Quality of Service Parameters for Internet Service Provision

Final Report

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1. Introduction

This is the final report of Bannock Consulting’s project for the European Commission’s DG Information Society, Quality of Service Parameters for Internet Service Provision.

The purpose of the project is to propose and discuss some parameters which individuals and SMEs can use to measure the Quality of Service they receive from the Internet, in particular – though not limited to – from their Internet Service Provider. The parameters will be discussed with regard to their meaning and relevance to particular types of user. This will be done in light of conversations with several of the key players in this market – telecommunications companies, Internet service providers, and consumer and small business representative organisations.

Part I of this report sets out some background to the study – what users want from the Internet, how it works, some of the factors affecting the speed and reliability of the users’ connection, and some of the issues relating to the cost of Internet access. We also discuss whether or not quality of service can be guaranteed – and if this matters – and some of the guiding principles behind our parameter selection.

Part II presents some background to the selection of our proposed parameters to measure Internet Quality of Service, as well as the list of parameters themselves, which were developed and refined in the course of interviews with Internet Service Providers, Network Access Points and telecommunications companies. We also discuss in general terms some possible practical applications for the parameters.

Part III presents our conclusions.

We have striven to make this report readable and understandable to the layman, as well as being informative for people who are already familiar with the Internet. It is impossible to do this without some discussion of technical issues, though we have tried to keep these to a minimum.

This report was written by David Turnbull, Olivia Jensen and Peter Smith of Bannock Consulting, with contributions from Alan Doran, Stuart Berman and Kevin Carter, for which the authors are grateful.

Bannock Consulting
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PART I - Background
2. What do users want from the Internet?

Before a user can decide how to spend his time online, he needs to be able to connect. A business with a permanent connection to the Internet will have few worries about being able to connect, but the user dialling up from home cannot take this for granted. It is more than just a matter of deciding which ISP (Internet Service Provider) to use and signing up to it, as some ISPs limit the number of subscribers they accept concurrently, and not every ISP has a swift and easy process for becoming a subscriber. Even the right ISP will not necessarily guarantee access all day everyday.

For the individual user, not being able to get online is inconvenient and disappointing, but this is not always the fault of the ISP – the telephone company (telco), for example, also plays a role. The telephone connection is certainly of relevance to the user’s QoS, though, so there must be parameters to reflect this. There are several possible measures of inconvenience: how many times the user tries to get a connection and can’t, how long he is not able to get a connection for on any particular occasion, and how often and after how long the call gets terminated after an initially successful connection. Even if it only occurs very rarely, one long period during which he is unable to get online may be more of an inconvenience to the user than sometimes not being able to get online at the first try, or without a brief delay. The worst case is when a telephone connection is made but the ISP fails to establish routing. This is because the consumer is charged and yet gets no service.

Much more is at stake for the SME that is unable to get online. Many SMEs in Europe are hoping to take advantage of the lower transaction costs and communication costs that the Internet offers to raise the efficiency of their business and to reach more customers. If customers and suppliers are used to dealing with the SME over the Internet, then not being able to get online will be a serious disruption to business. At this early stage in the development of the Internet for B2B and B2C transactions, companies are conscious of building their online reputations in the face of stiff competition. Reverting to faxes and phone calls could be a disaster for a SME trying to build a web presence. Care must also be given to the choice of a web-hosting service for an SME wanting to publish content on the web – the best ISP for this may be different from the best ISP for Internet access.

Once online, though, what are the services that people want to access through the Internet? We can identify five broad categories:

- Information
- Entertainment
- Communication
- Presence
- Commerce

2.1.1 Information

For the household or individual private user, and also for companies wanting to carry out research, the Internet can be an impressive source of information.

How does the user want to access the information on the Internet?

- Surfing the web
- Downloading data files
- Access to proprietary content
- A friendly, customisable interface
- Filtering of information

To surf the web, all that the user needs from the ISP is a point of connection to the network beyond the ISP – the Internet. In theory, he would then be able to reach any website anywhere in the world through the mesh of pipes and junctions that makes up
Despite the amount of material available on the web, some users like to have the extra proprietary content that is provided by the larger ISPs. Whether this will continue to be the case is debatable. As users become more familiar with using the web, they are likely to discover sites that offer more specialised information or more effective tools than those offered by the ISP. Also, most of the content provided by ISPs is not proprietary - even if you use another ISP for Internet access you can still get to the information on the site. Most of the content available to AOL subscribers, for example, is available to anyone with web access through AOL's website. Despite this, many ISPs are developing a marketing strategy that involves providing more rather than less content to attract and retain subscribers.

Similarly, with regard to the interface offered by the ISP, some users would like it to be as simple and straightforward as possible, seeing it as a jumping off point for the web, where as other users would like to be able to create a personalised, information-rich interface. It is therefore difficult to say a priori which approach constitutes superior QoS. ISPs are likely to gradually distinguish themselves along these lines, in which case the user will be able to get the appropriate QoS in this regard.

A filtering system for information may be an important issue in households where children may be using the web. The content on the web itself is generally unregulated, so parents may wish to restrict the material that their children can access by using an ISP that has a filtering system, or software packages which claim to filter out offensive material. For an individual, however, restrictions on the information he can get access to might reflect a decline in QoS. Filtering may be useful to all email users if it protects them from unsolicited email, known as 'spam', though filtering is not always totally effective.

The information needs of an SME are likely to be similar to those of the individual or family user in terms of reach, although the motives might well be business-oriented rather than surfing for leisure purposes.
Their requirements in terms of speed may be more stringent, for example, in a business that uses any kind of time critical information, and the loss of a few extra seconds in the receipt of information might mean the loss of a deal or a miscalculation.

2.1.2 Entertainment

For the moment, televisions, videos, music centres and video games consoles provide household entertainment. This may all change with the Internet. Using the Internet is not only a form of entertainment in itself, it is also a distribution channel for other forms of entertainment.

- Audio: music can be downloaded from the Internet for future enjoyment. It is also a way to access radio stations from all over the world.
- Video: there is huge potential for visual entertainment to be provided over the Internet. Once broadband access is available, people will be able to enjoy video-on-demand, a huge range of programming and real-time broadcasts from other parts of the world (for example of a live concert or sports event) all through access to the Internet.
- Games: users can download game software from the Internet, and play against others anywhere in the world over the Internet.

These activities are typically much more demanding in terms of bandwidth than simple web-surfing. They also require higher speeds and lower packet-loss to be enjoyable for the user. For the ISP, this means much more stringent requirements in QoS, and probably the expansion of their upstream bandwidth to keep customers satisfied, as well as other QoS enhancements.

2.1.3 Communication

The Internet offers a fast, cheap method of communication over long distances. It makes it possible to transmit large amounts of data, and to reach a wide audience.

For the individual, the main method of Internet communication at the moment is email. Of all the Internet’s uses, email is the least demanding in terms of QoS. A delay of several seconds in data transmission is unlikely to be noticed by the user. However, the reliability of the ISP’s mail server is important as lost messages or long delays in accessing them would be noticed by the user and could have harmful effects on an SME’s relations with its customers.

Email is not the only form of communication offered over the Internet; it can also be used for voice telephony, although this requires a faster and more reliable connection than email, and video-conferencing. Video-conferencing is particularly demanding in terms of bandwidth – it requires more data to be sent than telephony (both pictures and sound) – as well as potentially allowing more than two participants to be connected.

The Internet also constitutes a way to access a company’s proprietary network from a distance, a development that makes possible a revolution in working habits. An employee working at home could have access to all the information on his company’s network over the Internet, and communicate just as effectively from a distance as in the office.

2.1.4 Presence

For SMEs, the most important use of the Internet may be to attract potential customers and to deal with established customers. The website is the company’s face on the web and therefore crucial in its Internet strategy.

For the business setting up a website, there are multiple considerations.

- How much webspace is needed, and how much does the ISP provide? An individual may have modest requirements for webspace, but a business might need substantially more in order to publish catalogues, user guides and so on.
- How reliable are the ISP’s webservers? Uptime is crucial here, as any unavailability of a website might have very harmful effects on business. What constitutes acceptable levels of availability
varies depending on the type of business, and can be difficult to measure.

- How many established or potential customers are on the ISP’s network? As we will see below, the Internet is really a whole series of ISPs’ networks connected together. The connections between the various networks are thought to add to delays and unreliability, so an important consideration when choosing an ISP is the number of users connecting to the Internet through the ISP’s network. In the survey mentioned above on the ISPs used by popular websites, it was revealed that UUNET was the most popular even though it did not have the highest levels of speed and reliability. The explanation for this can be found in the reach of UUNET’s network. UUNET at the time was the carrier for AOL, the ISP with the largest number of dial-up customers in the world and so a website on UUNET has the potential to reach a greater number of people reliably and quickly.

- Is it possible to have a dedicated server with the ISP? What about uninterruptible power supplies, diesel generators, and so on.

- Does the ISP offer e-commerce housing, secure servers, support for credit card transactions, and so on? These are obviously crucial if the business hopes to use its website for transactions with customers.

The importance of the access speed and reliability of its website to a business will depend on its nature. Real-time information providers, for example, have to be sure that their ISP delivers the speeds that the business needs to keep its customers satisfied. SMEs publishing sales catalogues only on the Internet may be more worried about reliability, and for the individual publishing information for his own pleasure, cost may be the most important consideration.

2.1.5 Commerce

For the individual, e-commerce is one of the most exciting things about the Internet. For SoHos (small office or home office businesses) and other SMEs, e-commerce and, more broadly, e-business, has the potential to revolutionise the organisation and operation of businesses. While the impact of e-commerce is likely to be very far-reaching, the requirements from the ISP for the customer and the business to engage in e-commerce are not very different from the QoS level that is necessary for the other Internet-based activities discussed above. Communication times and reliability will again be the primary considerations, as well as security and confidence.

