

UK Mobile Broadband Performance Analysis

Initial Findings 2009



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Executive Summary

In autumn 2008 Epiteiro commenced a research project to measure the quality of experience (QoE) of mobile broadband services in the UK for the purposes of i) setting a baseline of service levels and ii) establishing a like-for-like process for comparing against fixed line services including ADSL, cable and FTTx.

This report details the performance of mobile broadband networks in the UK based on data collected from December 8th 2008 to May 8th 2009. Major mobile broadband operators were analysed including Hutchison 3, O2, Orange, T-Mobile, Vodafone and Virgin Mobile. Over 1.4 million tests recorded performance data from more than 1,300 testing agents located throughout England, Wales, Scotland and Northern Ireland.

Epiteiro sought to further understand mobile broadband and also compare it to similarly-specified, nationally-available ADSL services. The following key points were discovered:

- Mobile broadband users experience, on average, 24% of maximum headline 'up to' speeds advertised
- The average mobile broadband speed achieved is less than 1 Mbps
- Of the 1,300 agents tested, the fastest 20 agents posted an average speed of 1.8 Mbps
- The average Ping time is 150msec which exceeds the recommended 100msec ceiling for internet game playing. Similarly specified ADSL broadband services achieve an average of less than 50 msec
- Web browsing, on average, is 34% slower than speeds achieved on ADSL connections though smaller but popular web sites download in less than 3 seconds
- Trends in mobile data indicate TCP download speeds improving at a rate of 11% over the test period

Data for the report was collected mainly by Epiteiro's isposure™, a freely downloadable application for consumers of all broadband services to chart their actual broadband service level and compare it to other ISPs in their area. isposure™ can be downloaded from www.isposure.com or www.thinkbroadband.com as bundled with Think Broadband's TBB meter.

Due to the difference in performance between nationally available ADSL and mobile broadband service levels, Epiteiro recommends that consumers fully monitor the actual service levels they receive to ensure broadband services meet their requirements.

Epiteiro will continue its research into broadband performance in the UK and will endeavour to include emerging femtocell (mobile data and voice services backhauled over consumer broadband), LTE and WiMAX analysis in future reports.

Introduction

Since 2000 Epiteiro has benchmarked broadband performance and regularly published Internet Performance Index (IPI) reports examining numerous key performance indicators (KPIs) that affect consumer experience. Epiteiro provides relevant data to ISPs, industry bodies and telecommunication regulators for benchmarking and network management purposes.

Founded on Epiteiro's ISP-I™ technology that tests Internet services from the customer experience perspective, this report details the performance of mobile broadband networks in the UK, specifically cellular HSDPA, based on data collected from December 8th 2008 to May 8th 2009. During this period Epiteiro's network of testing agents executed tests on leading mobile and fixed line ISPs. The analysis of that data forms the basis of this report.

Epiteiro conducted this research independently without association or partnership with any ISP, regulator or other interested party. The project remains in operation.

Objectives of the Research

Epiteiro's objectives for researching mobile broadband were the following:

- Understand the Quality of Experience (QoE) the UK general public achieves with mobile broadband services
- Understand the technical potential of mobile broadband networks
- Compare mobile broadband with similar, nationally-available ADSL broadband services
- Provide a benchmark and baseline for recording improvement of services over time

Defining Mobile Broadband

Mobile broadband is an undefined term with respect to speed and technology used. GPRS, 3G, HSDPA, HSDPA+ and WiFi technologies may be considered by UK service providers as mobile broadband thus there is a variance in what is promoted to the public.

For the purposes of this research Epiteiro focused on cellular broadband services that rival ADSL fixed line broadband packages. Thus GPRS (because of its low speed) and WiFi (as it connects via fixed line infrastructure) were excluded in favour of researching cellular broadband services advertised to the UK public in the range of 3 Mbps to 7.2 Mbps.

Why Measure HSDPA Mobile Broadband Performance?

Mobile broadband is of interest due to a number of coinciding factors that are fostering consumer and business uptake, addressing the urban/rural divide and potentially affecting broadcast entertainment.

According to recent research, mobile broadband is the fastest growing type of internet service with European sales of both smartphones and dongles (that enable computers to communicate over HSDPA services) rising from 4.3 million devices in 2007 to over 11 million devices¹ in 2008. Further research reveals mobile broadband via only dongles, not including smartphones, now constitutes 12% of all European broadband connections, up 74 percent from the previous year, with 60% of all subscribers based in the UK, Germany and Italy².

Increasing popularity for mobile broadband in the UK has been linked to lower subscription and device costs, new pay-as-you-go services and the flexibility that is generally enjoyed with wireless communications.

Mobile broadband is also being suggested by leading operators as a viable means of providing broadband services to rural 'not spots' where, due to distances from the exchange, ADSL broadband service is not possible. Ireland has selected mobile broadband for its National Broadband Scheme³ to address the rural/urban divide challenge with download speed targets of 1.2 Mbps at cell edge to 5 Mbps at cell centre.

Emerging 3GPP Long Term Evolution (LTE) technology, offering the potential of speeds approaching 150 Mbps, is further raising the interest in mobile broadband as a means of broadcasting video and processing other bandwidth-intensive applications.

Scope of Testing

Epitiro tested the leading mobile broadband service providers in the UK including 3, O2, Orange, T-Mobile, Vodafone and Virgin Media using a variety of test methodologies as discussed in the Methodology section. Data from BT's mobile broadband service, launched towards the end of the data collection period, was not considered for this report.

In excess of 1,300 testing agents were used to gather information across the UK with test results from England, Wales, Scotland and Northern Ireland. There were a minimum of 160 agents per ISP.

Tests were conducted from December 1st 2008 to May 8th 2009 with over 1.4 million test results recorded.

