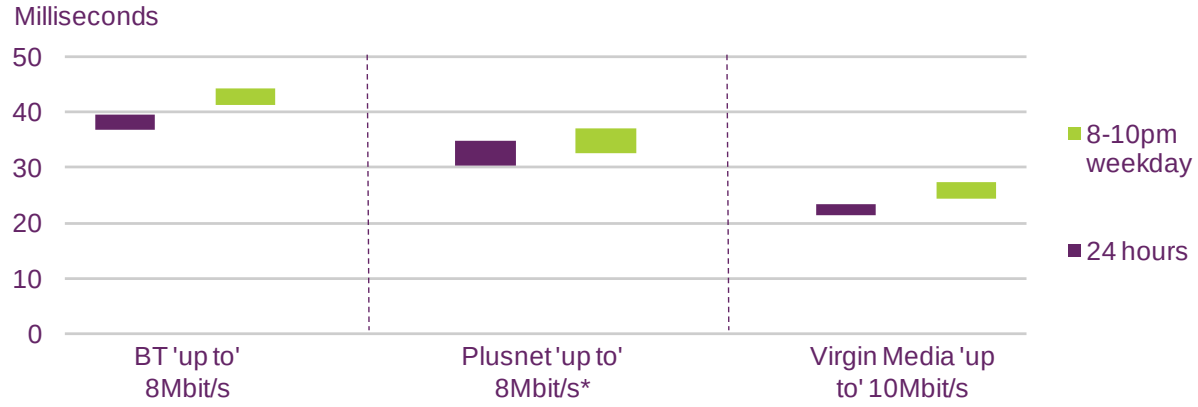
Source: Sagentia Media Research

Latency

8.15 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. A connection with low latency will feel more responsive for simple tasks like web browsing. Certain applications, particularly some games, perform far better with lower latency (note that in Figures 8.9, 8.11 and 8.13 lower latency represents better performance and is indicated by lower bars).

8.16 There was a wide range of performance among the 'up to' 8Mbit/s and 10Mbit/s ISP packages covered by our research. Virgin Media's 'up to' 10Mbit/s service was significantly better in terms of latency than BT and Plusnet's 'up to' 8Mbit/s services over the 24-hour period and in the peak period, while Plusnet's 'up to' 8Mbit/s ADSL service performed better than BT's over both time periods (Figure 8.8).

Figure 8.9 Average and peak time latency for 'up to' 8Mbit/s and 10Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Better performance is indicated by a low speed (i.e. lower values).

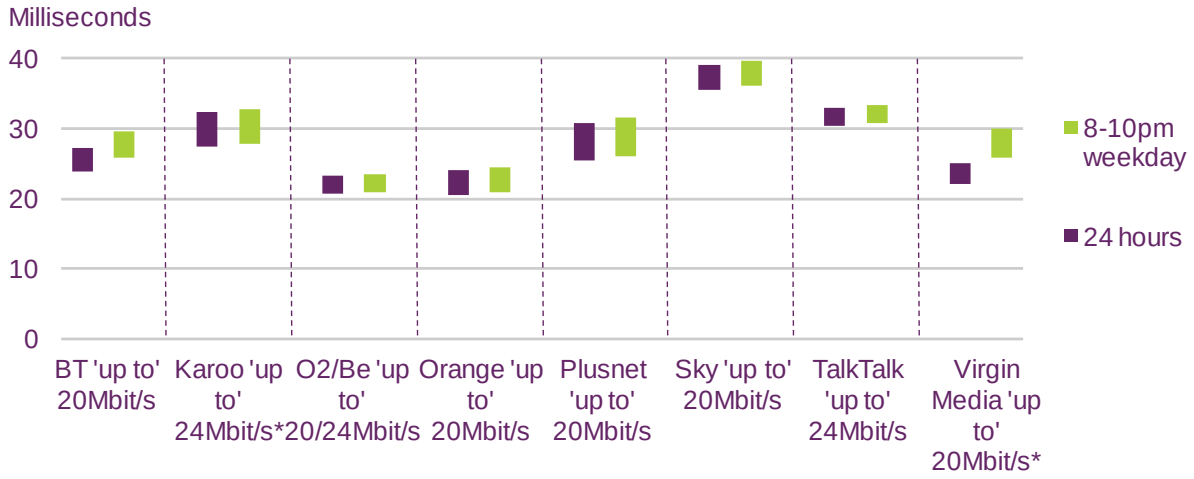
Figure 8.10 Significant differences to a 95% level of confidence between latency for 'up to' 8Mbit/s and 10Mbit/s ISP packages, average and peak times, May 2011

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

Source: Ofcom

8.17 O2/Be and Orange had the lowest levels of latency among the 'up to' 20Mbit/s and 24Mbit/s ISP speed packages over the 24-hour period, while Sky's 'up to' 20Mbit/s ADSL service had the highest average levels of latency (Figure 8.11). Again, lower latency represents better performance and is indicated by lower bars.

Figure 8.11 Average and peak time latency for 'up to' 20Mbit/s and 24Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

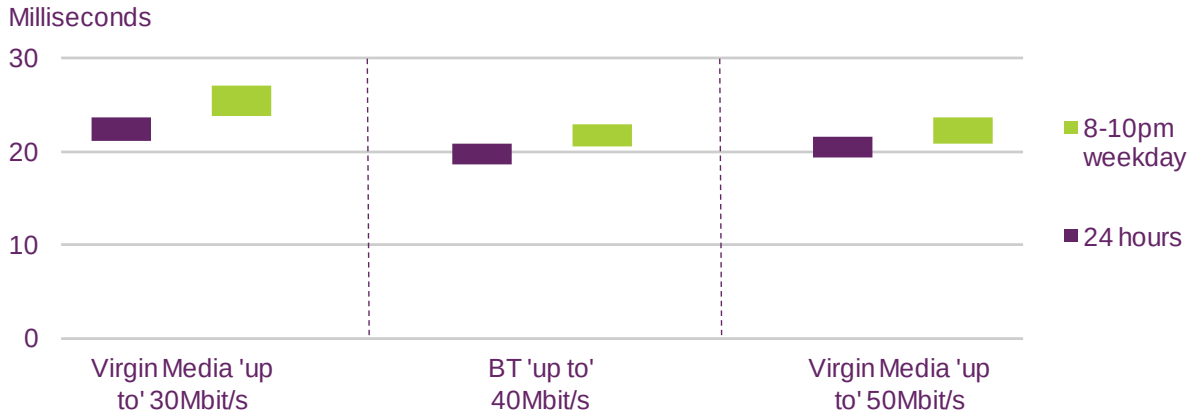
Figure 8.12 Significant differences to a 95% level of confidence between average and peak time latency for 'up to' 20Mbit/s and 24Mbit/s packages, May 2011

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

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

8.18 The only differences in levels of latency among the super-fast ISP packages covered in our research was that BT's 'up to' 40Mbit/s FTTC service, on average, had lower latency that Virgin Media's 'up to' 30Mbit/s services during the 8 to 10pm weekday peak period (Figure 8.13). Again, lower latency represents better performance and is indicated by lower bars.

Figure 8.13 Average and peak time latency for above 'up to' 24Mbit/s packages, May 2011



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

Figure 8.14 Significant differences to a 95% level of confidence between average and peak time latency for above 'up to' 24Mbit/s packages, May 2011

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

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

Packet loss

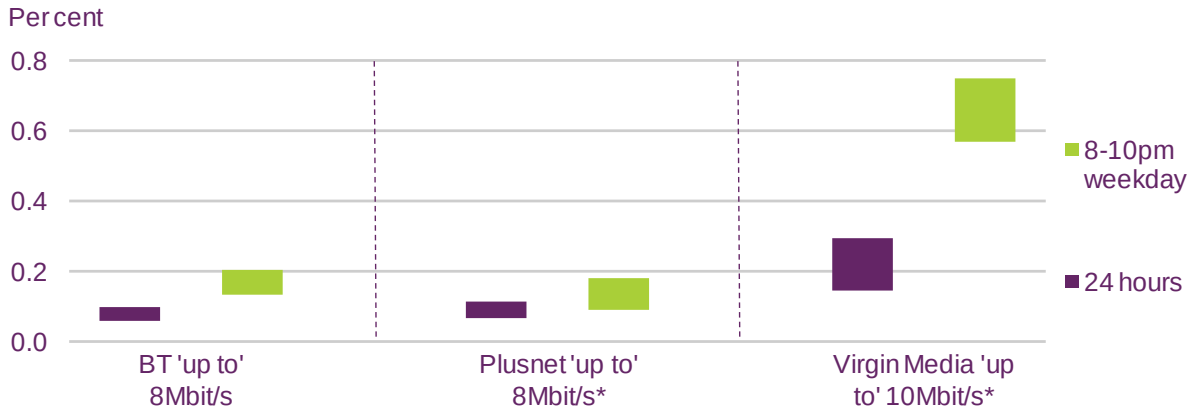
8.19 Packets of data can be lost during transmission over an internet connection. Packet loss can considerably degrade the performance of real-time applications, and although network protocols such as Transmission Control Protocol (TCP) automatically deal with packet loss to minimise the impact on the 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).

8.20 Levels of packet loss were low among most of the ISP packages covered by our research, with none having loss of more than 1% (at which level it is unlikely that users of most internet applications would experience any noticeable degradation of service – see Figure 8.8 above). Note that in Figures 8.15, 8.17 and 8.19 better performance is lower packet loss, which is indicated by lower bars.

8.21 Among the 'up to' 8Mbit/s and 10Mbit/s ISP packages covered in the research, Virgin Media's 'up to' 10Mbit/s service had higher levels of packet loss than BT and

Plusnet's ADSL services both across the day as a whole and during the 8 to 10pm weekday peak period (Figure 8.15). The relatively large confidence interval ranges associated with Virgin Media are the result of greater variation in performance across the sample.

Figure 8.15 Average and peak time packet loss for 'up to' 8Mbit/s and 10Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011
**Caution: small sample size (<50).*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Note that better performance is indicated by lower packet loss (i.e. lower values).