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### Sample Users

- **Family**
  - They use the Internet for shopping and entertainment in the evenings and at weekends. They have two young children who want to use the Internet for downloads, games etc.

- **Teleworker**
  - User works for a large company and wants to work from home and also uses the Internet for general surfing and information access

- **Start-up SME**
  - Wants to use the Internet to establish a customer base, and to facilitate internal processes.

- **Established SME**
  - Uses the Internet to deal with their suppliers and their customers

Making sense of the technical terms used in discussions of QoS and interpreting these according to their own QoS requirements may be difficult for individuals, SoHos and SMEs. Some sample Internet users (see box) may help to illuminate how the QoS parameters actually relate to the ways that people want to use the Internet. We will return to these sample users after our exposition of suggested QoS parameters, to see what might be important for each.
3. Aspects of QoS

3.1. Downstream performance – communicating with your ISP

In order to use the Internet, the user must establish an interconnection with the backbone, one of the high speed data pipes that makes up part of the network of networks that is the Internet (a concept explained further below). A very large business might consider having its own dedicated link to the Internet, which would be very fast but very expensive. Instead, most users have a connection to an ISP, which then consolidates the upstream traffic to the backbone in a single connection for many users.

The connection between the user and the ISP is known as the ‘last leg’ as it is the final stage in the journey taken by the data when the user is downloading information from a site on the Internet. The data pipes that make up the core of the Internet tend to be of a very high capacity and are therefore capable of transmitting vast amounts of data at very high speeds. The last leg is likely to be the narrowest data pipe and so is the likely determinant of the maximum speed at which the user can receive (or transmit) data.

It will be seen below that the nature of the Internet makes it impossible for the user, or even the ISP, to control the speed and reliability of the entire journey as data travels over the Internet, and so it is impossible to have an absolute guarantee of performance. However, the type of connection between the user and the ISP will make a significant difference to latency and reliability. It will also be the main contributory factor in the cost of their Internet connection, and, unlike much of the rest of the data’s journey, it is within the control of the user and ISP.

This section looks at the alternative ways that the home user or SME can connect to their ISP and the implications of this choice on QoS.

At the moment, most home users dial-up to their ISP using a modem over a standard PSTN connection (public switching telephone network). This uses traditional twin copper wires to carry data in analogue form. Because of the limit on the speed at which data can be sent via this medium, it is known as ‘narrowband.’ The user employs a modem to convert the digital data from their own computer to an analogue signal that can be carried over the telephone network. The data is then reconverted to digital data by the ISP’s modem. It is also possible that the telephone company converts the data to digital and then back to analogue if, for example, it uses optical fibre for part of the connection.

Standard modem speeds have increased rapidly, but the conversions back and forth between analogue and digital mean that modem connections still have much higher latency – or delay – than purely digital Internet connections, even when the former are compared to data travelling through several routers. A ping test – the time that it takes 32 bytes of data to travel to and from a point – may be used for this comparison. A sample test shows a time of 160ms for a ping between two modems, and 120ms for a ping between two machines connected via digital links through eight routers. Furthermore, the switches in the telephone system tend to have a maximum speed of 64kbps so improvements in modem speeds cannot augment dial-up PSTN connection speeds much further.

There are a number of alternatives to the narrowband dial-up connection, technologies collectively known as broadband. There is a fairly straightforward trade-off between speed and cost, although this may change as a result of the rapid change in technology.
The box on ‘Internet connection speeds’ shows the vast improvements in speed of the various broadband platforms over traditional connections; and due to their digital nature they will tend to have lower latencies associated with them, as the data do not need to be transferred back and forth between analogue and digital forms. The following sections describe these technologies in more detail.

### Sample Internet connection speeds

<table>
<thead>
<tr>
<th>Connection type</th>
<th>Max speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Ethernet</td>
<td>100Mbps</td>
</tr>
<tr>
<td>T-3 (standard US b-bone)</td>
<td>45Mbps</td>
</tr>
<tr>
<td>E-3 (Europe b-bone)</td>
<td>34Mbps</td>
</tr>
<tr>
<td>4-cable</td>
<td>20Mbps</td>
</tr>
<tr>
<td>Cable modem</td>
<td>10Mbps</td>
</tr>
<tr>
<td>ADSL download</td>
<td>2-5Mbps</td>
</tr>
<tr>
<td>ISDN</td>
<td>128kbps</td>
</tr>
<tr>
<td>Standard modem</td>
<td>56kbps</td>
</tr>
</tbody>
</table>

Note: bps= bits per second, k=1,000, M=1,000,000

#### 3.1.1 ISDN: Integrated Services Digital Network

ISDN is, in essence, a purely digital phone line, replacing the more traditional analogue system. ISDN is the connection currently being used by many smaller businesses for their permanent Internet connections but the speeds are not as high as xDSL, particularly for downloading information. In fact, isdn is often considered to be narrowband rather than broadband, even though it can offer superior speeds to PSTN dial-up. The future of ISDN – at least for Internet access; it is, for example, the default technology for all new lines, including residential ones, in some countries such as Germany – is unsure in the face of competition from the other forms of broadband access because it cannot compete on speed, although it has had a head start in establishing itself in much of Europe, as it is an older technology.

Pricing has also been a factor affecting take-up in Europe and accounts for some discrepancies in ISDN adoption between different countries.

#### 3.1.2 DSL: Digital Subscriber Line technologies

xDL upgrades the existing copper lines, extending their data-carrying capacity by occupying parts of the bandwidth unoccupied by the voice signal. xDSL can deliver data at speeds ranging from 512kbps to 13Mbps, over 230 times the rate over a 56kbps modem on a traditional copper phone line. In its first trials, xDSL was used for video-on-demand, but the trials were not commercially successful and the technology is now targeted towards Internet access.

As well as speed, another advantage to this technology is that voice and data are carried at different frequencies, so phone calls and Internet access can take place simultaneously and a separate Internet connection is not necessary. The xDSL connection is ‘always open’, meaning that users should have fewer connection problems. However, in practice, its speed depends on the length of the local loop (in telecommunications terminology, the connection between the telephone exchange and the final user), possibly making it inappropriate for suburban and rural areas where this distance could be long.

There are a number of variants of xDSL, of which ADSL (Asymmetric DSL) will probably have the widest rollout. It is ‘asymmetric’ because it offers faster speeds when receiving data (downloading) than when it is sending data (uploading) – up to 40 times normal copper wire speeds. Internet use mainly involves downloading information from websites – at least for individuals and SoHos – so it is the down-link that is more important to most users. Another variant of xDSL, VDSL (Very high speed DSL), offers data transmission speeds of up to 13M bps.

For the moment, it remains to be seen if xDSL will be taken up quickly by consumers and SMEs, as its roll-out may be slow and limited and the cost for use may be
high. There are some grounds for optimism though – in the UK, BT took on 100,000 customers for its ADSL service in the first month and charge 39 pounds per month, which for heavy users may be less expensive than narrowband. Areas with high concentrations of businesses will be the first to benefit from access. The long-term potential of xDSL has been called into question by those who doubt that traditional copper wires can be continuously upgraded as bandwidth requirements grow and grow. However, the speeds it offers are very impressive, and the additional infrastructure requirements are low which makes it an attractive option for telcos and consumers. There are some issues with contention ratios, though, as some ISPs are contending the service at ratios of up to 50:1 which can degrade the customer experience right down to narrowband speeds.

3.1.3 Cable
Fibre-optic cable transmits voice and data traffic over fibre using light streams. It provides huge amounts of bandwidth and effectively eliminates networking delays. This is mainly used at the moment for the long distance backbones (particularly undersea), and also within cities, but it is likely to be rolled out to end-users in the future. These cables may be capable of carrying up to 6.4 terabytes per second on a single fibre strand.

At the level of the consumer connection, cable has been used mainly for one-way data transfer for television programming. The potential of using cable for interactive applications such as Internet use is now coming into its own, providing ‘always on’ access at speeds up to 100 times those achieved by PSTN dial-ups.

Cable networks have not spread that extensively in Europe, where their poor reputation for service and/or their cost of use has limited their spread to 25% of the market for television access. At the moment, cable access is limited and fragmentary. Many companies are now in the process of extending their cable networks in order to take advantage of the increase in demand for cable that the Internet is causing.

Not all cable networks are capable of handling two-way traffic, and delivering the broadband speeds that users will come to expect. This is especially the case in continental Europe where cable networks were often laid by local authorities with the limited purpose of television broadcasting. This means that they will need to be upgraded before they can be used for broadband Internet access.

Cable seems an attractive form of broadband access for the home user, as it combines high speed Internet access with other services, and it is well-suited to roll-out in suburban areas. However, it requires significant investment in infrastructure and it may not reach all rural areas as the costs of installation (bringing the connection from the main cable right up to the user’s door) are high. It is also possible that cable will not be able to deliver the kinds of speeds promised as all the users in a neighbourhood will connect to the same main area cable. As more and more homes in a particular neighbourhood connect, the data burden on the shared cable will increase and will slow the speed of the individual connections, particularly at peak times. As a result, the QoS of cable is less reliable than a leased line where only the line owner uses the connection. Density of optical nodes is therefore a key QoS determinant for cable users.

3.1.4 Wireless technologies
There are two aspects to the phenomenal development being seen at the moment in wireless technologies. One is making access to the web possible on mobile phones over the mobile networks that are already operable. This is made possible through WAP technology (wireless application protocol) which adapts the content of a website to make it displayable on the screen of a certain types of mobile phones that have recently been introduced to the market, as well as providing stripped down content more suitable for low-speed connections. At the moment, this provides a useful way
of accessing time sensitive information on the Internet while on the move, but is likely to be seen as a complement to fixed access to the Internet, rather than a replacement.

Accessing the Internet through a mobile phone may have positive implications for e-commerce. Currently Internet purchases are mostly settled using credit cards and there has not been a way to handle micropayments. The mobile phone company could make these possible by adding the costs of purchases to the user’s mobile phone bill, even for very small amounts – a technology already on trial in Europe.