Mobile broadband services that Epitiro subscribed to were established by the usual consumer process without indication that the services would be used for testing purposes. No changes were made or requested regarding the operation of the broadband package provided. Headline speeds advertised ranged as follows:

Mobile ISP	Advertised 'up to' Headline Speed
3	3.6 Mbps
O2	3.6 Mbps
Orange	3.6 Mbps
T-Mobile	4.5 Mbps
Virgin Mobile	3.0 Mbps
Vodafone	7.2 Mbps

Table 1 – Mobile ISPs Tested and Advertised Headline Speeds

Methodology

Data was collected and managed via Epitiro's ISP-IT[™] broadband monitoring service consisting of deployments of ISP-IT[™] configured PCs or 'hardware agents' and isposure[™] 'software agents' that both collect performance data of monitored network services and forward results to a centralised database and reporting system. Testing is maintained 24x7 from Epitiro's Network Operating Centre.

Epitiro sought to analyse UK mobile broadband from two perspectives; i) actual QoE achieved by the General Public and ii) potential Network Capability.

To determine a measurement of the general public QoE, Epitiro collected data from 1,300 isposure[™] software agents that were deployed on consumer laptops and computers throughout the UK. isposure[™] software agents report consumer QoE measurements to Epitiro and also inform end users of their individual network performance. The software agents are downloaded freely by the general public from www.isposure.com (see About isposure) or as part of the ThinkBroadband TBB Meter www.thinkbroadband.com and are active whenever the user is on-line. Being a web-based software application, isposure[™] easily scales to provide mass coverage of urban, rural, transient and sea-faring users. The isposure[™] test agent also works for cable, FTTx, ADSL and all other broadband services thus enabling direct comparison across the industry. The data in this report was predominantly based on data collected from isposure[™] software agents deployed in England, Wales, Scotland and Northern Ireland (see Figure 1).

To further understand mobile broadband network capability Epitiro also deployed ISP-IT[™] hardware agents in controlled environments. ISP-IT[™] hardware agents are computers designed to automatically connect to the internet and run tests via a subscribed broadband connection. The specification of the computer is typical of one available for home use. ISP-IT[™] hardware agents use the same underlying mechanisms as an end user connecting to the internet and to the services made available via their ISP however, as a controlled device, the hardware agents are free of any service impediments such as viruses, firewalls etc.. These agents were deployed in Cardiff, Belfast, Birmingham and London and monitored 24 x 7 from environment-controlled data centres.

ISP-IT[™] hardware agents were used to analyse Line Synchronisation Speeds and Traffic Management Practices and to provide reference data for metrics recorded by isposure[™] agents. Epitiro also configured a number of ISP-IT[™] hardware agents as drive testing using units to measure performance of mobile broadband under varying radio signal strengths.

Epitiro endpoint servers are located in the public data network (PDN) at Telehouse, the UK's primary Internet peering exchange, located in London's Docklands.

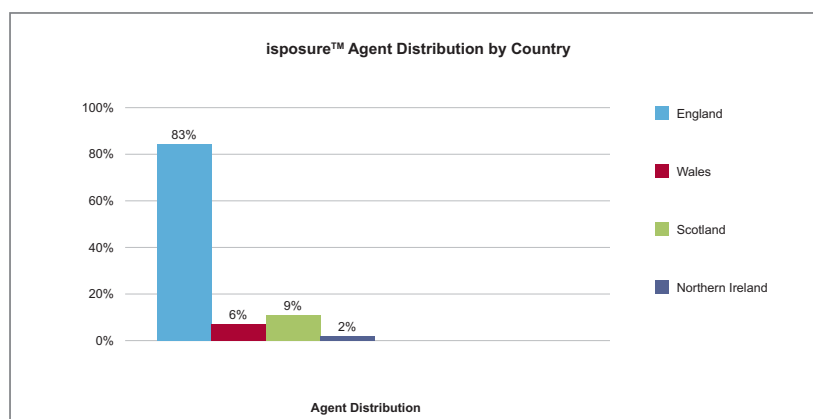


Figure 1 - isposure[™] Agent Distribution by Country

End User Experience in Context

Epitiro structured this report on metrics indicative of the performance of popular broadband tasks frequently executed by consumers including web browsing, email, downloading media, streaming media and interactive on-line gaming.

Web Browsing (Surfing the Net)

The web browsing quality of experience is generally associated with the time it takes to locate and download a web page within a web browser application. The speed or bandwidth of a customer's connection is one factor that contributes to the overall experience. In this report Epitiro examines underlying aspects such as non-cached HTTP download speeds and DNS Server resolution time along with associated failure rates.

Downloading Media

Increasingly the UK general public is using the internet as its source for movies and music. These files are considerably larger than web pages and thus require significant bandwidth in order to provide a reasonable level of service and tolerable waiting times. Epitiro examines TCP Throughput speeds and Traffic Management practices that combine to affect consumer experience when downloading media.

Streaming Media

Streaming of internet music, on-line radio stations and video media has grown in popularity in the UK amongst fixed line broadband users. The student community (due to non-permanent lodging) and long distance commuters are market segments that would embrace these applications over mobile broadband. Packet loss is one essential metric this report investigates as an indication of potential customer experience for streaming media.

Gaming

Interactive gaming on the web allows end users around the globe to compete but relies on the internet to be responsive to player commands. Ping time is examined as a leading indicator of gaming quality of experience with 100 msec seen as the ceiling (slowest) time acceptable for good game play. With in-game advertising alone forecasted to reach sales of \$1 billion⁴ USD by 2014, the on-line gaming market is an important economic concern for broadband service providers.

Key Performance Indicators (KPI)

For the purposes of this study the EpiTiro ISP-I™ hardware agents and isposure™ software agents were configured to perform a scripted test routine that measured the following metrics;

- Synchronisation speed
- TCP upload and download speed
- Non-cached HTTP download performance
- HTTP Download Failures
- DNS response times
- Ping time
- Packet Loss

Failures that occurred during the tests were also recorded to provide an indication of network reliability. A brief description of each metric measured follows.