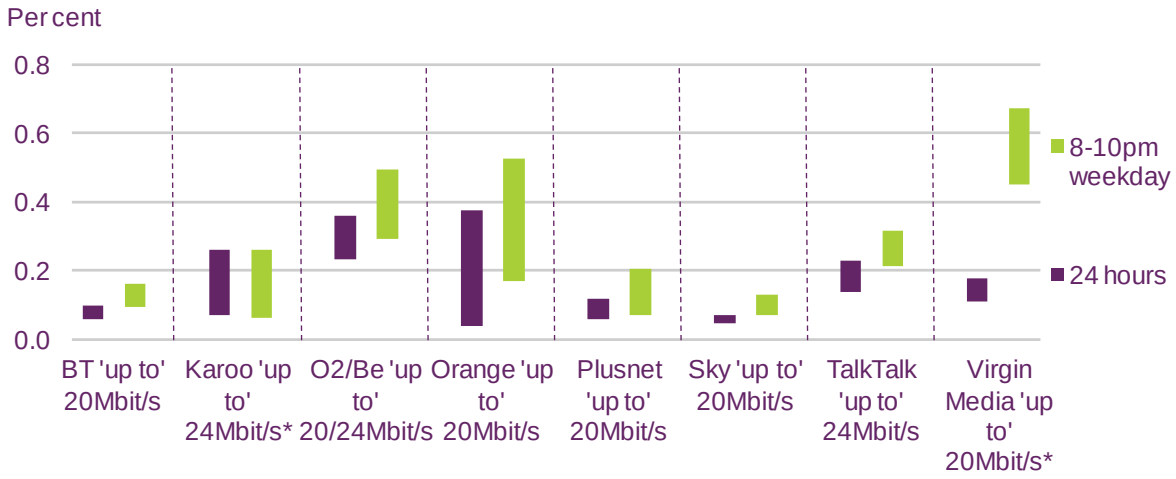
Figure 8.16 Significant differences to a 95% level of confidence between average packet loss for 'up to' 8Mbit/s and 10Mbit/s connections, May 2011

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

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

8.22 Among the 'up to' 20Mbit/s and 24Mbit/s services, Sky had lower packet loss than O2/Be, Plusnet, TalkTalk and Virgin Media over the 24-hour period, while Virgin Media's 'up to' 20Mbit/s service had comparatively high average packet loss at peak times (Figure 8.17). Again, better performance is lower packet loss, which is indicated by lower bars.

Figure 8.17 Average and peak time packet loss for 'up to' 20Mbit/s and 24Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

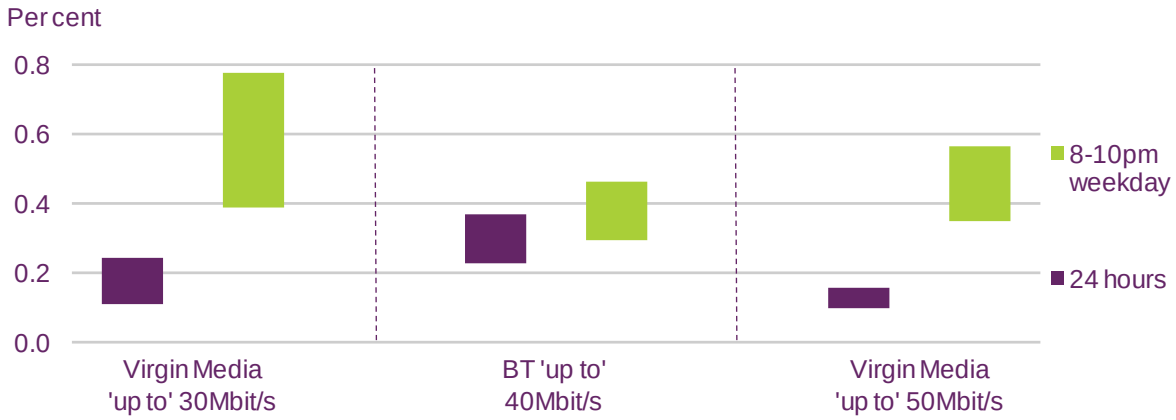
Figure 8.18 Significant differences to a 95% level of confidence between average packet loss for 'up to' 20Mbit/s and 24Mbit/s connections, May 2011

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

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

8.16 The only significant difference in packet loss among the super-fast services covered in this report was that Virgin Media's 'up to' 50Mbit/s service had lower packet loss than BT's 'up to' 40Mbit/s FTTC service across the 24-hour measurement period (Figure 8.19). Again, better performance is lower packet loss, which is indicated by lower bars.

Figure 8.19 Average and peak time packet loss for above 'up to' 24Mbit/s packages, May 2011



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

Figure 8.20 Significant differences to a 95% level of confidence between average packet loss for above 'up to' 24Mbit/s connections, May 2011

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

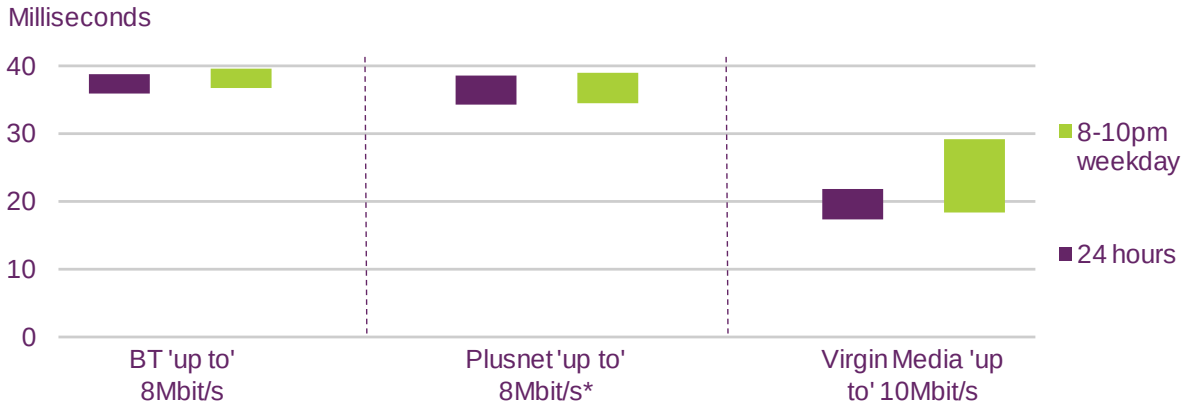
Source: Ofcom

DNS resolution

8.17 DNS (the domain name service) plays a crucial role in the internet. This protocol translates domain names (such as ofcom.org.uk) into the IP addresses that are actually used to route traffic (e.g. 194.33.179.25). Every ISP maintains its own DNS servers through which customers' computers issue queries to translate names into IP addresses. When these servers fail or operate slowly, web browsing and other online activities suffer. A slow DNS time does not affect download speed, but can severely affect the responsiveness of the internet while browsing. Note that in Figures 8.21, 8.23 and 8.25 better performance is faster resolution times, which are indicated by lower bars.

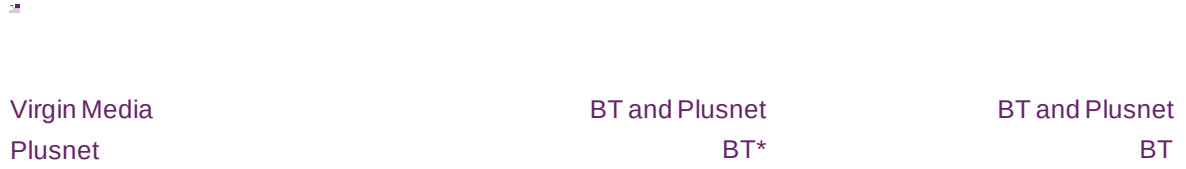
8.18 There was some variation in DNS resolution times across the packages covered by our research, although these were unlikely to have much impact on the user experience. Among the 'up to' 8Mbit/s and 10Mbit/s packages Virgin Media's 'up to' 10Mbit/s cable service performed better than the other lower-speed connections on average both across the whole day and during the 8 to 10pm weekday peak period (Figure 8.21).

Figure 8.21 Average and peak time DNS resolution time for 'up to' 8Mbit/s and 10Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Note that better performance is indicated by faster resolution times (i.e. lower values).

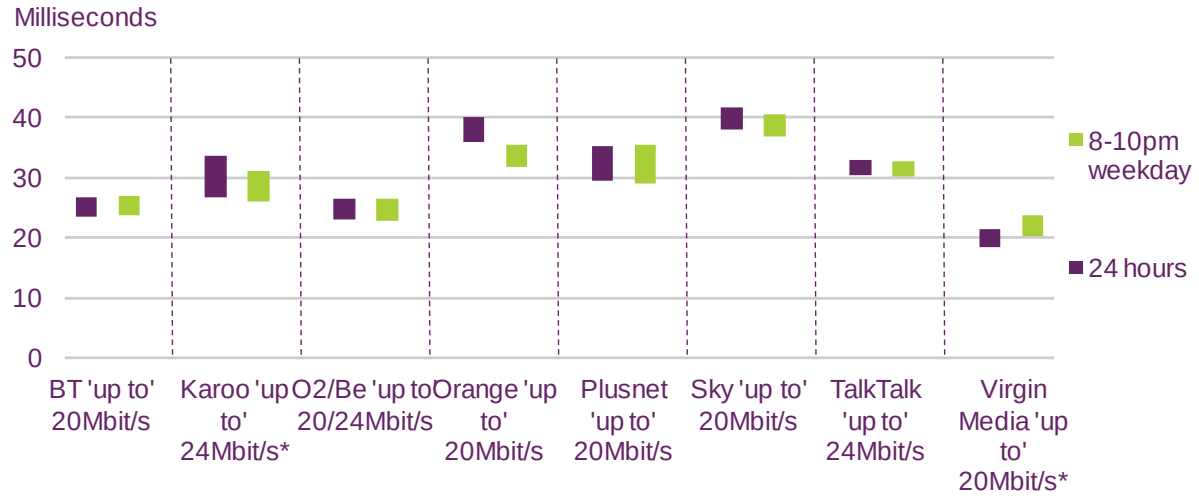
Figure 8.22 Significant differences to a 95% level of confidence between DNS resolution time for 'up to' 8Mbit/s and 10Mbit/s packages, May 2011



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

8.19 Virgin Media's 'up to' 20Mbit/s service also performed well among the 'up to' 20Mbit/s and 24Mbit/s services, in particular across the whole day (Figure 8.23). Again, better performance is faster resolution times, which are indicated by lower bars.