3-G, or high performance mobile data systems, is a burgeoning area in the field of Internet technologies and it should make wireless Internet access possible. At the moment, using a mobile phone for Internet access is only possible at speeds of around 9,600bps. 3-G uses higher and wider frequency bands to allow higher data transmission rates and could in theory allow speeds of up to 2Mbps, some 35 times the bandwidth of traditional copper wire technologies. In practice, these speeds may not be available for many years, and coverage may be ‘spotty,’ with gaps between the areas that are covered by 3-G transmission.

There have also been some interesting developments in the field of so-called ‘Fixed Wireless’, or WLL (wireless local loop). Using line-of-sight technology between transceivers and rooftop aerials (hence ‘fixed’), speeds of up to 384kbps have been achieved. While this has the advantage of not needing cables to be laid, the technology is still relatively new.

3.1.5 Other technological developments
Satellite technology has so far been used for long distance connections between major ISPs, but the development of technology that will allow two-way communication rather than just downloading may make it possible for satellite to be used for consumer access. A satellite could be used by a local ISP in places where the distances are too great or the population too sparse for cable or other broadband technologies.

The development of digital TV may make it easier for those without a computer in their household to access the Internet. This may reduce the ‘digital divide’ between those who have Internet access and those who do not, as TV penetration is close to 100% of the population.

Both of these developments mean that the services offered over the Internet will be increasingly widely accessed.

3.2. Upstream performance - how does the ISP connect to the Internet?

We saw in the previous section that there are many ways of connecting to an ISP. The speed – or width – of your connection will place an effective upper limit on the speed at which you can communicate over the Internet. However, it is rare that the connection to your ISP is used at full capacity. In practice, a number of other considerations will affect the effective speed at which you can communicate with the Internet. This section will explore some of these factors.

3.2.1 How do the data get from A to B?
The physical hardware that makes up the Internet can be compared to a road network. Just as one does not build a road from every single conceivable origin to every conceivable destination, but rather builds lots of small roads which feed into a series of networks of progressively fewer but larger roads joined at junctions, so too with the Internet. In terms of tangibles, the Internet is made up of a series of routers
(junctions) connected to each other by data pipes or bandwidth (roads).

An Internet ‘journey’ – i.e. data travelling from one computer to another over the Internet – will pass through several routers or junctions. Just to give an order of magnitude for the number of hops, to get from the authors’ network in London to the European Commission’s Cordis website in Luxembourg requires around 19 hops (i.e. travels through 19 routers), and the data travels via Virginia in the United States. To get to the site of an ISP in Zambia takes 14 hops (again crossing the Atlantic twice), and to get to Toyota’s site in Japan takes about 17.7

There is no a priori reason why any particular number of routers is optimal, either in toto or for a particular journey. As with any similar network, there is a trade-off between the number of junctions, the complexity and congestion of each of the junctions, and the time taken to travel to the junctions.

However, to add to the complexity of the Internet, the data pipes and routers are not communal; companies own them. In the case of data pipes, the owners are typically either telcos or Internet service providers (ISPs). Routers are more complex. They can be roughly divided into internal and external – internal routers send data around the ISP’s network, and external routers share data with other networks. The former – internal routers – are owned by ISPs, and together with their data pipes form the ISP’s network.

There are many terms for external routers, and they are often used interchangeably – NAP (Network Access Point), IXP (Internet Exchange Point) and sometimes MAE (Metropolitan Area Ethernet). As there do not seem to be standard definitions for these terms, we will use the acronym NAP to mean any point where two or more ISP networks exchange traffic. There is a range of arrangements that the term covers, from a point where two bandwidth owners swap data with each other – typically using private peering – to ‘public’ NAPs where a large number of ISPs meet. A good example of the latter would be LINX (London Internet Exchange), where some 100 ISPs peer; though not all peer with each other.9 The ownership structure and business model varies from NAP to NAP.

The figures below show some examples of networks owned by national, European ISPs. Figure 3, for example, shows the major nodes of Oléane’s domestic network in France; Figure 4 shows FORTHnet’s network in Greece and Figure 5 shows nodes and principal links for Xlink in Germany.
A popular misconception is that all data can use the whole Internet: any data flowing from Cologne to London, for example, will follow the same route. This is not the case, due to the non-communal ownership of the Internet data-pipes and routers. An ISP needs to agree a deal with another ISP before using its data-pipes, even if both are members of the same NAP. If one thinks of the Internet as a road system, not all traffic may use all the roads or even all the junctions, as not all ISPs have reached data-exchange deals with all others, or even have bandwidth to the same routers as all other ISPs. The source and the destination ISPs, and the structure of the deals between these ISPs and any intermediary ISPs will determine the spectrum of possible routes that the data can take.

This can have apparently perverse results. For example, if two individuals in Marseilles are video-conferencing over the Internet, the data may well be travelling through Paris, if this is the nearest spot where their respective ISPs share a NAP. In the above examples of data travelling between London and Luxembourg, and between London and Zambia, the journey was via the States, which was the location of a NAP where ISPs exchanged data. More subtly, if the two ISPs do not have a traffic-sharing arrangement, the data may have to travel through the networks of one or more other ISPs in order to reach its destination.

For example, the journey from the authors’ network in London to the European Commission’s Cordis website in Luxembourg starts off with the authors’ ISP in the UK, U-Net. The data is then transferred to AboveNet’s network in the States, before being routed back to LINX in London, where it is transferred to the European Users Group Network through the Netherlands to Luxembourg, where it is transferred to Intrasoft International, who host the Cordis website.

The journey from the authors’ network to Toyota’s website in Japan again starts with U-Net in London, before being handed off to AboveNet in the USA, which takes the data as far as Palo Alto in California. The data is then transferred to IIJ’s network, which transfers the data to Japan, before handing it off to Toyota’s network.

The task of deciding which route the data takes across the Internet is a very complex one. The routers – or junctions in the network – act as combined traffic lights and traffic police. When data reaches them, they examine the destination of the data, and decide which is the most appropriate next router to which the data should be sent. This depends on their routing tables – which are ‘programmed in’ and report which ISPs talk to which, i.e. have peering or transit arrangements with each other. It also depends on which routers are deemed to be ‘available’ – i.e. functioning. Routers communicate with each other, over the Internet bandwidth, and tell each other about routers that they have had difficulties communicating with, thus keeping other routers up-to-date about which routers are having technical difficulties and should be avoided. The role of the router is therefore complicated but key to the efficient operation of the Internet.

### 3.2.2 How does the route taken by the data affect the user?

Of primary interest, in terms of quality of service, is not the route taken by the data – which is broadly transparent to the user –
but rather how this affects the speed and reliability of the data transfer process. There are some key terms when measuring overall Internet performance – latency, jitter and reliability (see box).

**Latency, jitter and reliability**

If you ‘ping’ an Internet host (i.e. measure the duration of a round-trip for a small amount of data – a packet – to another computer):

- **latency** refers to how long the trip takes

- **jitter** refers to how much the latency varies, generally between specific source and destination computers

- **reliability** refers to how often the data makes it back – it is the converse of ‘packet loss’, which measures how many packets sent out get lost. Packets are deemed to be lost once they have passed through a certain number of routers – typically 255 – without reaching their destination.

Latency – the time taken for data to travel across the Internet – can be broken down into three constituent parts:

- the time taken for the first bit of data to travel down the data pipes from source to destination;
- the time taken for the whole of the message to arrive; and
- the time spent at routers (i.e. queuing at the junctions of the Internet).

These times cannot be measured accurately, but they can be estimated.

On a particular day in March, the quickest ‘ping’ speed between the authors’ network in London and TF1’s website in France – taking a geographically direct route, with no detours across the Atlantic – was about 20ms for a round trip. The same trip would take light about 2ms, so we can estimate the time taken for the first bit of data to make the journey to be about 2ms. The size of the data packet was 32 bytes, and travelled down 11 data pipes. If we assume (conservatively) that each data pipe was only a T1, then the time taken for the entire message to make the journey would be about 2ms as well. This would make the time spent at routers about 16ms, or about 80% of the time taken. Even if our estimates of the time not spent at routers were doubled, to be more conservative and allow for some congestion on the data pipes, then the time spent at routers would still be around 60% of the journey time.

If we consider again the journey between the authors’ network and the Cordis website in Luxembourg, the typical ‘ping’ speed is about 300ms. To travel from London to Virginia and back is about 7,400 miles, so doing it twice will be about 14,800 miles. This will take light about 80ms, or about 25% of the journey time. Because of the very high speeds at which data travels down data-pipes, the fact that the journey can seem full of detours is not particularly significant to the latency.

Jitter and reliability are more difficult to generalise about. Other things being equal – which they rarely are – it seems common-sensical that the more hops data makes, the more chances there are for delays and outages to occur. Clearly, this is not a hard and fast rule, as a two-hop journey may be subject to all sorts of problems if the bandwidths to the intermediary router are congested or if the router is not performing. Equally, a 20-hop journey may be very reliable and suffer from little jitter if all the bandwidths and routers used are operating below capacity and are well maintained.

So how do latency, jitter and reliability manifest themselves to the user? We will consider three sample web-based activities: downloading, video-conferencing and email.

**Downloading**

A sizeable download, one taking 10 minutes, for example, is not going to be oversensitive to latency, which is effectively a ‘one-off’ increment to the download time. The difference between latencies of 100ms and 1,000ms in a ten-minute download is
about 0.0015% of the download time. The 40ms taken to travel across the Atlantic and back would be about 0.01% of the same download.

### Adaptive transmission rates

A server transmitting data over the Internet – e.g. when someone downloads a file from it – splits the data into chunks, or packets, which are sent out separately. Typically, not all the packets are despatched at once. The server will dynamically adapt the rate at which it sends out data, depending on the rate at which it receives acknowledgements for packets already sent (or ACKs) from the recipient of data. The ultimate goal of this adaptive rate of transmission is to send new packets out over the Internet at the same rate as the receiver downloads them.