TCP Throughput Speed

Consumers and businesses display a growing interest in actual download speeds achieved versus the 'up to' package speeds purchased. EpiTiro measures the achieved TCP throughput in terms of speed percentage of headline (advertised) speed. Various views of the data, including by time of day, are included.

Due to the tendency of proxying services on Port 80 for HTTP in 3G networks EpiTiro's mobile broadband TCP throughput tests "trained" using a variety of TCP Ports and selected optimal conditions for maximal throughput thereby avoiding any proxying, port management or traffic policies that may have been in force.

HTTP Download Speed

The HTTP download speed test indicates the rate at which an ISP can download website content. The HTTP test makes a request to the specified URL and records the time taken and the amount of data downloaded, from which the speed of the download is derived. ISP-I™ and isposure™ agents are also able to download the embedded content, such as images on a web page, and factor this into the speed calculations.

EpiTiro selected a basket of the most frequently accessed national and international websites, in order to give a wide view of internet performance to websites. HTTP Failures that required end users to re-select a web page were also recorded.

Ping performance

Ping times are used to assess the responsiveness of a broadband connection, largely for the purposes of interactive gaming. A 'ping' is the time taken to send a request to a remote server and for that server to respond with an acknowledgement. The ping test is conducted on the same basket of URLs used in the HTTP tests.

DNS Lookup Time

A DNS server takes an address readable by humans (e.g. www.google.com) and converts the address to an IP address, or a specific set of numbers which identifies a particular website. The quicker this happens, the more promptly the Internet will respond to a click on a hyperlink or resolve a web address. The DNS test records the time taken (in milliseconds) to resolve a fully qualified domain name to a corresponding IP address. Epitiro's test methodology ensures that the DNS query is performed on the DNS servers, and not returned from any local cache.

Packet Loss performance

Real-time applications such as streaming video and IP telephony require virtually uninterrupted transmissions. However, data packets may be discarded due to traffic congestion thus affecting the experience of watching video or conversing using VoIP. This test records the average packet loss that occurs as a percentage of total data sent.

Line Synchronisation or Connection Speed

In fixed broadband installations the service provider equipment communicates with the customer's home modem to agree the fastest speed at which broadband can reliably work, in consideration of a customer's distance from the exchange and other service-limiting factors. This is termed Line Synchronisation Speed which is usually less than the 'up to' headline speed advertised and unique to every individual installation. The handshaking process can take up to a week to arrive at a reliable speed for new installations. Epitiro extracts fixed line synchronisation speeds from the 'handshake' setting in the customer's router.

For mobile broadband, the Line Synchronisation speed, advertised as Connection Speed, is set by the mobile broadband ISP at the technical maximum limit of the cell. Typically 3.6 Mbps or 7.2 Mbps line synchronisation speeds are measured from mobile customer devices. Theoretically these speeds are obtainable if only 1 user were to be connected to a cell and under ideal communication circumstances. Epitiro extracts mobile broadband line synchronisation speeds from the dongle device information.

Report Format

Epitiro's objective for this research was to understand mobile broadband performance overall rather than provide a league table of service providers. For this reason several steps are taken within this report to conceal the identity of mobile ISPs.

- Each graph has anonymous ISP labelling that is randomly applied per graph. For example, an ISP labelled "A" in one chart may not necessarily be labelled "A" in another chart.
- As ISPs vary in their 'up to' speeds advertised, care has been taken when presenting findings as not to inadvertently identify an ISP

Fixed broadband services of 2 Mbps, 4Mbps or 8Mbps from leading national ADSL ISPs were used for comparison with mobile broadband services.

TCP Download Speed Results – General Public Experience

The maximum TCP download speed is measured by demanding that the broadband connection work at full capacity to download a large amount of data located on a controlled Epiro server. Identical test methodologies are used for mobile or fixed (ADSL, Cable, FTTx or other) broadband services.

The following charts show the average speeds achieved by the UK General Public as measured by the 1,300 software agents throughout the test period.

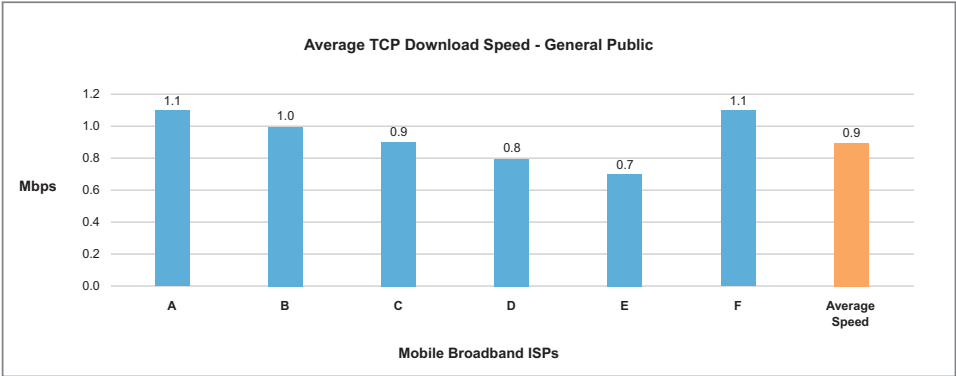


Figure 2

Average TCP download speeds delivered to the general public (Figure 2) ranged from 0.7 Mbps to 1.1 Mbps throughout the full test period with the average speed of all ISPs measuring 0.9 Mbps. Test times were taken at random times from each agent up to 4 instances per day creating a results database of over 750,000 data points. Mobile broadband consumers experienced an average of 24% of advertised headline speeds based on all services measured as seen in Figure 3.