Figure 8.23 Average and peak time DNS resolution time for 'up to' 20Mbit/s and 24Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

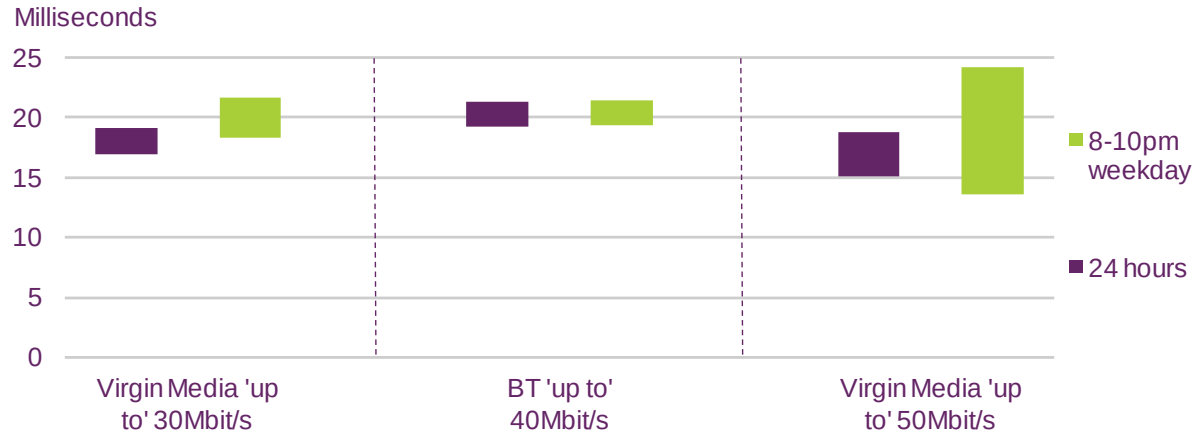
Figure 8.24 Significant differences to a 95% level of confidence between DNS resolution time for 'up to' 20Mbit/s and 24Mbit/s packages, May 2011

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

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

8.20 There were no differences between DNS resolution times among the super-fast ISP packages covered in this report (Figure 8.25). Once again, better performance is faster resolution times, which are indicated by lower bars.

Figure 8.25 Average and peak time DNS resolution time for above 'up to' 24Mbit/s and above packages, May 2011



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

Figure 8.26 Significant differences to a 95% level of confidence between DNS resolution time for above 'up to' 24Mbit/s packages, May 2011

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

Source: Ofcom

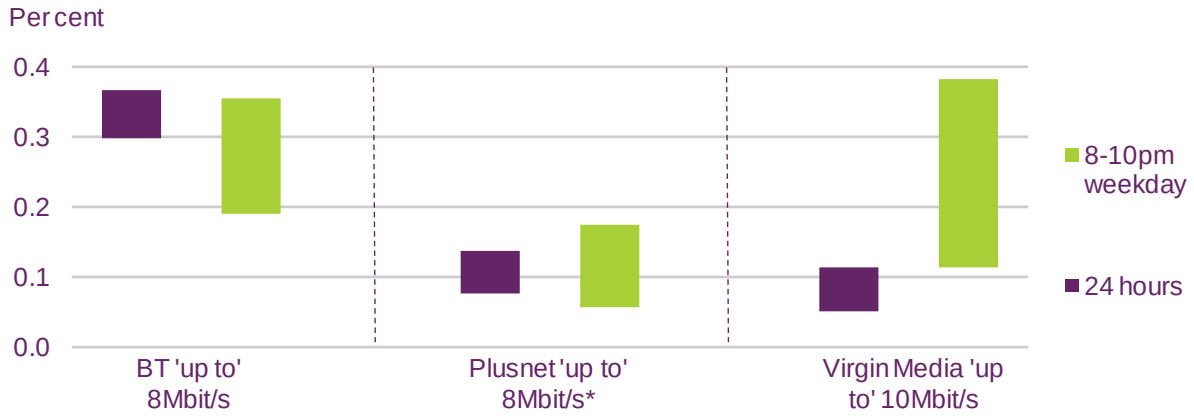
DNS failure

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

8.22 Figures 8.27, 8.29 and 8.31 show the proportion of DNS requests which failed for each of the ISP packages included in our research (note that in these charts better performance is indicated by lower failure rates times, which are indicated by lower bars). The relatively large confidence interval ranges associated with some packages is the result of greater variation in performance in these samples.

8.23 Figure 8.27 shows that among the 'up to' 8Mbit/s and 10Mbit/s ISP packages, Plusnet's 'up to' 8Mbit/s service performed well over both the 24-hour and peak periods.

Figure 8.27 Average and peak time DNS failure rates for 'up to' 8Mbit/s and 10Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Note that better performance is indicated by faster resolution times (i.e. lower values).

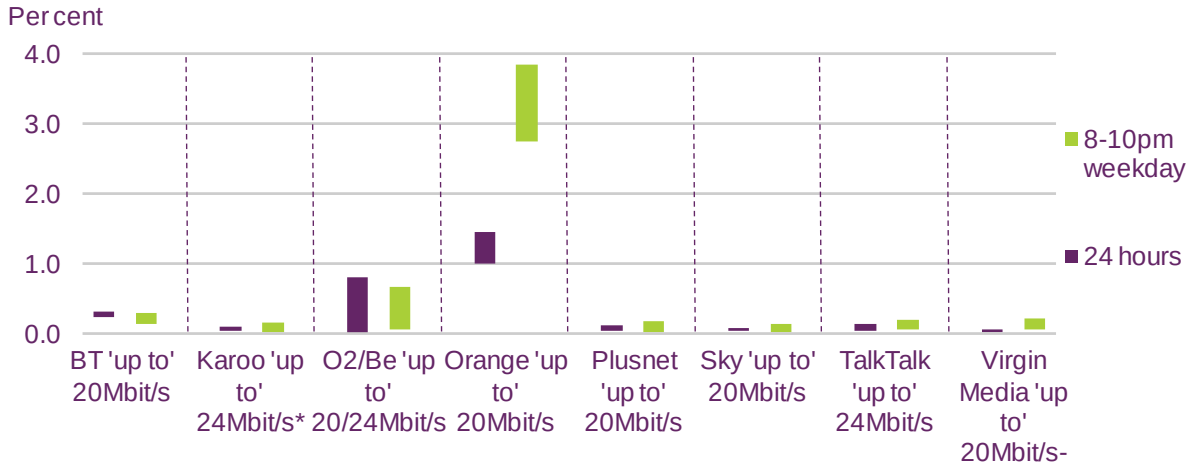
Figure 8.28 Significant differences to a 95% level of confidence between DNS failure rates for 'up to' 8Mbit/s and 10Mbit/s packages, May 2011

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

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

8.24 Orange had high DNS failure rates compared to the other 'up to' 20Mbit/s and 24Mbit/s packages, both over the 24-hour period and at peak times (Figure 8.29). Again, in this chart better performance is indicated by lower failure rates and lower bars.

Figure 8.29 Average and peak time DNS failure rates for 'up to' 20Mbit/s and 24Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011
**Caution: small sample size (<50).*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

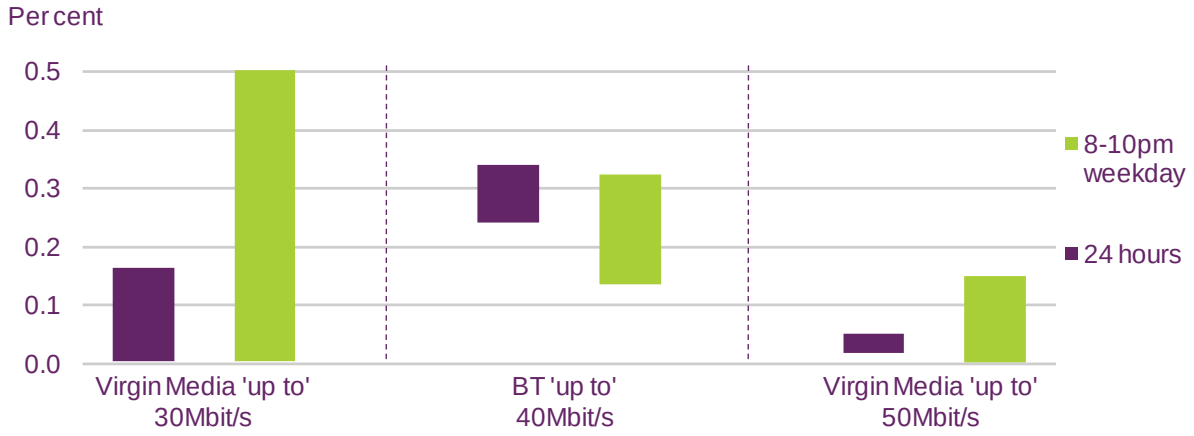
Figure 8.30 Significant differences to a 95% level of confidence between DNS failure rates for 'up to' 20Mbit/s and 24Mbit/s packages, May 2011

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

Source: Ofcom

8.25 Virgin Media's 'up to' 30Mbit/s and 50Mbit/s services had lower DNS failure rates than BT's 'up to' 40Mbit/s service across the whole day, while there were no differences between the super-fast packages at peak times (Figure 8.30). The large bar for Virgin Media's 'up to' 30Mbit/s service during the 8 to 10pm weekday peak period indicates that a wide range of results was recorded, and once again, in this analysis better performance is indicated by lower failure rates and lower bars.

Figure 8.31 Average and peak time DNS failure rates for above 'up to' 24Mbit/s packages, May 2011



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

Figure 8.32 Significant differences to a 95% level of confidence between DNS failure rates for above 'up to' 24Mbit/s packages, May 2011

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

Source: Ofcom

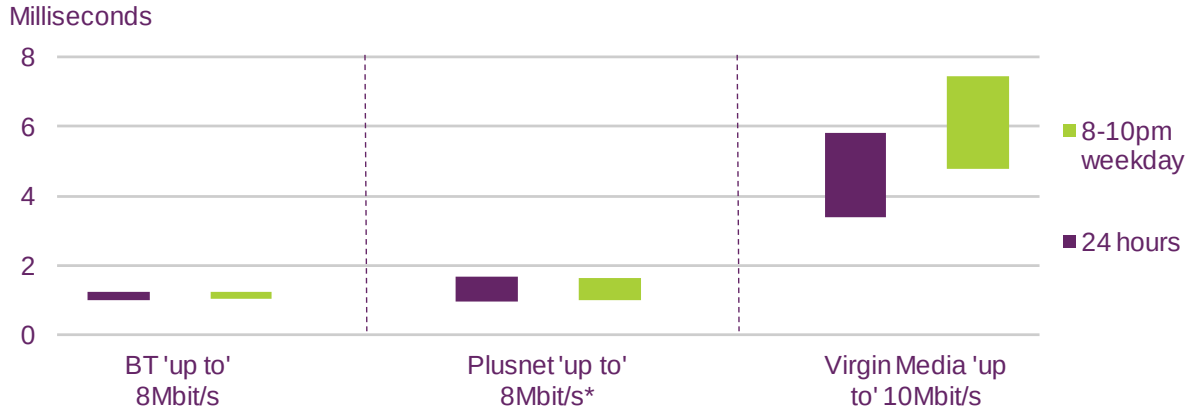
Jitter

8.26 '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).