High levels of jitter can cause the server to make very conservative estimates of the speed at which the recipient can download the data, leading to non-efficient use of the network.

Equally, jitter may not be a large problem – the file being downloaded is cut up into small ‘packets’ of data, which are sent individually. With moderate levels of jitter, the packets may be received in a different order than they were despatched, but they are simply reassembled into the correct order by the destination computer. This process is transparent to the user and has no effect on the download, which is not deemed complete until the final packet has been received. See, though, the box on ‘adaptive transmission rates’ for details of how high levels of jitter could be problematic.

Reliability could be a significant factor. If packets are lost, they need to be resent. Typically, packets are lost on busy stretches of bandwidth, and download speed may be unaffected if the congestion is sufficiently upstream that even the resent packets are arriving quicker than the source computer can download them. However, congestion can be a vicious cycle – packet loss tends to occur on congested bandwidth, requiring packet resends, and hence more congestion. Reliability could therefore affect download speed considerably.

#### Video-conferencing

Video-conferencing, on the other hand, has different characteristics. Latency is key – the difference between 100ms and 1,000ms is noticeable if you are waiting for someone to reply to a question you have asked. Equally, jitter will cause jerky pictures or muffled sound, as to interpret video and audio, one pretty much needs the data in the right order. Reliability, on the other hand, could be less of a problem. If you receive 99% of the packets quickly and in the right order, and 1% simply never make it, one probably has enough data to reconstruct useable video and audio streams.

#### Email

For email, there is typically a three-step journey – the sender uploads the message to their ISP’s mail-server, which then routes the message to the recipient’s ISP’s mail-server, and the recipient then downloads it from their ISP’s mail-server. Each journey will have separate latency, jitter and reliability statistics associated with it. However, general norms of service render most of these measures trivial given the comparatively small size of email messages. The communication that the users pay for is with a computer on their ISP’s network, and therefore not many router hops away from their own computer, and generally lower latency, jitter and packet loss.

### 3.2.3 Causes of delay on the Internet

So what are the current causes of delays on the Internet? It seems unlikely that bandwidth is the major cause of delays. In many articles, Andrew Odlyzko at AT&T argues that bandwidth utilisation is low – using a combination of several empirical sources – and that this may actually be economically optimal. He produces estimates of bandwidth utilisation of around 10-15% for Internet backbones. This does, of course, mask a lot of variation but suggests that de-
lays are generally not caused by a lack of bandwidth.

An unpublished study\textsuperscript{15} carried out in 1997 examined whether or not popular servers were reachable. For those that were reachable, the causes of delays in accessing them are cited below in Figure 6.

\begin{itemize}
  \item 45% of the delays were caused by server outages, i.e. the computer one was trying to communicate with was too busy to send information over the Internet in a timely fashion.
  \item 42% of the delays were caused by network transmission errors – possibly due to router congestion or bandwidth congestion – unfortunately the report is unpublished, so it is difficult to be sure.
  \item 13% of the delays were caused by DNS problems – i.e. a failure to convert the name of the website into a network address. This is most likely the ISP’s DNS servers being either down or busy.
\end{itemize}

These findings, albeit unpublished and possibly out of date, reinforce the point that some delays are outside the control of the ISP – server outages, for example. However, problems with DNS servers are within the ISP’s purview, and network transmission problems, as well as the relatively high figure for server unavailability (20%) may be due to poor upstream connectivity on the part of the ISP.

### 3.3. The cost of accessing the Internet

It is possible to get very fast and very reliable Internet access if you are willing to pay for it - the jump in price from dial-up PSTN to ISDN or xDSL reflects the big improvements in speed and reliability that are associated with these types of connections. For most consumers and small businesses, though, cost is a high priority.

Broadband technologies are not equally available throughout Europe, and pricing regimes have not yet settled down. To give an idea of the magnitudes in pricing broadband, in the UK, ISDN access at 128kbps is available for around £100 a month. A 2Mbps ADSL line is available from around £200 a month – though this offers a permanent connection.

The trade-off between speed and cost is most clear-cut for consumers, as they can compare the cost of finding information or entertainment online with the cost of getting it from other sources. For business, the decision is more complicated, as it may be difficult to estimate the increase in efficiency or customer reach that an Internet strategy might bring. But for either group, cost is undeniably important.

Studies suggest that many home-users in Europe are put off using the Internet by the amount that it costs. This is demonstrated by the differences in usage between Europe and the US. In the US, the average time spent online each day is 55 minutes, compared to users in Europe who spend 17 minutes a day online on average.\textsuperscript{16} Only one quarter of European Internet users are online for more than half an hour each day. Another survey of Internet use in Europe re-
vealed that Europeans tend to be more focused in their web-surfing than American users, visiting certain sites of interest rather than surfing indiscriminately.

The explanation for these different Internet habits is almost certainly the pricing structure. At the moment, most home users connect to the Internet through a dial-up PSTN connection. For a dial-up customer, connecting to the Internet means paying per minute for a local call on top of the ISP’s subscription (although BT have recently introduced “Surftime” a fixed price access charge). In the US, on the other hand, most telephone companies charge for local calls at a flat rate. Figure 7 suggests at least a partial link between call charges and Internet penetration.

At the moment there are a number of pricing structures that are available for Internet access, although not all of these are available across the continent. For the consumer, the variety is an advantage, as it makes it more likely that they will be able to find a pricing plan that suits their patterns of Internet use.

One pricing model is the free subscription model introduced in the UK by Freeserve and now being introduced in other European countries and in the US and targeted to residential PSTN customers. In this model, the user pays for the phone calls but pays no subscription charge to the ISP. Obviously, this reduces the costs to users, and the increase in Internet take-up in Europe is associated with the number of ISPs offering this price model.

Experiences in France, Italy and Belgium testify to the surge in Internet use after the introduction of this business model. In France, one million new subscribers joined the members of the national ISP association between October 1999 when free subscriptions became available, and January 2000.17

The same phenomenon occurred in Belgium where the introduction of free connections added 328,000 new subscribers in the autumn of 199918 and in Italy where Internet subscribers rose by 4 million between July and December 1999, of whom 2 million joined Telecom Italia after it started its free service in September.

The ISP is able to offer access with no subscription fee because of the structure of payments between telcos. The charge for the call is shared between the originator of the call – in this case the voice telephony provider – and the terminator of the call, in this case the ISP (or another telco, which has a contractual agreement with the ISP). The payments that are made to the ISP by the telcos are known as ‘ingress’ and it is these that provide the ISP’s revenue.
This is not an easy arrangement for the ISP to sustain, and in some cases it may be thought of as a temporary scheme to attract subscribers. Many ISPs operate in highly competitive environments with slim profit margins and relying on ingress can be a risky but necessary strategy. It is especially difficult to sustain in countries where telecoms liberalisation was concurrent with, or just preceded, the explosion in Internet use. In many of these countries, the dominant ex-monopoly telco was able to take advantage of its market position to become the dominant ISP. Their reach and infrastructure allows the telco to provide a free service more profitably than ISP competitors and to charge other ISPs rates for leased lines and network access that make the free subscription model unprofitable.

The introduction of flat-rate Internet access pricing models undermines the economic logic of the ingress model. ISPs are therefore trying to diversify their revenue sources. They are looking to commissions on e-commerce transactions conducted through their sites and to advertising as future sources of revenue.

Another model that has recently been introduced is the flat-rate connection fee. This has been the predominant model in the US. In the UK, some ISPs are offering what amounts to a ‘free-free’ model, in which the user pays a one-off connection charge and makes no, or minimal, further payments. ISPs are trying to restrict this service to home users and have introduced conditions to discourage business use such as only allowing flat rate access in the evenings or at weekends, 10 minute time-outs (automatic disconnection after 10 minutes of inactivity) and compulsory session termination after two hours.

In the US, subscription-free broadband access has recently been introduced by the BDG (broadband digital group) in California. It offers ADSL service at 144kbps. The user has a bar across the bottom of their browser that displays targeted advertising and the company collects data on the user’s Internet habits for marketing purposes. The business model depends on the amount of money that they can make from advertisers and marketing companies and may not turn out to be sustainable.

Earlier pricing structures with subscription fees and call charges may not disappear entirely. People who only want to use the Internet for short periods of time may find that the flat-rate structure is not advantageous to them and the costs of supplying broadband access means that consumers will almost certainly have to continue to pay for the higher QoS levels.

As the Internet becomes more and more central to personal and business life, the demand for broadband is certain to grow. Unfortunately, it is not just a matter of being willing to pay for the higher level of service as the roll-out of broadband has been slow in many places, and it may be months or years before these high speed services become available to businesses across the whole of Europe.

3.4. Can Quality of Service be guaranteed and does it matter?

The primary function of the Internet is to allow computers to communicate with each other. By definition, communication involves two or more parties. It remains difficult, therefore, for any single player to unilaterally determine the speed of communication with all other parties. The most any individual – or any ISP – can achieve is obtaining dedicated bandwidth to a particular router or series of routers. The speed at which data is communicated will also depend upon the congestion at the router, the bandwidth of the other party to the communication to the router and also the speed at which the other party can send data down their bandwidth to their router.
Guaranteeing a certain data communication speed with, say, AltaVista would require dedicated bandwidth between oneself and AltaVista. Guaranteeing a certain data communication speed with everyone on the Internet would require dedicated bandwidth between oneself and everybody else on the Internet. This would not only be totally impractical; it would also obviate the economies achieved by bundling people's varying bandwidth requirements.

There are compromises possible between the two extremes of dedicated bandwidth between two particular computers or networks, and the global but non-guaranteed nature of the Internet. One example of this would be the service offered by Anx. This is, in effect, a private network which guarantees quality of service between members of the network. This is not the same thing as the Internet – in fact their website states that “The public Internet and ANX service are completely separate and distinct entities.” However, it demonstrates neatly the point that there is a trade-off between guaranteed QoS and the universality of the Internet, and that points in the middle of the spectrum are possible and achievable. However, given the desire for a ‘global’, or ‘public’, Internet the possibility for completely guaranteed QoS is non-existent.