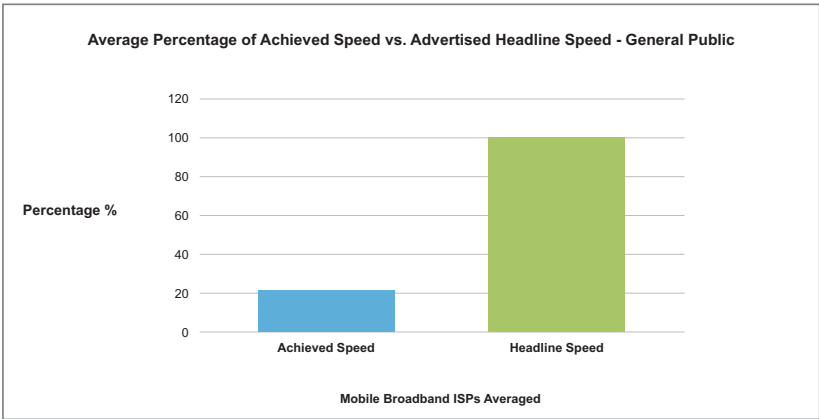


Figure 3

The distribution of average agent TCP throughput measurement is shown in Figure 4. The majority of scores (92%) were measured speeds between 0.6 Mbps and 1.4 Mbps, on average. Average speeds were recorded exceeding 2.2 Mbps though statistically they are represented as 0 on the chart.

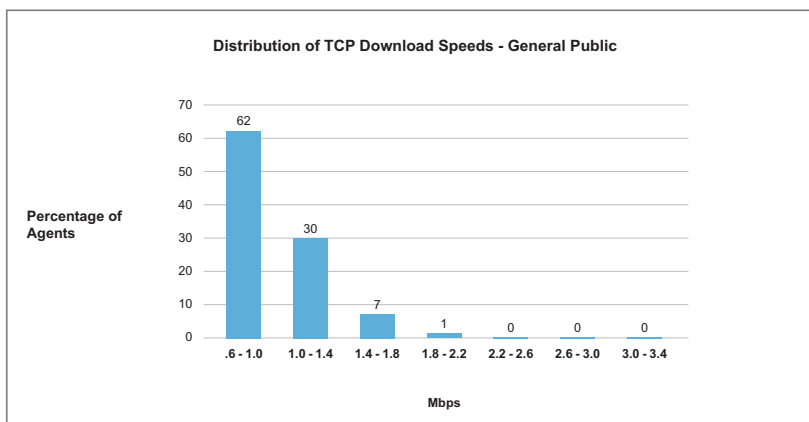


Figure 4

Figure 5 shows the general public experienced a consistent drop in performance in peak hour (6 pm until 12.00 a.m. midnight) for ISPs. On average there is a drop of 20% of TCP throughput speed during peak hours.

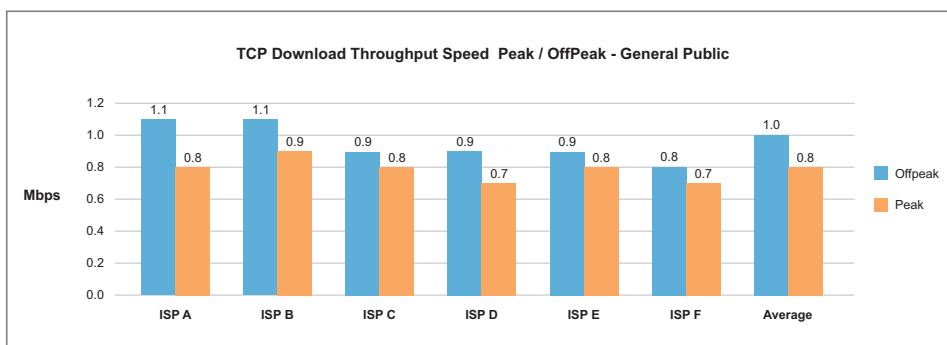


Figure 5

Epitiro analysed the Overall Top 20 agents of the 1,300 agents in the test group to record the highest scores achieved, on average. The overall average speed of the Top 20 measured was 1.8 Mbps over the duration of the test period with the highest individual average score of 3.2 Mbps. All mobile broadband ISPs had agents that were in the Top 20 (Figure 6).