8.27 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 (note that in Figures 8.33, 8.35 and 8.37 better performance is indicated by lower jitter, which is indicated by lower bars). As during the November/December 2010 research, we conducted separate tests to determine levels of upstream and downstream jitter in May 2011.

8.28 All of Virgin Media's cable broadband packages had higher rates of upstream jitter than the comparable ADSL and FTTC packages covered in this report over both the 24-hour and weekday 8 to 10pm peak periods. There were no differences in upstream jitter between the two 'up to' 8Mbit/s ADSL services covered in this report (Figure 8.33).

Figure 8.33 Average and peak time upstream jitter for 'up to' 8Mbit/s and 10Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Note that better performance is indicated by shorter times (i.e. lower values).

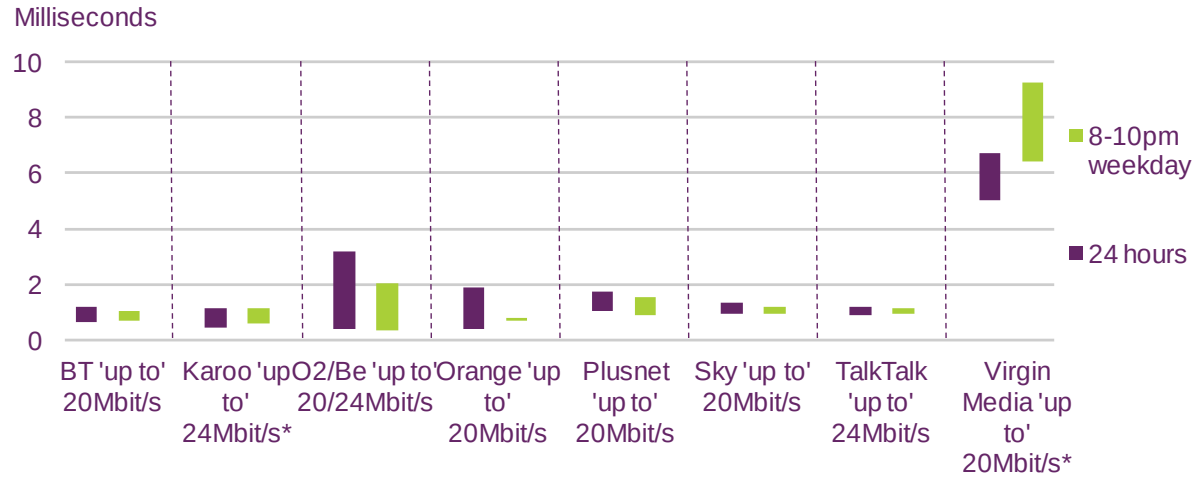
Figure 8.34 Significant differences to a 95% level of confidence between average and peak time upstream jitter for 'up to' 8Mbit/s and 10Mbit/s packages, May 2011

BT	Virgin Media	Virgin Media
Plusnet	Virgin Media	Virgin Media

Source: Ofcom

8.29 As with the lower speed packages, Virgin Media had the highest levels of upstream jitter among the 'up to' 20Mbit/s and 24Mbit/s services included in this report, while there were no differences between levels among the ADSL ISP packages (Figure 8.35). Again, in this chart better performance is indicated by lower jitter, which is indicated by lower bars.

Figure 8.35 Average and peak time upstream jitter for 'up to' 20Mbit/s and 24Mbit/s packages, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

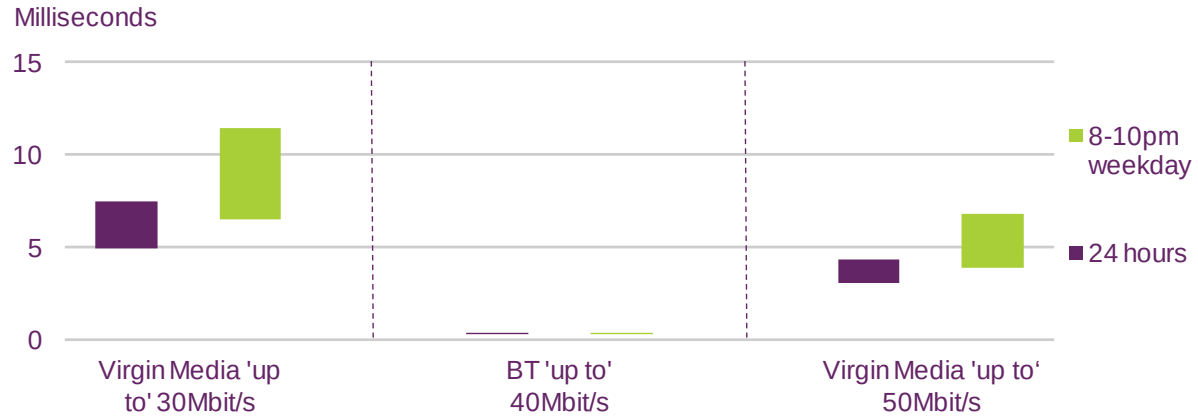
Figure 8.36 Significant differences to a 95% level of confidence between average and peak time upstream jitter for 'up to' 20Mbit/s and 24Mbit/s packages, May 2011

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

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

8.30 BT's 'up to' 40Mbit/s service had lower upstream jitter than Virgin Media's 'up to' 30Mbit/s and 'up to' 50Mbit/s both over the 24-hour period and at peak times (Figure 8.37). Again, in this chart better performance is indicated by lower jitter, which is indicated by lower bars.

Figure 8.37 Average and peak time upstream jitter for above 'up to' 24Mbit/s packages, May 2011



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

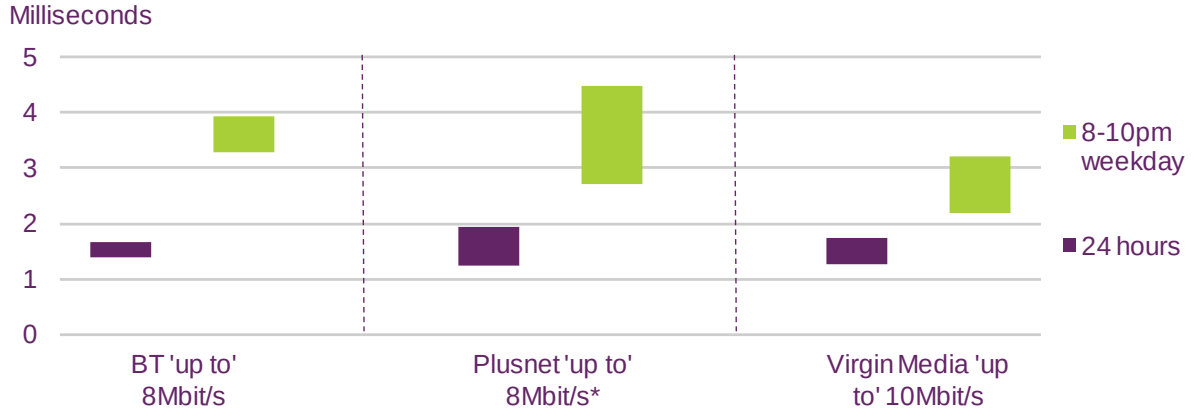
Figure 8.38 Significant differences to a 95% level of confidence between average and peak time upstream jitter for above 'up to' 24Mbit/s packages, May 2011

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

Source: Ofcom

Among the 'up to' 8Mbit/s and 10Mbit/s ISP packages there were no differences in levels of downstream jitter, either over the 24-hour period or during the peak 8 to 10pm weekday period (Figure 8.39). Again, in this chart better performance is indicated by lower jitter, which is indicated by lower bars.

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



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean; (6) Note that better performance is indicated by shorter times (i.e. lower values).

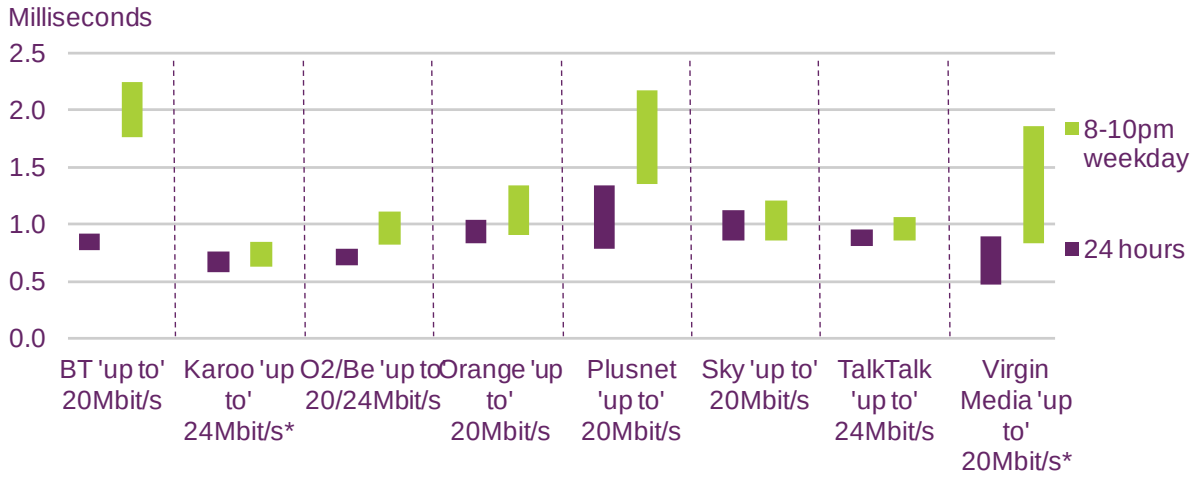
Figure 8.40 Significant differences to a 95% level of confidence between average and peak time downstream jitter for 'up to' 8Mbit/s and 10Mbit/s packages, May 2011

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

Source: Ofcom

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

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



Source: SamKnows measurement data for all panel members with a connection in May 2011.
**Caution: small sample size (<50)*
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3 and in the Kingston-upon-Hull area for Karoo; (2) Includes on-net customers only for LLU operators (3) Data for ADSL operators have been weighted to ISP regional coverage of LLU lines and distance from exchange; data for Virgin Media's cable service have been weighted to regional coverage only; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