It is initially disconcerting to know that there cannot be guaranteed levels of data communication speed over the Internet – it would appear to limit its use for business-critical applications, and reduce the scope for ISPs to differentiate themselves. However, this is not the case.

The lack of guaranteed service does not necessarily render the Internet unusable for business-critical purposes. Of course, total guarantees of service do not exist with any technology; in practice, businesses will use a technology provided it is cost-effective to do so – where there is a high risk that a technology will fail, they will adopt a back-up technology.

Consider the telephone system, for example. Businesses have a reasonable expectation that the telephone system will operate round the clock, every day of the week. Indeed, for many businesses, the telephone could be defined as a business-critical technology. And yet, failures do occur. On 25 February 2000, network outages hit the UK telephone system meaning that local-rate numbers, used by call-centres, ISPs and the like, were unobtainable for many customers for much of the day. Electricity is another example. For most businesses, some business-critical applications will be dependent on electricity. And yet, power cuts do occur – the level of service is not guaranteed. Businesses can develop strategies such as keeping diesel generators for key systems or investing in ‘uninterruptible’ power supplies for computers.

Differentiation is also possible in the absence of guaranteed QoS. Consider, for example, airline travel. On most flights there are two or three distinct service levels, with very different fare structures. However, there can be no guarantee that one service level will be superior to another. Travel first class, and there may be a crying baby sitting behind you. Travel economy and it may be empty, allowing you to stretch out over four seats and get a full night’s sleep. The airline cannot explicitly guarantee QoS. Instead, passengers pay for the reasonable expectation that the QoS will be higher in first class, as indeed it is most of the time.

The same is true of most good or services consumed. Holidaymakers will pay a premium to go to a generally sunnier destination in the reasonable expectation that it will be sunny, but it may not be while they are on holiday. People will pay a premium to send mail first class, where it is available, in the reasonable expectation that it will arrive sooner than second class mail, but this is not guaranteed.

So the lack of absolute guarantees does not necessarily prevent a market for differentiated service levels – they have merely to be sufficiently separate that customers can form reasonable expectations of the different service levels, and be willing to pay a premium for a higher expectation of service.
PART II - QoS PARAMETERS
4. Background to the Parameters

4.1. Developing QoS Parameters

Useful parameters must have certain qualities. Their purpose is to allow the user to make an informed decision of how to connect to the Internet. To make this possible, the selected parameters must be:

- **Relevant.** In section 2.3 above, we established that Internet needs can be summed up as speed and reliability balanced against cost. A parameter is only useful, therefore, in so far as it reflects the actual experience of the end user in these respects. The relevance of any upstream measure will need to be justified in its relation to the end-user's experience.

- **Comprehensible.** Home and SME Internet users are faced with a gulf between their vocabulary and experience and that of the ISPs. The meaning of the parameter and the method of the calculation must be clear enough to the user that they can define and defend their QoS needs.

- **Quantifiable.** While anecdotal evidence or opinion can be useful in taking a decision, it is not a systematic way to compare the level of service, and so the parameter should preferably be expressible as a number to assist comparison. Of course, not every aspect of QoS can be boiled down to a number, and some important considerations could be lost were this criterion to be applied too strictly.

- **Measurable.** If a parameter cannot be reliably and accurately measured for a technical reason then it is not going to be possible to use it for fair comparisons between ISPs or technologies. The measurement process itself should not affect the performance of the system or the values generated, and the technique should preferably be auditable, i.e. verifiable by an independent actor, even if the ISP normally makes the measurements. One of our interview respondents noted that many exaggerated claims for reliability were currently being made by networks which were simply unverifiable.

- **Comparable,** in the sense of being applicable to different technologies. If the user is trying to decide between a low-cost/low-service scenario and a high-cost/high-service scenario, then they must have some parameters that can be applied to all possible technologies on which to base their decision.

- **Revealing.** While a general parameter measuring speed, for example, has clear relevance for the end user, it does not help to identify the area in which the problem is occurring and thus whose area of responsibility it falls in.

- **Available.** Finally, the parameters must be available in the public domain to be useful. This does not necessarily affect the choice and design of the parameters, but will affect their usefulness. We discuss how they may be made available after our exposition of the parameters themselves.

The discussions above have shown that the needs of the user are multifarious and the complex organic nature of the Internet is such that it is necessary to identify a range of parameters for QoS. The actual experience of using the Internet and the level of satisfaction that the user experiences is not a measurable commodity, nor would it be possible to use such a measure as the basis for a QoS agreement between the user and their ISP. Instead, a package of technical measurements may be used which together...
build into a picture of the user’s QoS experience.

Trying to limit the number of parameters may be counter-productive as it gives the ISP an incentive to focus on a particular measure, perhaps at the expense of general QoS. There will also be trade-offs between certain measures – for example between cost and reliability of service.

Against these considerations the following section will consider various parameters for QoS, seeking to identify a set of measures that may most usefully form the basis for judging the performance of the ISP from the point of view of the consumer or SME.

4.2. Choice and development of parameters

Based on our discussion above, we have identified five broad areas of QoS which the parameters should measure. These are:

- Ability to connect, that is how quick and easy it is to connect to the ISP;
- Downstream connectivity, that is how quick and reliable the connection between the user and their ISP is;
- Upstream connectivity, that is how quick and reliable the connection between their ISP and the rest of the Internet is;
- Cost, that is the cost of Internet connectivity and presence; and
- Others, that is a selection of other criteria on which the individual or SMEs experience of the Internet can be judged.

Within each of these broad headings, we developed some initial parameters to try to capture important and measurable aspects of the users’ experience.

We then discussed these parameters with a selection of key industry players – ISPs, NAPs and telcos. As part of this process, our list of parameters was somewhat revised, but we also gained some depth in our insights as to what these parameters measured, how they could be refined, and what various values meant for the user’s experience. Appendices 1 and 2 present some more detail, as well as a list of the people interviewed.

For the sake of clarity of exposition, we will only present here the final set of parameters, as well as some discussion of what they mean and how they could be measured.

Finally, it is important to remember that not every parameter will be relevant to every user – the final chapter in this section will revisit our sample users described in Chapter 2, and consider which parameters will be important for which users. It will also discuss how the parameters could be measured and how they could be used as a basis for various comparisons.
5. Ability to connect

The first step in using the Internet is – by definition – connecting to the Internet. As discussed above, there is a wide variety of means of doing this and even within the same technology – such as using a modem for a dial-up connection – there are a number of different types of ISPs with whom one can connect. These include ISPs who charge a subscription fee, those who rely on splitting the cost of the phone call with the telco in order to derive a revenue stream, and those who rely on advertising and do not charge the user for Internet access at all. These different business models for ISPs may well offer different levels of QoS to their customers.

In addition to the main parameters below, the ease of setting up an account with the ISP could be considered. This includes such factors as how quickly the software to subscribe arrived, if it was possible to sign up online, if installing the software was trouble-free and if support was available. Since these factors are difficult to measure objectively and are likely to constitute a ‘one-off’ experience they have not been included as general measures of quality of service. The ease with which the user can switch between ISPs is also not explicitly considered for the same reason.

The parameters described below are designed to be reasonably comprehensive – not every parameter will be relevant to every user and to every technology. The most striking example of this is the development of new ‘always on’ technologies such as xDSL and cable modems, where the achieving of a connection is rendered almost irrelevant, though connection interruption may remain a problem.

Parameter 1: Number of attempts required to achieve connection

Definition
The average of and variation in the number of attempts the user has to make before successfully connecting to the ISP.

Discussion
Ideally, connection would be achieved first time, every time, so both the average and the variation should be low.

Dial-up customers who consistently find they receive two or three ‘busy’ signals are likely to become frustrated with the service, blame the ISP for the problem and ultimately switch providers.

In fact the responsibility for the busy signal may not lie with the ISP and actually be caused by congestion on the telephone exchange into which the user is dialling, or some other telephone network problem, such as ‘flaky’ lines or connections. Andrew Bonar, founder of Surflondon, and Ian Robertson from Fastnet International both suggest that this is more often than not the case. We would note, though, that where an ISP has contracted with a telco to provide free or local-call rate numbers and the telco is not able to meet the resulting network requirements, this is, in a sense, the responsibility of the ISP.

To appreciate the likelihood of a dial-up customer getting a busy signal due to the ISP having a large number of users online, considering the modem contention ratio is useful. This is the ratio of subscribers to ports (modems). In general the higher this figure is, the harder it will be to connect first time (you can only have as many customers online as you have modem ports available). A contention ratio of roughly 8:1 or lower is considered good.22

- 22 -
The measure is however, at best, a guide. Potential problems with the measure lie in the fact that while an ISP may have an attractive sounding contention ratio, its users may nonetheless have difficulty connecting first time. Conversely, the customers of an ISP with a relatively poor sounding contention ratio, say 30:1, may be able to connect first time more often. This must be understood within the context of the distinction between ‘user’ and ‘subscriber’ as well as a consideration of the call tariff structure for the particular ISP.

Consider two ISPs, one of which has a toll-free access number and one without. While they may have the same contention ratio, it is likely that the customer of the free call ISP would be less likely to connect on the first attempt, as at any given time more of the free call ISP subscribers are probably going to be users (i.e. actually online) as they will tend to connect more often and spend more time online per connection.

Thus, the contention ratio needs to be considered in the light of the subscribers’ actual Internet usage. The measure is less relevant for large ISPs (i.e. those with 500,000 or more subscribers) as their users’ aggregated behaviour becomes more predictable. Steve Rawlinson of ClaraNet argues that instead of focussing on maintaining an attractive sounding contention ratio, ISPs should instead ensure they have enough modems to cater for their peak concurrent usage.