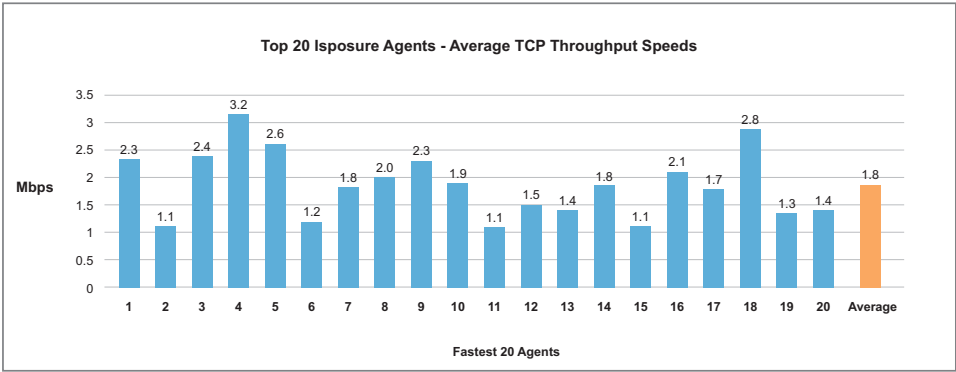


Figure 6

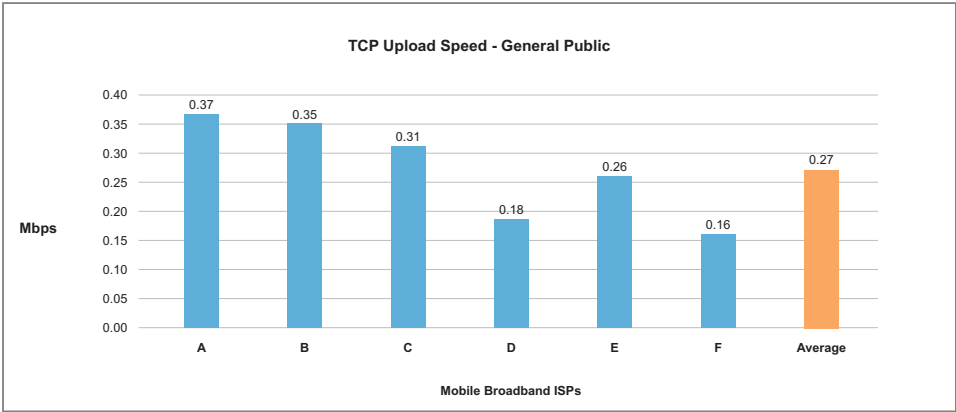


Figure 7

Although consumers and ISPs focus on download speeds, upload speeds are of interest as internet telephony and video conference calling uses this bandwidth as do emails and attachments.

Upload speeds measured by isposure agents varied significantly by ISP yet averaged at 270 Kbps which is adequate for using mobile broadband for VoIP (64 Kbps Skype) but less than adequate for video (384 Kbps Skype) calls. Note that three mobile broadband ISPs rivalled the average upload speed for the UK’s 8 Mbps packages (380 Kbps) as measured by Ofcom⁵.

TCP Throughput Test Results – Controlled Agents

Epitiro's deployment of 24 controlled test agents were used to examine mobile broadband service capabilities. Stationary ISP-I hardware agents in a controlled environment were positioned to achieve strong signal strengths and take TCP throughput measurements every 15 minutes.

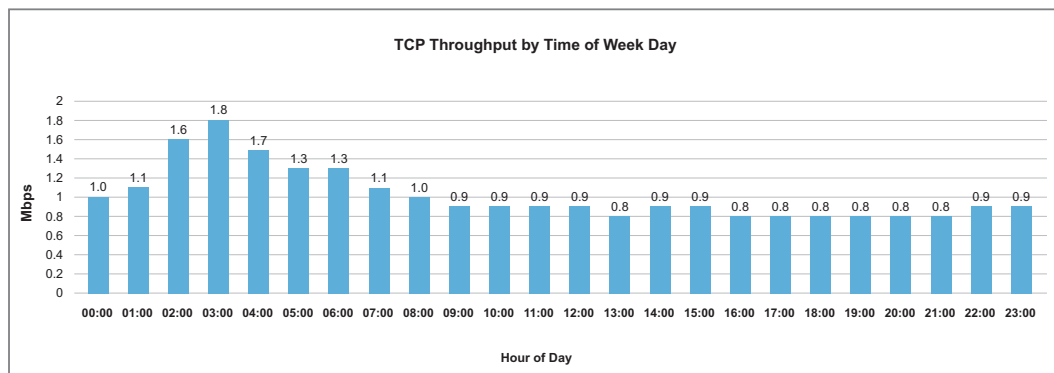


Figure 8 - TCP Throughput by Time of Day

Figure 5 previously showed that the average speed experienced by the general public using isposure software agents dipped approximately 20% during peak hours, indicating that network contention or congestion was present.

Figure 8 shows that the best speeds delivered to our controlled deployment of hardware agents occurred between 2 a.m. and 5 a.m. The highest average measurement for any hardware agent on any ISP was 3.2 Mbps.

Traffic Management Practices

Fixed broadband providers typically invoke traffic management policies that limit bandwidth to users specifically downloading movies and MP3 files, especially during peak periods. This is a necessary step to ensure all users receive an acceptable level of service from a finite amount of ISP bandwidth.

Epitiro simulated peer-to-peer activity from file servers in order to chart the reaction of fixed line and mobile broadband ISPs.

While fixed line ISPs showed traffic management policies were active, Epitiro did not detect active traffic management policies on mobile broadband networks throughout the test period.

Line Synchronisation Speed vs TCP Throughput Speed

Epitiro's ISP-ITM hardware agents extracted the synchronisation speeds as determined by the mobile broadband service provider.

While each residential fixed broadband installation has a unique connection speed set depending on the length and condition of their line, the mobile broadband Line Synchronisation speeds measured over the 5 month test period did not waiver and were measured as either 3.6 Mbps or 7.2 Mbps precisely.

Each ISP had a synchronisation speed equal to or higher than its advertised 'up to' speed.

Non-Cached HTTP Download Speed Results

Typical web page content consists of many small sized files that, even when combined, are still considerably smaller than an average-sized MP3 file. Consequently web pages download to a browser in much less time than movies or MP3 files. However the nature of how HTTP works – requesting and delivering each little file on the web page individually – results in an overall slower speed of service compared to a request for a single large movie or MP3 file.

Epitiro strives to download all types of content – text, imagery, java scripts, etc. – from its basket of web pages tested in order to ensure HTTP speeds are representative of actual customer experience.

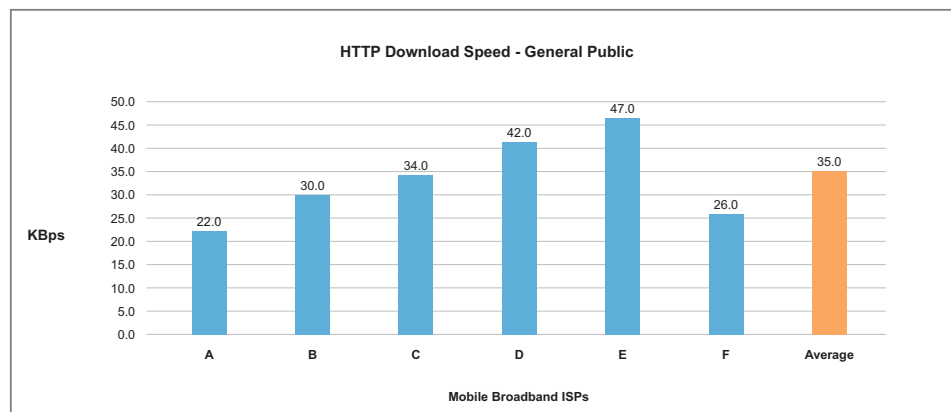


Figure 9

The average overall HTTP download speed across all isposure™ agents was 35 KBps or approximately 0.3 Mbps. At this rate the www.google.co.uk homepage @ 8KB would take less than 1 second to fully download while www.bbcnews.co.uk @ 80KB would take approximately 2-3 seconds to fully download, not considering DNS lookup times and end user computer processing time required to display the web page in a browser.