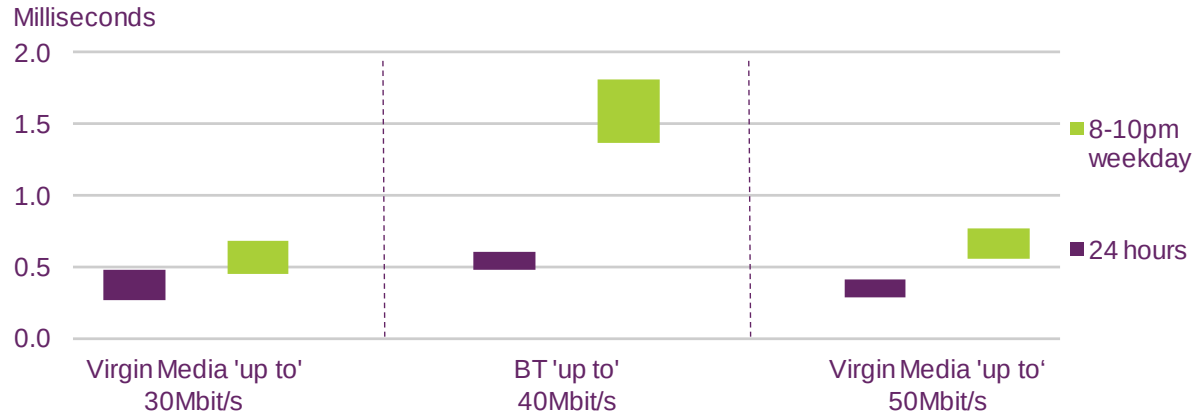
Figure 8.42 Significant differences to a 95% level of confidence between average and peak time downstream jitter for 'up to' 20Mbit/s and 24Mbit/s packages, May 2011

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

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

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

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



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

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

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

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

Section 9

Conclusion and next steps

Implications for consumers

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

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

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

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

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

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

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

Implications for ISPs

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

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

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

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

Next steps

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

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

Annex 1

Glossary

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Exchange The local telephone exchange is the building where all consumers' copper telephone lines are connected to enable telephone calls to be switched, and where network equipment is installed which enables consumers' data traffic to be routed via an operator's core network to its destination.

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

Headline speed The speed at which a broadband service is marketed, usually expressed as 'up to' (for example, in February 2011 all of BT's nationally available ADSL broadband services are advertised as "up to 20Mbit/s").

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

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

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

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

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

LLU (local loop unbundling) LLU is the process whereby incumbent operators (in the UK this means BT and Kingston Communications) make their local network (the lines that run from customer's premises to the telephone exchange) available to other communications providers. The process requires the competitor to deploy its own equipment in the incumbent's local exchange and to establish a backhaul connection between this equipment and its core network.

Local loop The access network connection between the customer's premises and the local telephone exchange, usually a loop comprising two copper wires.

Maximum line speed The highest download speed that a broadband connection is capable of delivering. Also known as the access line speed. As it is a characteristic of ADSL broadband that speeds degrade with distance from exchange, the maximum line speed varies, and, for ADSL1 connections, only those users who have a line length of less than 1km typically achieve maximum speeds of close to a headline speed of 8Mbit/s.

Mbit/s Megabits per second. A unit measuring the bit-rate.1Mbit/s is the equivalent of 1,000kbit/s.

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

Multi-thread test: A test involving the download of two or more data files simultaneously - in the case of our research, three files (see Technical Methodology – Annex 2).

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

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

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

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

Streaming content Audio or video files sent in compressed form over the internet and consumed by the user as they arrive. Streaming is different to downloading, where content is saved on the user’s hard disk before the user accesses it.

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

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

Upload speed Also uplink or upstream speed. Rate of data transmission from a customer’s connection to a network operator’s access node, typically measured in Kilobits per second (Kbit/s).

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

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

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

Annex 2

Technical and research methodologies

1. Technical methodology

The technical methodology chosen is the same as that used in Ofcom's first round of research into broadband performance in 2008/9 and was based on that created by broadband performance company SamKnows Ltd, Ofcom's technical partner in this research project. SamKnows recruited a panel of UK residential broadband users and supplied monitoring units to each panellist. SamKnows also managed the collection and aggregation of the performance data and made a major contribution to the analysis. Also see paragraph 2.5 onwards.

All panellists were sent a hardware monitoring unit which they were instructed to connect to their router. The unit sits between the participant's existing router and the rest of their network, so allowing the performance monitoring unit to determine when the network is free to run tests (it should be noted that the device operates in a bridging mode, rather than routing).

SamKnows developed a customised OpenWRT firmware image which is installed on the units. At the point of delivery, this is all that is present on the device; apart from a single script that checks for the availability of the software component at boot-up, the physical unit contains no additional software. This is beneficial both from a security perspective (everything is destroyed when the power is lost) and also from a support perspective (any problems with a unit's configuration can be undone simply by power-cycling it). New versions of the software can be delivered remotely without requiring a reboot.

Software within the unit then performs a range of tests to a set schedule, running over 14,000 separate tests from each panellist over the course of a day. The software was configured to identify other network activity and not to run tests when such activity was detected. This avoided compromising results by running tests at a time when bandwidth was being used by other internet-connected devices in the household (including those using a wireless connection).

The software uses a combination of standard Unix tools and customer code developed in the C programming language.

All monitoring units maintain accurate time using *ntp*.

We believe that this technical methodology is a significant improvement from any other research into UK broadband performance, which has typically relied on software monitoring solutions that do not account for the impact on speed of PC set-up, or having more than one computer using a broadband connection.

Speed tests

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

For our multi-thread HTTP downloads, all units download 3 x 2MB files using separate TCP sessions (in parallel). An initial lead-in period is used to ensure TCP window sizes are increased before measurements are made. Multi-thread tests were run nine times per day,

once every six hours in off-peak periods and once every hour at peak times. Typically the download speeds achieved using the multi-thread tests in the early hours determine the maximum speed the line can support.

Additionally, it is understood that some ISPs operate transparent HTTP proxy servers on their networks. To overcome this, the web servers are configured to respond with the following headers, which should disable caching in standards-compliant proxy servers:

Cache-Control: "private, pre-check=0, post-check=0, max-age=0"

Expires: 0

Pragma: no-cache

Upload tests were performed using 3 x 1MB files with a similar initial lead-in period to that used for download tests.

Five speed-test servers are deployed in a range of different data centres in and immediately around London to handle the traffic. Each server is monitored constantly for excessive network load and CPU, disk and memory load. The test results gathered by each server are compared against one another daily to ensure no significant variation in the speed attainable per server. Units cycle through the speed-test servers in a round-robin fashion when testing.

Testing web page loading times

The test downloaded the HTML and media assets of a simple web page hosted on a SamKnows managed server. This makes use of up to eight concurrent TCP connections to fetch the assets. Both tests make use of libcurl.

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

Tests were run every hour.

Testing latency, packet loss and jitter

A bespoke application was used to test latency, packet loss and jitter. The application was designed to run continuously to get a statistically robust set of data. The test utilised UDP rather than ICMP and sent approximately 600 packets every hour.

Testing recursive DNS resolver responsiveness and failures

Testing an ISP's recursive DNS resolution can be accomplished using many tools, such as *nslookup*, *dnsip* and *dig*. For the purposes of our solution, *dig* was chosen for the flexibility it offers.

Typically, an ISP will have two or more recursive DNS resolvers. Rather than using the DNS servers provided by the DHCP leases to the testing units, the software on the units tests the ISP DNS resolvers directly. This allows us to determine failure of a single DNS server. Furthermore, it also overcomes another issue – that of people changing the DNS servers being returned in DHCP leases from their router (this proved quite common with customers of some ISPs).

The tests record the number of milliseconds for a successful result to be returned. A successful result is deemed to be one when an IP address was returned (the validity of the IP address is not checked). A failure is recorded whenever the DNS server could not be reached or an IP address was not returned. The hostnames of four popular websites were queried every hour.

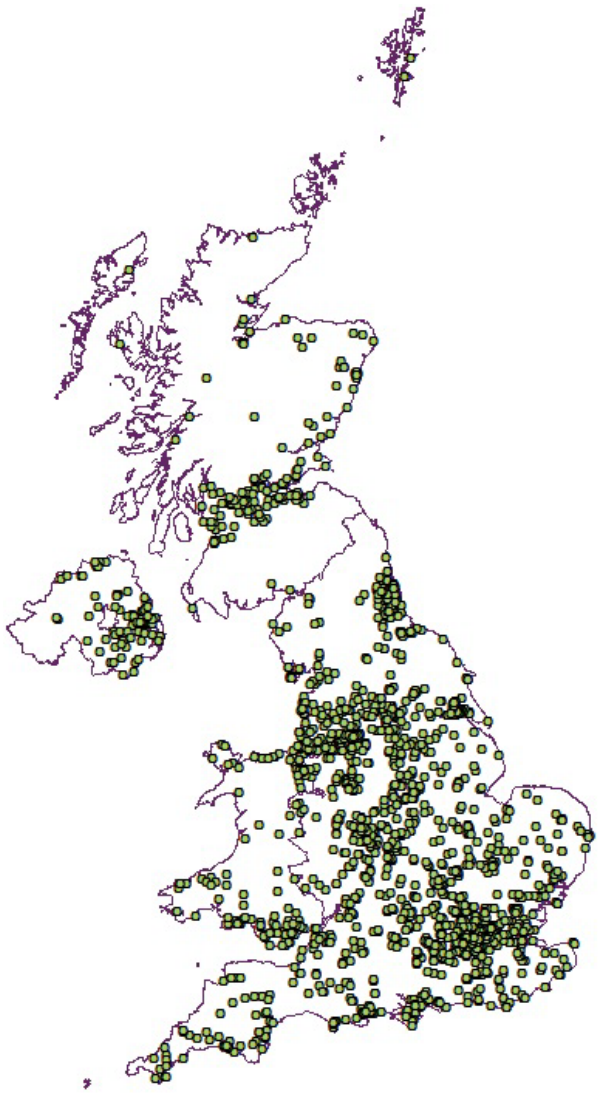
Connections with usage caps

Some of the test units were deployed on broadband connection with relatively low usage caps. To avoid using a significant proportion of the available download limit each month the test schedule for the test units on these connections was reduced.