While being unable to connect first time every time may simply be an inconvenience for an individual wanting to check email, or view sports results, for the business user who may need to connect to the Internet urgently, this problem could prove costly.

This parameter is largely irrelevant to users with ‘always on’ connections, such as xDSL or a permanent ISDN connection, as they will always have a connection to their ISP.

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**Parameter 2: Time to connect.**

**Definition:**
The average of and variation in the time taken for the user to establish a connection with the ISP server.

**Discussion**
This measures the time from when the user’s computer dials the ISPs server until getting logged on. It includes the time taken by unsuccessful dial up attempts and the time taken to log on - the time the modems take to negotiate with each other, and for the ISP to verify the user name and password. In practice, this parameter is affected by the termination hardware used by the ISP, the speed of connection and the quality of the phone line.

As well as the factors described above, which may mean that several attempts are taken to connect, the time will vary according to the compatibility of the user and ISP modems. This time taken for the hardware to negotiate decreases with the widespread adoption of successive standards for modems (currently the V90 standard). Since no two modems are ever perfectly compatible, to be generally applicable, this parameter would need to be tested using several different devices at several different connection speeds.

This parameter is largely irrelevant to users with ‘always on’ connections.
Parameter 3: Time to connect during the busiest hour of the week.

Definition:
The average of and variation in the time taken to establish a connection and log on to the ISP server during their busiest hour (i.e. that when the most users are online).

Discussion
This measures the time from when the user’s computer dials the ISPs server until getting logged on during the ISPs busiest hour of the week. Ian Robertson of Fastnet commented that the latter stage shouldn’t be any different irrespective of how busy the ISP was.

Since by definition this is when most users will be trying to log on it is an important measure. For business ISPs it is likely to be the start of business hours on weekdays while for home-user-based ISPs it may be weekday evenings and weekends.

This parameter may be more important for SMEs – who may need to connect at specific times during the week in order to conduct business – than for individuals who browse the Internet for recreational purposes and may object less to there being busy periods during which it is more difficult to get online.

This is a very difficult parameter to measure as it is impossible for an outsider to know the busiest hour of the ISP.

Once again, this parameter will be largely irrelevant for those with an ‘always-on’ connection.

Parameter 4: Frequency of connection termination.

Definition
Number of times per month the user’s connection is terminated for reasons other than their choosing to disconnect.

Discussion
For dial-up connections, connection termination, or line drops, will occur due to defects in the telephone system in the vast majority of cases, according to the ISPs we interviewed. The reasons may also lie in the user’s PC trying to multitask beyond its capability causing it to become overloaded and simply give up on the connection, or due to line interference resulting from another person trying to use the same line, or due to certain Intelligent Network (IN) features, such as call waiting.

There tends to be a consensus amongst ISP staff interviewed that connection termination is generally not ISP-based but caused by a ‘user error’ such as a problem with their hardware or a problem arising from the telco. However, if a user is able to connect to a different ISP without such termination problems, it is reasonable for them to conclude the problem was down to the ISP, or at least associated with the ISP’s particular set-up.

While they may not be willing to admit it publicly to their customers or potential customers, it is highly likely that some network managers disconnect so-called ‘hogs’ –
people who leave their connection idle for long periods.

Also it is known that upgrading or maintenance of terminating hardware necessitates disconnections. There have also been cases where immature software on the modems has caused many user disconnections.

In the case of users with an ‘always on’ connection, termination may be caused by problems with the telecommunications infrastructure – such as a workman cutting through a cable accidentally, or a hardware fault either with the user or the ISP.

In practice it is extremely difficult to identify the reason for connection termination, and this parameter may identify ISPs with more problems than others but may not be able to help in identifying the source of the problem.

In addition to being inconvenient, and requiring reconnection, termination can frustrate the user’s e-commerce experiences in particular. It is particularly disconcerting to lose connection while an online financial transaction is being processed. This results in uncertainty as to whether orders were successfully placed. Connection termination is more of a problem for those users for whom a continuous connection is particularly important for their online activities. Amongst personal users this would be the case for online gaming enthusiasts and for people accessing real-time streaming media such as news bulletins.

Parameter 5: Frequency and duration of ISP ‘outages’.

**Definition**

Occurrence and duration of ISP server being unobtainable.

**Discussion**

This is a situation in which the ISP server is unavailable or unobtainable. Software or hardware bugs, server upgrades taking place, a loss of power supply or other technical problems with the server, can cause this. During these generally brief periods the ISP is in effect ‘off-air’.

Ian Robertson, Manager of Fastnet International, commented that ‘outages’ should only occur due to power failure, and that ISPs ought to have back-up or alternative power supplies available to get their service running as quickly as possible. It was suggested to us that it is good practice for the ISP to inform their customers of forthcoming server maintenance resulting in temporary unavailability. Outages can also occur if the backbone provider is undertaking maintenance.

We note, though, that in the authors’ experience, ISP outages occur for many reasons other than power outages, such as a small ISP losing its link to the bigger ISP that they use for their connection to the backbone.

In order to test this parameter comprehensively, one would need to test the HTTP, FTP and mail servers separately to get an accurate reflection of the situation.
6. Downstream connectivity

Once connected to the ISP, an important element of the user’s QoS is the speed of communication with the ISP itself as the ISP is the focal point through which all communication with other computers connected to the Internet will occur.

This section will discuss some parameters which can be used to measure the speed of the connection between the user and the ISP. Again, not all the parameters will be as important to every user – each parameter will need to be judged for its relevance to each particular situation.

One subtlety which emerged during our interviews was that most interest is currently being paid to download speeds – how quickly users can retrieve information from the Internet – rather than to upload speeds – how quickly users can send information to other computers on the Internet. At present, upload speeds have very little impact on the majority of users’ experience. For most of the time, users’ uploads will consist primarily of email, inputting data such as text on a form, and mouse actions such as clicking icons and links. Since these actions for the most part require very little bandwidth, upload speed is not really a significant factor when considering the Internet experience for most users. In the near future, however, upload speed may become a far more significant factor. Although email doesn’t require high upload speeds, video conferencing, video mail, unified messaging some e-business applications, online gaming and uploading MP3 files do.

We raise this point as upload and download speeds are often asymmetric – we were told that the maximum upload speed of standard twin copper wires remains at 33.6kbps, even for the now standard 56kbps modems. ADSL is another example of a technology where the upload speed is a mere fraction of the download speeds achievable.

Inevitably, these measures will capture – as with the previous section on the ability to connect – an element of the QoS provided by the telecommunications infrastructure. Many of the ISPs we talked to emphasised problems with this infrastructure, and were keen that not all ‘blame’ be attached to the ISP. We would stress again that these measures are meant to be merely passive – they may reveal particular problems without necessarily revealing the precise cause of the problem. This, we feel, is entirely appropriate, as it is unrealistic to expect users to develop sufficient technical expertise to be able to pinpoint exactly particularly troublesome features of their Internet connection – the vast majority will only be interested in ‘headline’ performance figures, which is what our parameters try to capture.

We would emphasise that while there may be a general assumption that the user’s speed of connection to the ISP determines the speed with which the user can browse the Internet, this is not strictly true. The measure looks only at the rate of download downstream of the ISP. As such it ignores the quality of the ISP’s (upstream) backbone connection. This measures the ISP’s connectivity to the rest of the Internet and is consequently extremely important when considering the speed at which the user can browse the Internet. The downstream speed of connection will by itself determine how fast sites either stored in the ISP’s cache or hosted on their server may be accessed. One ISP commented that the actual connection speed bears surprisingly little relation to how fast the user’s browsing experience is while conceding that at present people do tend to attach a lot of importance to the headline number of the speed of connection to the ISP, which appears on a user’s screen once they have connected. Considered in conjunction with the quality of an ISP’s upstream connectivity however, the speed of connection will have a major impact on the user’s experience.

We consider the quality of the ISP’s upstream connectivity in the next section.
Parameter 6: Theoretical maximum speed of connection.

**Definition**
Maximum possible data transfer rate, measured in kilobits per second (Kbps) or megabits per second (Mbps), between the ISP and the user.

**Discussion**
The most obvious limitation on the maximum speed of connection is the hardware being used.

In almost all cases, there is a single headline figure which determines this. A user dialling into their ISP where both sides have compatible 33.6kbps modems, for example, will have a maximum connection speed of 33.6kbps. With a two channel ISDN connection, the maximum speed is 128kbps. These maximums are, however, theoretical - in practice, lower speeds may be achieved and, in some limited cases, higher speeds may be achieved through the use of software compression.

The actual speed achieved is the subject of our next parameter.

Parameter 7: Connection speed achieved.

**Definition**
Average and standard deviation of data transfer rates actually achieved.

**Discussion**
As mentioned above, the theoretical maximum connection speed may not be achieved in practice.

We were told by one ISP that we spoke to that for dial-up connections, the most likely limiting factor lies with the capacity of the telephony infrastructure, in particular by the customer’s local loop telephone exchange. If an ISP supports the V.90 standard and users dialling in with this technology are unable to connect at speeds above, for example, 43kbps the reason almost certainly lies with the quality of the local loop. Older telephone exchanges simply cannot support the rates of data transfer now being demanded by Internet usage. ‘Maxing out’ the capacity of standard twin copper telephone wires leads to ‘flaky’ connections in which the connection is more likely to be lost.

For some newer connection technologies - such as xDSL or cable - the maximum connection speed is high but because of contention ratios further upstream, the ‘full’ connection speed may not always be available. This issue will arise, for example, with cable connections where bandwidth to a neighbourhood is shared between all users in that neighbourhood. In the case of xDSL, there are issues about how much ‘upstream’ bandwidth is shared between users – in the case of British Telecom in the UK, we were told that the ratio of upstream bandwidth to the number of users was 50:1. Although, therefore, the maximum achievable speed is high, the actual bandwidth delivered may be substantially lower. This phenomenon should be most reliably captured by our parameter 9 below.
We were told that it is virtually impossible to know in any individual case why somebody is connected at a certain speed.\textsuperscript{28} It may be possible, though, with a large number of data points to be able to use such data to assist in the diagnosis of problem areas.