Comparatively, the Top 6 UK ADSL 8Mbps broadband services, also measured by isposure™ agents throughout the test period, averaged an HTTP download speed of 64KBps or approximately 0.5 Mbps.

Approximate download speeds for other web pages at the average HTTP speeds of mobile and fixed line broadband are listed below.

Web Site	Size	Avg. Mobile Broadband Download Time	Avg. Fixed Broadband Download Time
Glastonbury Festival	16KB	0.5 seconds	0.25 seconds
Facebook	39KB	1 second	0.5 second
BBC News	80KB	2.5 seconds	1 second
Guardian News	190KB	5.5 seconds	3 seconds

Table 2 – Web Page Download Estimates

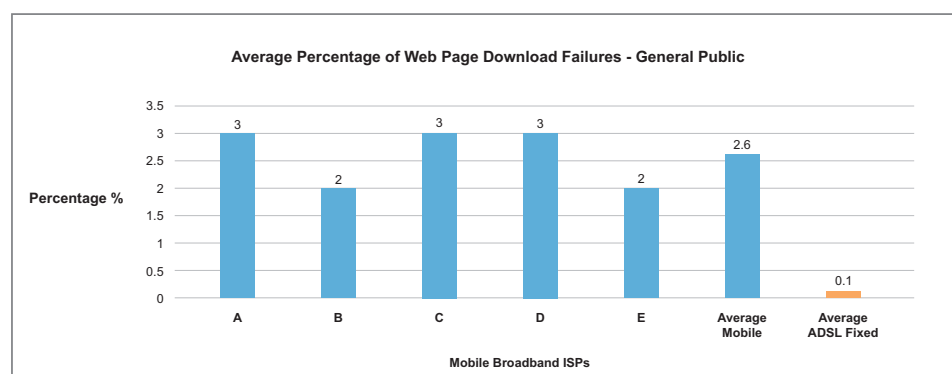


Figure 10

Mobile broadband Mobile broadband users are required to re-select web pages more often than fixed line broadband users. Approximately 1 in 38 web pages need to be re-selected by mobile broadband users compared to 1 in 1,000 pages for fixed line.

Ping Time

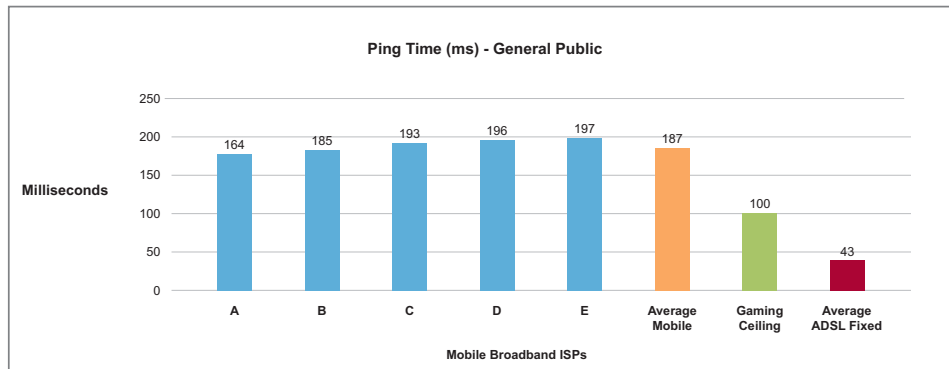


Figure 11

Ping times for mobile broadband exceed the 100msec maximum making mobile broadband currently unacceptable for game playing. The UK's fixed line average of 43 msec, as measured by Eptiro, is well within the range for excellent game playing.

Generally ping times increase during peak periods when network congestion either slows the processing of data or re-routes data over less direct paths that have multiple hops. While there was a difference recorded in peak / off peak ping times, all of the average times measured for ISPs exceeded the 100msec ceiling.

DNS Resolution Time

DNS resolution times for mobile broadband networks are approximately 3 times longer than similar-speed ADSL packages though at an average of 150 msec unlikely to affect customer experience significantly.

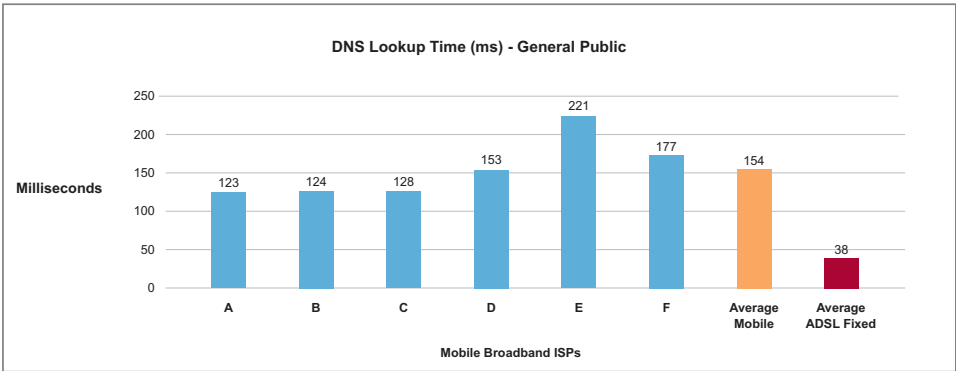


Figure 12

The difference in times may be of significance to mobile broadband service providers and is included here mainly for that reason. Long DNS lookup times affect the stated HTTP speed for downloading web pages given that it is a calculation of the total time it takes to download the full content from the moment of executing the command.