2. Research methodology

The performance data in this report is taken from a base of 1,710 panellists who had a broadband monitoring unit connected to their router in May 2011. Figure 1 details the geographical spread of the panellists, which is broadly in line with the geographic distribution of UK residential broadband subscribers.

Figure 1 Geographic distribution of panellists



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

Figure 2 details Ofcom's definitions of geographic broadband markets. These were an important consideration in recruiting our panel and applying statistical analysis because they enabled us to ensure that our panel was representative of the UK broadband market as a whole, and facilitated like-for-like comparison between ISP packages:

- Each panellist was assigned to one of the geographic markets, and we weighted the analysis accordingly to ensure that our overall findings were representative of UK residential broadband performance as a whole (for example, as Market 1 represents 11.7% of UK premises, we ensured that performance data from panellists in Market 1 contributed 11.7% towards the overall computation of UK residential broadband performance).

- For comparisons of ISP package performance we only used panellists who live within geographic Markets 2 and 3. This means that all panellists used for the ISP package comparisons live in areas served by a local telephone exchange in which at least one operator other than BT is present (i.e. there is at least one LLU operator). This avoids any potential distortions to the data for ISPs using BT Wholesale services (BT Retail, Orange and Plusnet), caused by the inclusion of panellists who live in (typically less densely populated) Market 1 areas and to whom LLU services are not available.

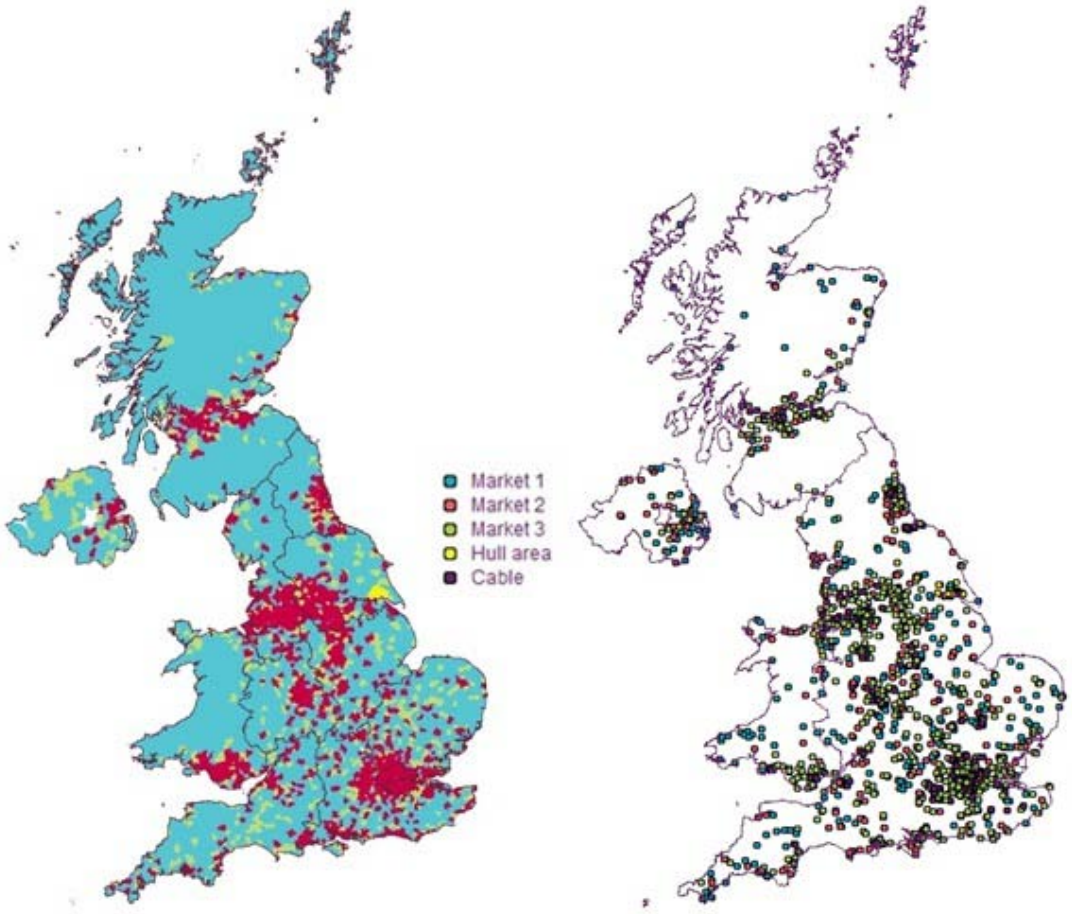
Figure 2 Ofcom definitions of geographic broadband markets

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

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

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

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



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

We have used statistical techniques to adjust our results to ensure that they are representative of the UK broadband population as a whole. This includes weighting the results from our panel by rural/urban, distance from exchange, geographic market definition and ISP. For the provider-specific comparisons we have also 'normalised' the data for ADSL operators by distance from exchange (using the straight-line distance from the panellist's location to the exchange), which we believe is necessary in order to provide like-for-like comparisons of ISPs which have different customer profiles.

All weightings applied have been developed by market research company Saville Rossiter-Base and reviewed by Ofcom before use. David Saville of Saville Rossiter-Base also made an assessment the research methodology and panel and helped ensure its suitability for purpose. Checks were also applied to ensure that straight-line distance was an appropriate metric to carry out normalisation, including comparing this distance with the line attenuation. Detail on the statistical methodology used is provided in Annex 3. The methods of analysis for the provider-specific comparison are based on those used in the July 2009 report which had expert review and endorsement by econometrician Professor Andrew Chesher of University College London[34].

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

Annex 3

Statistical methodology

Key statistical concepts used in this report

This report presents the findings from research which has involved the collection and interpretation of 455 million[35] data points. It has been a complex process, both technically and statistically, and as a consequence the analysis may not be as easy to understand as that in many of our research publications.

The Glossary in Annex 1 provides a detailed definition of the technical terms we use throughout the report. However, knowledge of the following is important in order to understand how we have analysed the performance data.

- We present data in the report only in cases where there are sufficient data points to deliver a statistically sound result. This means that we report performance only when statistical analysis indicates that our findings are accurate enough to be useful. Accuracy is determined by the number of measurement tests undertaken, the size of the sample (number of panellists) and also by the variation (spread or range of results) between panellists.

- In order to acknowledge the limited accuracy of the estimates and to ensure that we highlight only those differences that are statistically significant, for many charts we do not show a value but instead show a range around the mean value which indicates the statistical confidence we have in our results. The range we use is called a 95% confidence interval, which is a statistically-derived range calculated from the standard error (which is itself calculated from the sample size and the variation within the sample). A 95% confidence interval means that if we repeated the research again with a different sample assembled in the same way there would be a 95% probability that the mean value would be in the range shown. Where we have large samples and/or little variation within the sample, the confidence interval is much narrower than where we have smaller samples and/or large variation within the sample. Differences are reported as significant if they are significantly different as judged by a two-tailed 5% test of statistical significance. In the tables where we present differences which are statistically significant we present differences which are significant to a 95% level of confidence, but also highlight those which are not significantly different to a 99% level of confidence.

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

- We have similarly weighted the data where we are comparing the performance of individual ISPs' packages in order to ensure that the analysis provides a fair comparison of actual performance rather than reflecting random differences in the ISP package customer profiles in the sample. A difficulty in comparing ADSL

[35] 433 million of these were to test connection latency.

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

- For ADSL comparisons we have included only consumers who live in an area where the exchange has been 'unbundled' by at least one LLU operator[36]. This means that ISPs using wholesale services (such as BT Wholesale's *IPstream or Wholesale Broadband Connect* products) can be compared on a like-for-like basis with LLU operators.

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

- Distance weighting was applied only to ADSL operators and not to cable or fibre to the cabinet (FTTC) services where performance is less influenced by distance from the exchange.

Sample size

A panel of UK broadband users was drawn from a pool of over 40,000 volunteers following a recruitment campaign by SamKnows in March and April 2010. The objective was to obtain a representative panel in order to monitor the performance of residential fixed-line broadband in the UK over a two-year period of research. In addition to obtaining a panel sufficient for monitoring changes in overall performance, the panel was recruited to enable specific analysis of the performance of the most common ISP packages in the UK, in particular higher speed packages (with advertised 'up to' speeds of above 10Mbit/s) which we expect to become standard over the period of research.

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

Quotas were set by Geographic Market classification (see paragraph 3.7 of the main report), LLU (see section 2.10 of the main report), ISP market and package shares, rural/urban, region (for ten regions in England, and for Scotland, Wales and Northern Ireland) and straight line ('as the crow flies') distance from exchange. In, addition restrictions were placed on the number of respondents per ISP allowed on any exchange.

The panel is currently over-representative of the higher speed packages, with 39% of the sample contributing less than 0.5 a response towards the UK average; this is a decrease of

[36] Local loop unbundling (LLU) is the process by which incumbent operators (BT for the large majority of exchanges and Kingston Communications for the area around Hull) make their local access network (i.e. the copper telephone lines that run from the exchange to consumers' premises) available to other communications providers. In exchanges which have been 'unbundled' an alternative operator (an LLU operator) has deployed its own equipment in the exchange and established a backhaul connection between this equipment and its core network.

20% since November 2010 as many ADSL operators have finished migrating their customer bases from 'up to' 8/10Mbit/s to 'up to' 20/24Mbit/s services and these services now represent a larger portion of the market. 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 (1.5% of the total in May 2011, and a reduction from 4% since November 2010). In our first round of research between October 2008 and April 2009, we found that the speeds delivered by 'up to' 2Mbit/s and less connections were consistent over time and between providers. In this report we have used data from 'up to' 2Mbit/s and less connections collected in April 2009 as representative of the performance of these packages, and have weighted them in accordingly when we present overall UK performance in this report.

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 2,795 measurement units were despatched, and 1,760 of these were connected by participants between 1st and 31st May 2011. Of these, 1,325 supplied data to the UK average, and 1,262 to the named ISP package comparisons.

Figure 1 Panellist numbers

Sample set	Number
Total number of boxes dispatched	**2,795**
Total number of boxes connected	**1,760**
Excluded because of missing data, (i.e. measurements, packages, distance)	17
Excluded 'up to' 2Mbit/s	5
Other exclusions to improve UK sample weighting (i.e. distance, market classification, region, ISP)	107
Total participants included in UK analysis	**1,325**
Total participants included in ISP package analysis	**1,262**

Source: Ofcom

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

The average number of measurements per respondent for the 24-hour multi-thread download speed tests in May 2011 was 490, from a theoretical maximum of 662 per respondent (i.e. if all panellists had their box connected on 1st May and all scheduled tests were run - tests were not run when the monitoring unit detected concurrent use of the bandwidth).