**Parameter 8: Latency, jitter and packet loss statistics communicating with the ISP.**

**Definition**
Average and variation in latency, jitter and packet loss (as defined in Chapter 3) when communicating with ISP servers.

**Discussion**
All Internet traffic passes, by definition, through the ISP. When browsing, for example, or video-conferencing, data will pass through one or more routers belonging to the ISP before being passed on to the Internet 'proper' – or possibly a cache if browsing. When using email, the user's communication will probably be exclusively with their ISP's mail-server.\textsuperscript{29} Therefore, if there are systemic problems connecting with the ISP's routers or mail-servers, the user's Internet experience will suffer.

This parameter should be able to measure the reliability of the ISP's internal network, and should be tested for several points on the ISP's network. Suggestions include the ISP's mail-server, the first of the ISP's routers used,\textsuperscript{30} and the ISP's DNS servers.

It is true that latency, jitter and packet loss are by no means the only factors of interest when considering network performance (see Chapter 3 for more discussion of this point). It is also true that the results are not necessarily fully transparent – a point reinforced by some of our interviews. A particular computer or router, for example, may give a relatively low priority to responding to 'pings', artificially increasing the latency of that particular node. It may be, then, that latency statistics for individual nodes are relatively insignificant.

However, latency may well be interesting if competing connection technologies are considered. A key factor affecting latency for dial-up connections is the fact that, for non-digital telephone lines, the data are sent in analogue form. This means that the originating modem must first convert the data into analogue form before sending them. The recipient modem must then reconvert the analogue signal into a digital message. The time taken to perform these operations is increased further by the sometime practice by telcos of themselves reconverting the analogue signal received into a digital signal to be transmitted, before it is switched back to an analogue signal prior to its destination (where it will be again converted into a digital signal to be understood by the destination computer). This can add significantly to latency for PSTN dial-up connections when compared to, for example, ISDN connections.

Jitter and packet loss can be far more revealing than latency when considering the ISP's internal network. High levels of jitter suggest a busy internal network, which will adversely affect the user's Internet experience if they are using time-critical Internet applications such as on-line gaming or video-conferencing. High levels of packet loss may reveal, for example, reliability problems with the ISP's mail-server or its DNS servers, which will be highly detrimental to Internet usage. One of our interviewees said that packet loss in particular is critical to the service the customer's receive.
**Parameter 9: Speed of download from ISP’s server(s)**

**Definition**
Average and standard deviation of time to download files from websites hosted by the ISP.

**Discussion**
As discussed under the above parameter, measuring jitter, latency and packet loss can be indicative of overall performance as well as revealing of particular problems, but do not necessarily affect the user’s experience. This parameter therefore will measure the average and standard deviation of the time taken to download a standard-sized file (e.g. 1 megabyte) from a website hosted by the same ISP as used to connect to the Internet. This single parameter will provide a guide - together with the previous parameter – to the efficiency of the ISP’s internal network.

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**Parameter 10: Speed of download from ISP’s mail-server.**

**Definition**
Average and standard deviation of time to download files from the ISP’s mail-server.

**Discussion**
This parameter is similar to the previous one, except that it measures the time taken to download a standard-sized attachment (e.g. 1 megabyte) from the ISP’s mail-server. The purpose of this is to measure how long it takes to retrieve sizeable email messages. The time taken to achieve the download will include the time taken to re-try if the download is unsuccessful and will therefore include problems such as the mail-server going down during a download, or excessive packet loss causing the download to abort.
7. Upstream connectivity

This section considers the ISP’s connectivity to the Internet ‘proper’ – i.e. beyond the confines of the ISP’s internal network. This is clearly important for the end user since the vast majority of Internet activity will demand the retrieval of data from beyond their particular ISP’s network. It is, as discussed in the first part of this report, the Internet’s global reach that renders it useful – a world-wide web which is not worldwide has considerably less value.

The customer’s ISP has to retrieve the required data through the Internet before the individual user can access it. In terms of the overall Internet experience, the ‘better’ the ISP’s upstream links are, other things equal, the faster and more reliable the user’s Internet experience will be. This section aims to identify what exactly constitutes a better or worse upstream connection. This area is less straightforward than the downstream connection considered in the previous section where, for example you can be connected at 56k, 128k or greater depending on the user and ISP hardware. It initially appears logical to propose a corollary between this and the ISP bandwidth to a NAP – which, as was discussed earlier in the report, is a connection point between ISPs – but, as will be seen, many more factors need to be taken into consideration. The quality of the ISP’s upstream connection depends on an even larger number of variables, many of which are not explicitly under the control, or responsibility of, the ISP. However, the ISP is responsible for establishing these arrangements, most notably peering, and ultimately the subscriber won’t care why their connection is better or worse, merely that it is.

Steve Rawlinson from ClaraNet comments that: “Some ISPs have resorted to the excuse that a troubled route is off their network and therefore there is nothing they can do about the problem, and this has led people to the conclusion that it might be better to connect to an ISP with a large network so that they have less of an opportunity to use this excuse. The truth is that this excuse is completely bogus and it is the ISP’s responsibility to make sure they have diverse routing whether they achieve that by building a network of their own or using others makes no difference.”

It appears that in setting up NAPs, Europe has benefited and learned from the earlier US experience. We were told by a European NAP we spoke to that whereas some US NAPs, such as MAE West and MAE East are frequently congested, this is, in general, not the case in Europe where NAPs are by and large well-managed and non-congested. Walter Van Dijk commented that AMSIX has been better able to predict growth of Dutch Internet traffic by looking at the US experience. Denis Curran from Inex, an Irish NAP, commented that private peering is used a lot in the US because some of the public peering points are badly run and can be congested. Since the peering parties control private peering arrangements, they can ensure that links are of adequate capacity.

From the perspective of the end user’s Internet experience – though not necessarily for the end users themselves -- it is vital to consider not just how congested individual NAPs become, but how congested individual ISP bandwidth connections to the NAPs become. This is because latency tends to increase markedly when bandwidth utilisation exceeds 70%. It is irrelevant to know that an ISP has peering arrangements at a non-congested NAP if the ISP they subscribe to has a congested connection to the NAP.

The issue of ISPs’ upstream connectivity is very complex, and many factors can affect the actual quality of service which the end-user experiences. The parameters outlined below reflect a first rather than definitive attempt to try and measure the most tractable of these factors in a way which is not too technically complex for users to understand, and yet at the same time permits meaningful and objective measurement of the users quality of service.
Parameter 11: Ratio of ISPs’ bandwidth to product of number of customers able to achieve simultaneous connection and the maximum bandwidth of those connections.

Definition
The ratio of the ISP’s upstream bandwidth to the product of the number of users able to achieve simultaneous connection (in a simple scenario, the number of modems the ISP has) and the maximum bandwidth of those connections (in the same simple scenario, the speed of these modems).

Discussion
The intuition behind this parameter is reasonably simple – what happens if everyone tries to log on and download a huge file at the same time? Does the ISP have enough upstream capacity to handle this?

In practice, such a scenario is relatively unlikely - most people do not log on and use 100 per cent of the theoretical maximum of their bandwidth at the same time. However, such events can happen, and the ratio should at least show how often a user’s speed will be inhibited by a lack of upstream bandwidth.

The number of customers able to achieve simultaneous connection is determined by the number of ports the ISP has, and the maximum bandwidth of the connections is determined by the type of hardware used for the connections – if the ISP merely offers dial-up access, the calculation is merely the number of modems the ISP has multiplied by the speed of these modems (for example, 56kbps). A similar calculation can be made for other technologies, such as ISDN or xDSL.

However, our interviews suggested that it would be very difficult to obtain an accurate assessment of an ISP’s upstream bandwidth – this could be defined as any or all of: their link to the NAP; the bandwidth of their own network; and the bandwidth which their upstream provider has available.

We were told that upstream bandwidth needs to be measured using the bandwidth the ISP can utilise, which is dependent on their upstream contract provision, rather than the amount they physically have. These figures may differ since although an ISP may have a 2Mbps link to a NAP, their port connection at that NAP may be limited (in their service agreement with the NAP) to 1Mbps. This cannot be externally verified. This scenario can arise because the cost of NAP connection is relatively expensive compared with the cost of the actual cables.

Keith Mitchell of LINX suggested that this is a key measure of ISP Quality of Service, but that measuring it would be difficult.

There is an element of possible discrimination against larger ISPs in using this parameter, as with more users, the more predictable are traffic patterns and the less likely that all users will want to use their maximum bandwidth at any one time. This parameter may need some more detailed consideration before use.
**Parameter 12: Proportion of packets travelling through the ISP’s routers which are lost.**

**Definition**
The percentage of packets that the ISP sends which are unable to find their destination (are dropped).

**Discussion**
Individual packets of data queue at routers, waiting to be sent to their destination. If the bandwidth that the data is waiting to use is full the router queues the waiting packets. When this queue is full the router discards packets, and these become lost packets. In addition packets which cannot find their destination after a given number of router ‘hops’ are dropped.

Steve Rawlinson from ClaraNet suggested that packet loss on the ISP’s own network could be used as a proxy -- “any ISP with non negligible packet loss on its own network is going to [have] miserable connections.” He suggests that in general it is particular routes that cause problems. Others have suggested that anything above 5% is unacceptable.32

These statistics are available from Internet monitoring companies. For example, MIDS provide a service called Matrix Internet Quality in which latency, packet loss and reachability statistics are gathered for ISPs worldwide.