Packet Loss

Packet loss is critical in real time communications such as VoIP and video streaming that rely on uninterrupted data. Generally mobile broadband is on par with leading ADSL fixed line broadband providers providing similarly –specified services. The exception is with one mobile broadband service provider, labeled Mobile ISP E, that struggled with an average of 2.1% packet loss. At 2.1% packet loss customer experience with VoIP packages would be negatively affected with partial or full words being eliminated from speech.

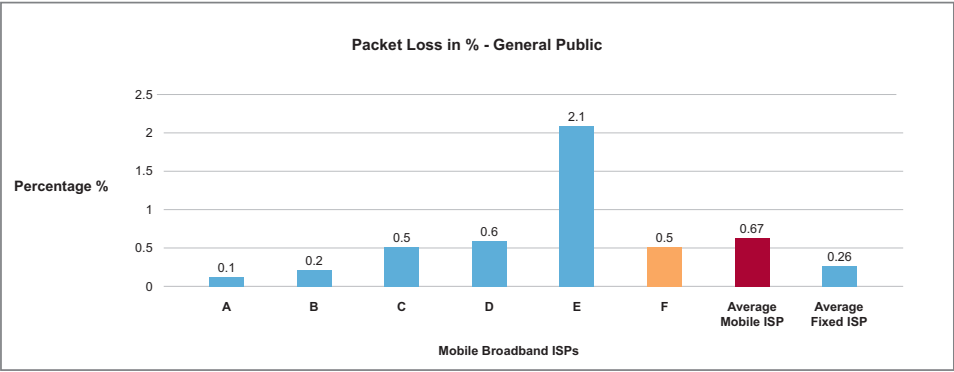


Figure 13

Packet loss varied with time of day yet remained less than 1% for all other mobile service providers. For VoIP applications, for example using Skype, the average packet loss occurring in mobile broadband would not negatively affect customer experience.

Conclusion

Mobile broadband operates at less than 24% of advertised headline speed and more slowly than equivalently specified ADSL broadband packages.

TCP download speeds showed an 11% improvement over the test period with each month showing an overall improvement. This suggests on-going investment into additional broadband infrastructure by the mobile internet service providers.

Not every mobile broadband service provider showed improvements each month, however.

Variances amongst mobile broadband ISPs are significant in terms of TCP and HTTP speed as well as Ping and DNS lookup times.

No mobile broadband ISP equaled an equivalent ADSL fixed line service provider in terms of overall performance.

In consideration of web surfing, mobile broadband posted slower HTTP download speeds, higher HTTP failures and slower DNS response times which combine to make an overall less desirable consumer experience.

Rural and remote users that cannot receive reliable ADSL services may benefit from using mobile broadband. Further research is required and will continue by Epiteiro.

Epiteiro is involved in research projects concerning emerging mobile broadband technologies such as LTE and WiMAX that potentially could reach TCP throughput speeds meeting or exceeding those achieved through current ADSL 2+ and FTTH installations. Should these new technologies become widely available in the market place they could resolve some of the obstacles impeding mass adoption of mobile broadband.

Recommendations

With performance levels varying significantly Epitiro at this time suggests businesses and consumers ensure they select ISPs to meet their needs and recommends the following steps;

- Business and consumers should be familiar with the KPIs and technology description in this report for the purposes of understanding mobile broadband service levels
- Business and consumers should be aware that achieved TCP throughput and Web Surfing speeds may be considerably lower than advertised headline speeds
- Epitiro would caution against using mobile broadband for interactive computer games requiring server response times of less than 100 msec.
- Rural consumers unable to receive ADSL services should investigate mobile broadband as a viable option
- Industry bodies and consumer organisations concerned with the development of mobile broadband services over time should consult Epitiro for further research results and publications

Ongoing Analysis

This initial report into mobile broadband services provides a baseline from which to commence ongoing monitoring and benchmarking. Epitiro will continue to test mobile broadband services in the UK and expand its coverage to provide the following detail;

- i) Quality by Location – comparing regional, urban, rural mobile broadband quality
- i) Stationary and Moving Users – understanding broadband performance whilst in motion
- i) Email – comparing email speed and reliability with fixed line broadband
- i) Femtocell Voice & Data Quality – insight into this emerging technology
- i) Consumer feedback – exploring the relationship between performance and satisfaction

Epitiro will also be conducting extensive video streaming testing on mobile broadband connections to benchmark the quality of broadcast entertainment to mobile computers now, and for the purposes of charting this inevitable eventuality.

Epitiro observed considerable differences in the performance of 3G dongles used throughout the testing and will further research the range of capabilities as a separate project.

Future publications will be based on an increasing number of agents as the uptake of mobile broadband services grows. BT's mobile services and other new entrants will also be monitored going forward.

About isposure™

The site www.isposure.com offers members of the public the means to see the average speeds over a period of time, plus compare their performance against the other ISP services available in their local area.



At time of publication there are in excess of 25,000 isposure agents throughout the UK reporting broadband performance statistics on over 200 ISPs. isposure is also available in over 70 countries around the world.

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2. Research Paper, Berg Insight, Sweden, April 2009
3. National Broadband Scheme for Ireland, Government of Ireland, 2009
4. In-Game Advertising: Market assessment and forecasts to 2014, Screen Digest 2009
5. UK Broadband Speeds 2008, Ofcom, January 2009

About Epitiro

Epitiro is the global leader in comparative broadband benchmarking providing customer experience insight to ISPs, cellular and fixed line operators, media providers, multi-national corporations and government regulators.