Average speeds are generally very accurately measured, so the main factor limiting the accuracy of the analysis reported here is the number of panellists and measurements.

Quotas were set before the exact LLU package market shares for LLU operators and the lines in Geographic Markets 2 & 3 for other providers were available but results were weighted to be representative at national level. In order to recruit ISP packages to match specific quota criterion above and achieve 100-150 panellists per package, only ISP packages with over 250,000 subscribers in total were targeted.

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

Sample panels

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

- **National Panel** (over 'up to' 2Mbit/s packages): 1,325 panellists. All with at least five valid test measurements across all download tests, with a validated IP address, single measurement speed check and distance and Geographic Market classification data. All published national figures include the weighted addition of an estimated figure for 'up to' 2Mbit/s and less packages, based on measured averages in April 2009.

- **ISP Package Panel**: 1,262 panellists. A subset of the National Panel consisting of panellists from Geographic Markets 2 & 3 only, panellists from LLU operators (O2/Be, Sky, TalkTalk) and Virgin Media were on-net only. There was a target of 100 valid panellists for each ISP package, but criteria for including in the reporting was an effective sample minimum of 50 valid panellists (those with a base of less than 75 should be treated with some caution).

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

Sample weighting

There were two weighting classifications applied to the data:

- **National Panel**. Weighting by ISP market and package shares by LLU/non LLU connections supplied by ISPs as at April/May 2010, urban/rural, Geographic Market classification and distance to exchange (fitted to April 2009 UK straight-line distance to exchange line distribution); and

- **ISP Package Panel.** Weighting to distance from exchange (those panellists with an unrecorded or straight-line distance to the exchange of more than 5km were excluded):

    - **'Up to' 8Mbit/s ADSL packages** were weighted to fit a modelled distribution of straight-line distance between premises and LLU exchanges, Gamma a=2.060 b=760

- **'Up to' 20Mbit/s and 24Mbit/s ADSL packages** were normalised by distance from exchange, to the aggregated distribution of straight-line distance between premises and exchanges of all panellists on those headline packages, Gamma a=2.170 b=619

- **Cable and Fibre to the Cabinet (FTTC) packages** were not weighted as speed of services is not directly related to distance from the exchange.

- As mentioned in paragraph 3.3, our measurement approach does not take into account respondent-specific issues, such as wiring, which may influence speed of connection. Such variation has greatest impact for high-speed services where a respondent has a short line length. We assessed several methods of accommodating this issue and asked Saville Rossiter-Base for guidance as well.

- The conclusion was that allowing for variance across the sample based on line length would not necessarily lead to the widening the confidence intervals to build in this element of respondent variability. This is because the calculation of confidence intervals requires a constant mean and standard error across the sample or sub-sample, under review. If we allow variance to differ by band, we would also need to allow the mean to differ by distance band, Leaving aside the increased complexity of the calculation, allowing the mean to differ by distance band to reflect respondent difference would reduce the variance in each band and reduce the confidence intervals for pooled estimate of the mean across the whole sample. The following calculation, based upon all non-cable 'up to' 20Mbit/s packages in November 2010, shows this to be the case.

Figure 2 Variation of Mean and Variance by distance band

Distance band	Sample	Mean	Variance	Standard Deviation
1	62	12.91482	13.9591	3.736188
2	68	11.60854	9.426042	3.070186
3	74	8.73505	10.31055	3.211005
4	78	5.877479	9.555718	3.091232
5	67	2.902841	5.732561	2.394277

Source: Ofcom

The average variance across the five cells is 9.8 giving a standard deviation of 3.1, giving a confidence interval of 8.48 +/- 0.3 Mbit/s. But the overall standard deviation, if mean is held constant, is 4.7 which would give a confidence interval of 8.48 +/- 0.5Mbit/s. Therefore, the current methodology over-estimates the variance in the sample and hence the confidence intervals.

Assigning participants to ISP and broadband package

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

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

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

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

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

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

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

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

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

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

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

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

Weighting to distance from exchange

As performance of ADSL broadband is significantly affected by the length of the line between consumer’s premises and the local exchange, any comparison between ISPs or technology could be affected by the distribution of distance among the sample.

Therefore it was necessary to weight the data by distance from exchange in order to provide like-for-like comparison between the previously published data (April 2009), ISPs' packages and technology to ensure that any differences identified were due to differing performance and not due to a differing distribution of line lengths.

Distance from premises to local exchange was captured as the straight-line ('as the crow flies') distance measured from the full post-codes of premises and local exchange. Different weights by distance were applied to each of the UK National, 'up to' 8Mbit/s and 10Mbit/s and 20Mbit/s and 24Mbit/s datasets.

National Panel

The national sample was weighted to match the line length distribution of the UK April 2009 research

Line Length Distribution April 2009: Gamma a=2.223 b=1000
Line Length Distribution May 2010: Gamma a=1.863 b= 1203

ISP Package Panel

The ISP package comparisons were made for subscribers in Geographic Markets 2 and 3 (see section 3.7 of the main report), and, where appropriate, LLU/on-net connections only. The line lengths in Markets 2 and 3 are typically much shorter than the UK average, and it was not appropriate to weight to the national average as previously.
SamKnows provided an estimated distribution of line lengths on LLU exchanges. Saville Rossiter-Base modelled this as a Gamma distribution and the 'up to' 8Mbit/s and 10Mbit/s ADSL packages were weighted to this distribution for the purposes of consistent comparison by distance from exchange.

Modelled LLU line length distribution: Gamma a=2.060 b=760

There were statistically distinct differences in the distribution of line lengths for those panellists on 'up to' 8Mbit/s or 10Mbit/s packages and those on 'up to' 20Mbit/s or 24Mbit/s packages and the same target distribution could not be used for both. The higher speed ISP packages had lower numbers over 2km from the exchange and to avoid missing weight categories the same distance bands could not be used.

The 'up to' 20Mbit/s and 24Mbit/s packages were instead normalised by weighting each to the aggregate distribution of line length among all 20Mbit/s or 24Mbit/s panellists.

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

Intra ISP Package weights

O2 and Be are reported combined as a single ISP package entity, but the product offering are considerably different. The O2/Be 'up to' 20/24Mbit/s package was therefore weighted in addition to operator split by LLU, to maintain representative samples.

Weighting Methodology

Straight-line distance from premises to exchange was coded into two sets of distance bands, one for National & ISP 'up to' 8Mbit/s and 10Mbit/s packages, and one for ISP 'up to'

20Mbit/s and 24Mbit/s packages. The size of each distance band was set to achieve approximately 10 observations in each band in the sample, given the number of connected panellists.

For all respondents in a given distance band, the average measurement value, was weighted (up or down) in proportion to the ratio of respondents in that band in the target distribution, and that observed in the relevant panel dataset.

Weighting Efficiency

Overall, against the entire weight frame, the National Panel achieved a weighting efficiency of 72%. The under 0.5's are primarily driven by the over representation, (against current market shares) of both higher speed packages and shorter line lengths in the panel. The over 2s are driven by the interaction between market shortfall and distance from exchange.

Figure 3 National Panel range of weights

Range	Count	Column N%
Less than 0.5	429	39%
0.5 to 1	400	36%
1 to 1.5	142	13%
1.5 to 2	94	9%
2 to 3	40	3%

Source: Ofcom

Overall, against the entire weight frame, the ISP Package Panel achieved a weighting efficiency of 80%. The under 0.5s are primarily driven by shorter line lengths on the high speed packages and over representation of BT Infinity and Virgin Cable 50.

Figure 4 ISP package panel range of weights

Weights	Count	Column N %
Less than 0.5	87	7%
0.5 to 1	883	70%
1 to 1.5	150	12%
1.5 to 2	88	7%
2+	48	4%

Source: Ofcom

Figure 5 Weighting efficiency by ISP package

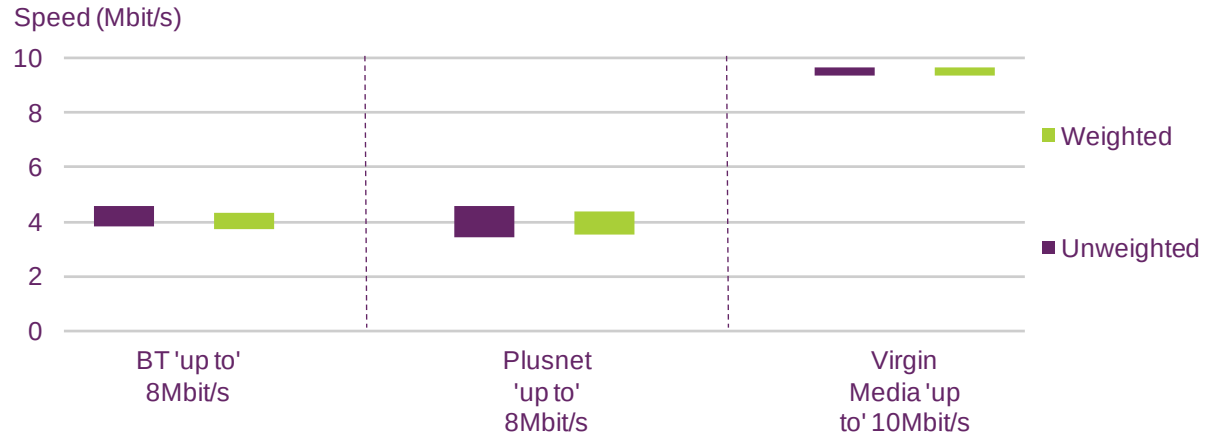
ISP package	Weighting efficiency
BT 'up to' 8Mbit/s	89%
Plusnet 'up to' 8Mbit/s	81%
Virgin Media 'up to' 10Mbit/s	100%
BT 'up to' 20Mbit/s	98%
Karoo 'up to' 24Mbit/s	71%
O2/Be 'up to' 20/24Mbit/s	84%
Orange 'up to' 20Mbit/s	84%
Sky 'up to' 20Mbit/s	95%
TalkTalk 'up to' 24Mbit/s	92%
Virgin Media 'up to'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