Voice, video and internet performance levels are benchmarked via Epitiro's extensive deployment of ISP-I™ edge-based devices with results available through an on-line database access service or regularly published reports. The company also provides bespoke test and benchmarking solutions with products such as DataLite™ and the Femtocell Test Suite™.

Clients such as BT, Orange, Telefonica O2, T-Mobile, Virgin Media, Vodafone, Telecom New Zealand, Tiscali, KPN and many others benefit from Epitiro's coverage of fixed and wireless broadband performance.

Since 2000 Epitiro has maintained ongoing monitoring of top internet service providers (ISP) around the world for the purpose of providing industry bodies with actual customer experience data of broadband services. Epitiro is based in Cardiff, Wales, UK.

About Thinkbroadband

thinkbroadband.com is the UK's most popular independent broadband news and information website offering advice and details on the services offered by broadband service providers. Based in London, thinkbroadband offers the TBB Meter, which includes isposure™, for consumers to test broadband connections on demand.

Appendix 1 Testing Methodology Background for This Report

1. End-to-end Data Quality of Service (QoS) Measurements Overview

End-to-end data performance measurements were made at the application layer and measured end-to-end according to the following process;

- One node transmits data and another node receives the data and measures its performance
- One end node is either the broadband subscriber's computer (desktop or laptop PC with a 3G network connection) or an ISP-I AT400/AT100 hardware agent
- The other node is a controlled server located in Telehouse and managed by Eptiro

The endpoint server measures the data received from the user equipment (UE) and sends back the results. Measurements are made by the same software that generated the uplink data during the downlink process.

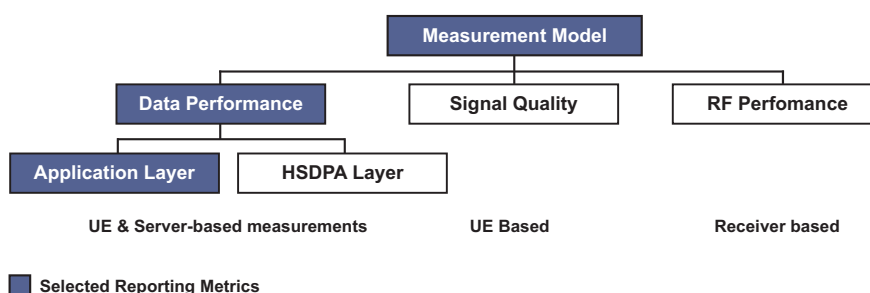
2. QoS and Standards

Eptiro implements international standards and recommendations by industry bodies such as ETSI, 3GPP and the ITU. The data and research findings can be directly compared to other studies using those standards.

Standards include:

- ITU-T Series G: Transmission Systems and Media, Digital Systems and Networks Quality of service and performance
 - o G1010 End-user multimedia QoS categories
- ETSI 202 057 Speech Processing, Transmission and Quality Aspects (STQ); User related QoS parameter definitions and measurements;
 - o Part 4: Internet access

QoS recommendations define quality of service for users according to specific parameters. The scope of measurement included in this research project though not necessarily covered in the report are indicated below:



End-to-End Performance	Included in Test Methodology
Download (Rx) Throughput: Min, Max & Average	Yes
Upload (Tx) Throughput: Min, Max & Average	Yes
Round Trip Time (RTT) – delay	Yes
Packet Loss	Yes
Retransmission	Yes
Throughput, retransmission per application	Yes
TCP/UDP performance	Yes
MMS performance	Partial

Accessibility	Included in Test Methodology
PDP Context activation parameters	Partial
Attach success rate	Yes
Connection success rate (IP Address)	Partial
Connection set-up time (IP allocation)	Partial
Session status	Partial
Application connection success rate	Yes
Application connection time	Partial

Mobility	Included in Test Methodology
Cell update success ratio	Partial
Cell reselection success ratio	Partial
Routing area update success ratio	Partial

Retention	Included in Test Methodology
Network initiated deactivation rate by SGSN, GGSN, HLR	Partial
Dropped contexts per application	Yes

3. About 3GPP User equipment, Field-testing and Conformance Standards

3GPP offers a set of test specifications designed for testing mobile network elements to ensure that each device meets a set of minimum acceptable standards. As examples:

- **3GPP TS 25.141** focuses on BS conformance tests and contains the relevant HSDPA specific measurement requirements. For Node B testing, 3GPP TS 25.141 specifies test models that describe the physical channel test set-up.
- **3GPP TS 34.108** describes common test environments for UE conformance testing. Baseline radio bearer combinations for testing HSDPA are specified, and generic set-up procedures for HSDPA tests are described.
- **3GPP TS 34.123** is the UE conformance specification for protocol tests. 3GPP TS 34.123 details over 50 HSDPA protocol test cases. HSDPA specific tests for MAC-hs, RRC, NAS protocols and Radio Bearer tests are also available.

By conducting exhaustive end-to-end testing Epitiro strives to address critical key concerns outside the scope of 3GPP including dongle device comparison, competitive analysis and load analysis on network resources.

4. About HSDPA and LTE

High-Speed Downlink Packet Access (HSDPA) is a 3G mobile telephony communications protocol that enables theoretical TCP broadband connection speeds of 1.8, 3.6, 7.2 and 14.4 Mbps.

Long Term Evolution (LTE) is an emerging mobile broadband technology that has the following objectives:

- Downlink peak data rates in excess of 100 Mbps with 20 MHz bandwidth.
- Uplink peak data rates up to 50 Mbps with 20 MHz bandwidth.
- Scalable bandwidth up to 20 MHz, covering 1.25 MHz, 2.5 MHz, 5 MHz, 10 MHz, 15 MHz, and 20 MHz in the study phase. 1.6 MHz wide channels are under consideration for the unpaired frequency band, where a TDD approach will be used.
- Reduce latency to 10 ms round-trip time between user equipment and the base station and to less than 100 ms transition time from inactive to active.

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