Source: Ofcom

Weighted and unweighted measurement data

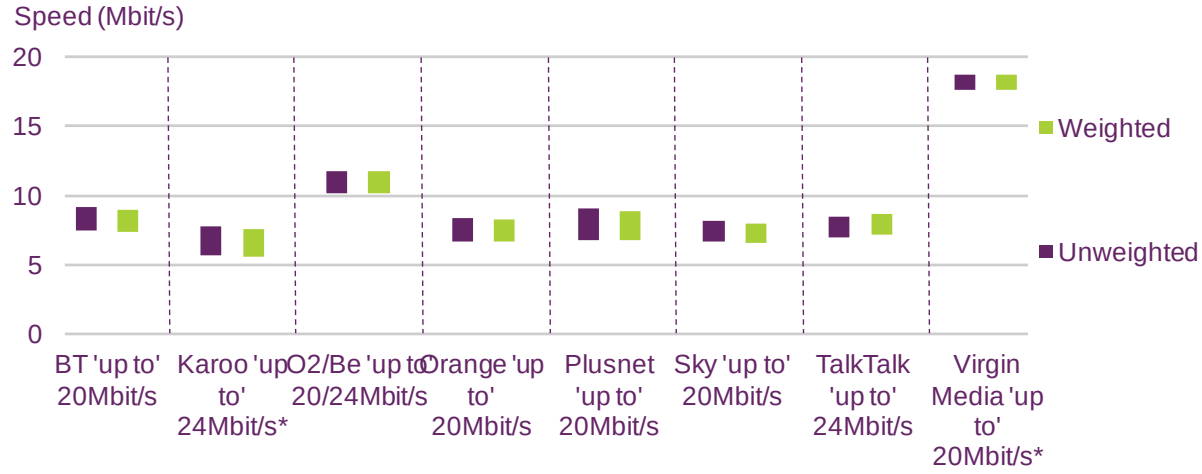
The effect of the combined overall ISP Panel weighting on the comparative relative ISP Package perform, is shown in the following tables

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



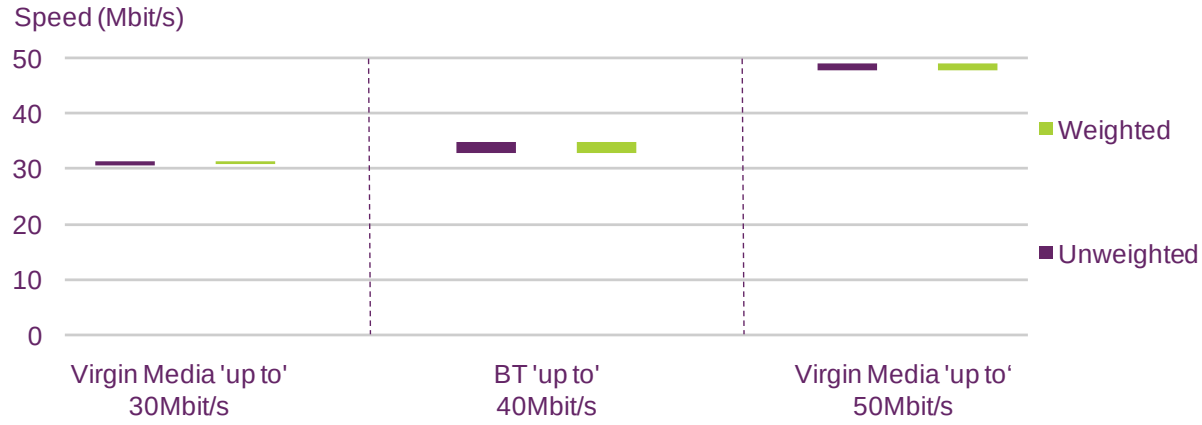
Source: SamKnows measurement data for all panel members with a connection in May 2011. Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been weighted to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

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



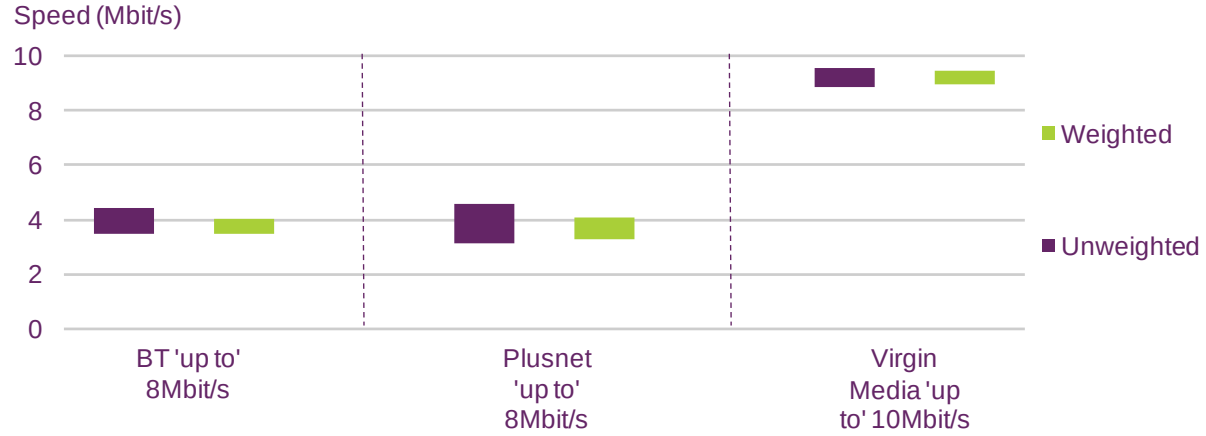
Source: SamKnows measurement data for all panel members with a connection in May 2011. Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been unweighted to distance from exchange and data for Virgin Media's cable and BT 'up to 40Mbit/s is unweighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

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



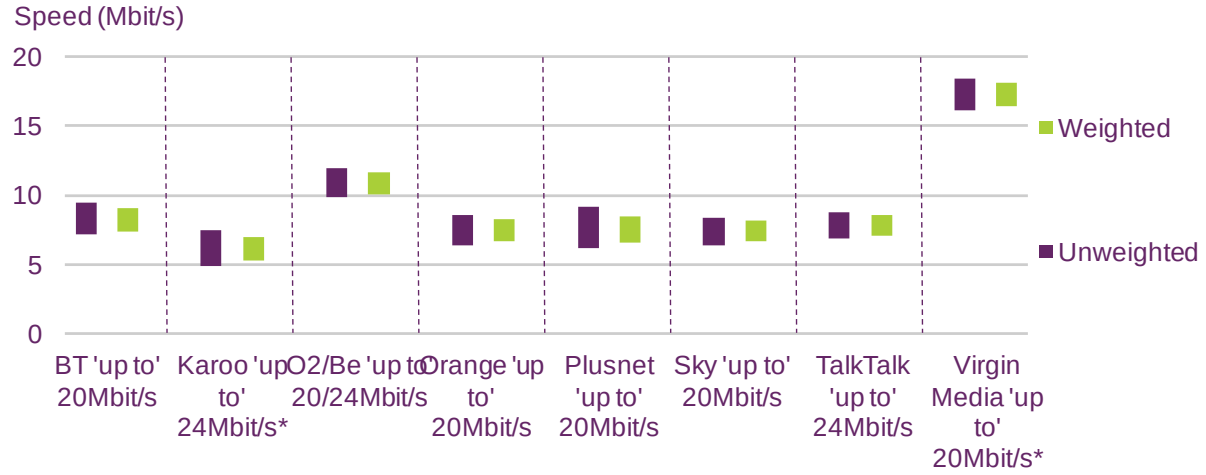
Source: SamKnows measurement data for all panel members with a connection in May 2011. Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been unweighted to distance from exchange and data for Virgin Media's cable and BT 'up to 40Mbit/s is unweighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 9 Peak-time download throughput speed for 'up to' 8Mbit/s and 10Mbit/s connections by ISP, weighted and unweighted figures, May 2011



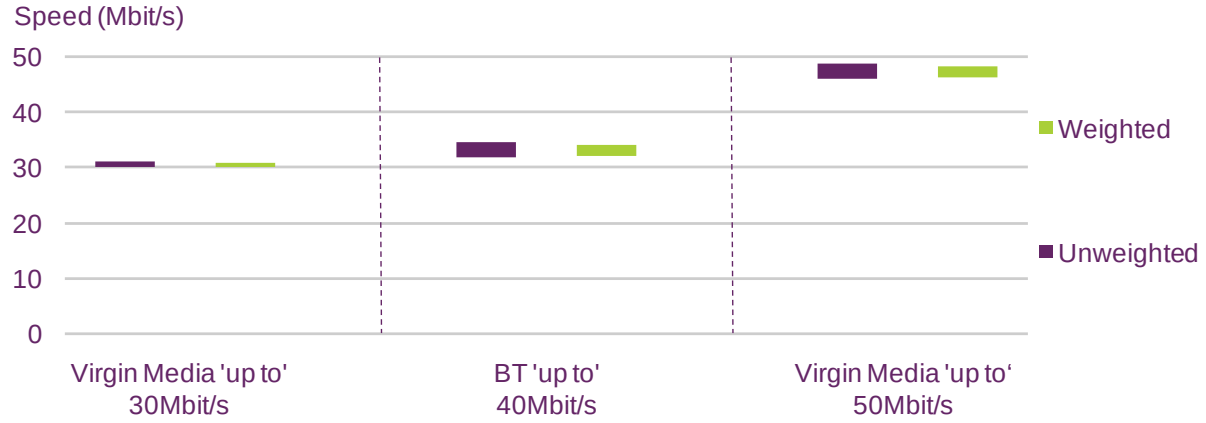
Source: SamKnows measurement data for all panel members with a connection in May 2011.
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been weighted to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

Figure 10 Peak-time download throughput speed for 'up to' 20Mbit/s and 24Mbit/s connections by ISP, weighted and unweighted figures, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been unweighted to distance from exchange and data for Virgin Media's cable and BT 'up to 40 Mbit/sis unweighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.

Figure 11 Peak-time download throughput speed for above 'up to' 24Mbit/s connections by ISP, weighted and unweighted figures, May 2011



Source: SamKnows measurement data for all panel members with a connection in May 2011.
Notes: (1) Only includes ADSL customers within 5km of the exchange and in Geographic Markets 2 and 3; (2) Includes on-net customers only for LLU operators (3) Weighted data for ADSL operators have been unweighted to distance from exchange and data for Virgin Media's cable and BT 'up to 40 Mbit/sis unweighted; (4) Data collected from multi-thread download speed tests; (5) The range shown represents a 95% confidence interval around the mean.