**Parameter 13: Proportion of designated sites connected to: (a) the ISP’s own backbone/backbone provider(s); (b) to the ISP through private peering arrangements; and (c) through public NAPs/IXPs.**

**Definition**
Proportion of designated sites (e.g. for a business its most demanded or business-critical websites - such as its suppliers’ websites, or websites used for research, and for indiscriminate users, this could be the top 50 visited websites)33 which are connected (a) to the ISP backbone/backbone provider, (b) via private peering and (c) via public NAPs.

**Discussion**
These data can be obtained from peering registries from the RIPE NCC document store.34 LINX also maintains a database of members’ peering details.

We were told that there shouldn’t be any difference for the end user according to the method of connection, whether it be (a), (b) or (c). An ISP with several well connected upstream providers and a very small network of its own will be better serving its users than an ISP with an enormous reach but clogged pipes.35

In practice, the user’s experience depends on such factors as the congestion of the peering partners’ networks, the quality of the backbone connected to, and the congestion of the NAPs peered at. As long as the ISP peers at non-congested NAPs and those
ISPs’ networks with which it has private arrangements are non-congested, this shouldn’t be an issue. There is no a priori reason why either method of connection should be preferable to another.

Denis Curran from INEX commented that if the NAP is well-managed, as most European NAPs are, a public peering point can be as good as a private peering. Private peering yields more control over the ISPs connections but is difficult to establish – large ISPs will generally only peer with other large ISPs in order that the volume of traffic between the ISPs is broadly symmetric - though we have heard it suggested that some larger ISPs are starting to offer private peering for a fee. These private arrangements are based on trust and are not advertised.36

Private peering is used a lot in the US as some of the public peering points are badly run and can be congested.

Assuming that the congestion of the routes taken by the data under the various scenarios – (a), (b), or (c) – is similar, the most likely difference between them will be the physical distance over which the data travels. As described previously, this, in itself, is unlikely to have a noticeable impact on the time taken for users to download data. The consensus among the ISPs and NAPs we interviewed was that this parameter will have little use in Europe.

Parameter 14: Proportion of time which designated sites are unreachable.

Definition
Proportion of time that designated sites (as defined under parameter 13) are unavailable.

Discussion
A website can be unavailable for many reasons. This can happen if a site has too many concurrent users, if the server on which the site is hosted is down, if power supply is terminated and for many other reasons. Although most of the reasons are beyond the control of the user’s ISP, instances of websites being unavailable will adversely affect the quality of service that users receive from the Internet. This can be relevant, for example, if comparing the quality of service received by users in different countries – if the top 50 websites in France are more prone to being unavailable than those in Germany, it could be argued that the Germans are receiving, in this particular regard, superior quality of service to the French.

Although many instances of unavailability are beyond the control of the ISP, there may be specific instances where there is a problem specific to an ISP – if for example, it has a private peering arrangement with the ISP hosting a specific website, but the peering occurs through a private IXP which is prone to power failure, this could cause a specific ISP to be able to offer less reliable connectivity to that specific website than another. In practice our interviews suggested that this was comparatively rare. However, we have maintained this parameter as even small differences between ISPs could affect users who want very reliable services considerably.
**Parameter 15: Latency, jitter and packet loss statistics for designated sites**

**Definition**
Average and variation of latency, jitter and packet loss statistics for the designated sites as defined under parameter 13.

**Discussion**
This parameter is similar to parameter 8, except that it measures latency, jitter and packet loss for the most commonly visited external sites.
As with parameter 8, this is quite a technical parameter that may not be particularly relevant to most users. In particular latency will not be of relevance to users who mostly browse the web or use email. However, it will be very relevant for users who wish to play games online or videoconference.
Jitter and packet loss statistics will be more relevant, even for users who just browse the web and download an occasional file. Both jitter and packet loss can adversely affect download, and indeed upload, speeds because of adaptive transmission rates (see Chapter 3). In practice, though, relatively small differences in these statistics will be unnoticeable to the user.

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**Parameter 16: Number of NAPs connected to and the bandwidth of the connections**

**Definition**
Number of NAPs at which the ISP peers and the bandwidth of the connections to these NAPs.

**Discussion**
Other things being equal, the more NAPs an ISP is present at and the more peering arrangements in place, the more likely it is that data will be carried more directly to the customer, reducing the likelihood of data travelling on a congested or troublesome route.
The more NAPs an ISP is connected to, the greater their redundancy (i.e. ‘spare’ capacity) and hence resilience to problems will be. If an ISP were present at only one NAP and there was a problem with that connection, they would lose all connectivity. This could happen, for example, if a workman puts a pneumatic drill through the data pipe connecting the ISP to the NAP. Greater redundancy (in this case, having direct connections to more than one NAP) also allows alternative routing arrangements in case of congestion at any one exchange.
However, it is also important that the ISP establishes peering arrangements at well-managed, and hence non-congested NAPs. One interviewee commented that while this was important in terms of allowing increased redundancy and diverse routing, the user’s experience ultimately depends on how well the ISP manages its internal network. This re-emphasises the point that none of these parameters should be considered in isolation.
We were also told that having relatively poor bandwidth to a large number of NAPs is an inferior solution to having high capacity robust connections to a small number of NAPs. Therefore, the number of NAPs connected to, the bandwidth of the connections and some consideration of the congestion of both the NAPs and the bandwidths should be taken into account. This is considered in the next parameter.

**Parameter 17: What are the bandwidth utilisation figures for the ISPs NAP connections and how congested are the NAPs at which the ISP peers?**

**Definition**
Average and standard deviation of bandwidth utilisation for ISPs' connections to its NAPs and the utilisation of the NAPs to which it connects.

**Discussion**
As discussed with regard to the above parameter, it is not just the number of NAPs with which an ISP peers which affects an ISP's connectivity to the rest of the Internet, but also how congested these links become. Over the course of our interviews, we were told that both the congestion of the link to the NAP and congestion at the NAP itself were important. Denis Curran, for example, commented that while INEX has never been congested, individual links to INEX do become congested. This is outside the control of INEX and under the control of the ISP.
8. Cost

At present the cost of Internet service provision seems to be the most visible area in which ISPs compete, and cost is often the easiest way for newcomers to compare various providers. With more familiar and easily defined products, such as clothes or a meal in a restaurant, consumers are better acquainted with the price/quality trade-offs that exist in these markets and are able to make sensible decisions about what they want to buy. In the field of Internet service provision, not only is the service relatively new, so that many consumers are still learning to judge the service they receive, but it is also complex and dependent on many different factors. This makes it very difficult to judge the quality of service one receives. It is at least partly due to this difficulty that the cheapest ISPs have the largest subscriber base.

It is however difficult to know exactly what is being paid for, and there are numerous costs which a complete newcomer to the Internet might not consider, such as domain name registration. Outlining the various cost parameters enables customers to know how various ISPs match their specific requirements and appreciate that the ISP that initially appears the cheapest may not prove to be so.

Considering dial-up Internet access, the introduction of ‘free’ ISPs has led to a change in the way ISPs hope to make profits. Initially, in the UK, this model worked by the ISP receiving a proportion of the call charges, known as ingress. As such, the service is not really free. The model allows ISPs to tap into the revenue stream generated for the telcos by Internet usage. The ISP charge is, however, invisible to the end user. The viability of this model clearly depends on the telecom pricing structure charging per unit of telephone call.

While this pricing structure has been prevalent in Europe, it is not so in the US or Australia. In the US users pay a monthly subscription fee, for which they receive unlimited Internet calls. In Australia, a local phone call costs 25¢ irrespective of duration. The ISPs are therefore unable to generate sufficient revenues by tapping into the call charges revenue to make the free model a viable option. Another factor of Australian Internet provision which provides an interesting counterpoint to the general European experience is the practice of charging customers per unit of data delivered. To recoup the costs of retrieving data internationally some Australian ISPs charge their customers according to the amount of data downloaded. Others set maximum limits on the number of megabytes which may be downloaded in a certain time period.

Our parameter regarding the cost of Internet access presumes that there is a time-based charge for being online rather than a traffic-based charge. This is because this is still the prevalent charging structure for European ISPs for dial-up access where there is a variable cost.

### Parameter 18: Cost of Internet access

**Definition**

Monthly cost of Internet access (including call charges) for (a) 10 hours usage, (b) 20 hours usage, (c) 50 hours usage, and (d) permanent connection. Separate measures to be given for working day and non-working access.
Discussion
Presently, there are many pricing options available. Dial-up users can choose a ‘free’ (in so far as there is no monthly subscription fee) ISP and pay local call charges, can pay a monthly subscription to get free Internet calls or pay a relatively small subscription charge which entitles them to permanently off-peak call charges. There are some ISPs which offer a ‘free-free’ service, in which there is no subscription charge and the calls are free, and there are also hybrid packages, such as subscription-based services which offer free calls during parts of the day and local call charges for the remainder. Permanent connections, such as ADSL, dedicated ISDN and cable, have no call charges but a relatively high monthly subscription fee.

Clearly the type of package that the user chooses depends on whether they are more likely to access the Internet during peak or off-peak periods, and the amount of time they expect to be online each month.

One difficulty in trying to measure the cost of Internet access is the prevalence of providers bundling their various services together. By subscribing to an ISP, the user may automatically receive a certain size of allocation for a web page and the option of multiple email accounts in addition to their dial-up service. This means that in many cases it may be difficult to isolate the cost of dial-up access from the general ISP subscription charge. Furthermore, the availability of a large number of packages, each offering different combinations of free peak/off-peak calls, means that ISP pricing structures are becoming so differentiated that comparing the monthly cost of access between them is difficult. This makes it difficult for individuals, or businesses to compare the exact cost of getting the same service from different providers.

Our proposed parameter, therefore, compares the costs of various levels of usage during both peak and off-peak times. Although this may lose some of the detail of a finely differentiated pricing structure, it should prove sufficient to give some broad ideas of the general costs.

We were also told that the cost of web hosting is mostly bandwidth and not the actual storage cost. It might therefore, be better to use bandwidth restrictions as a guide rather than size of space. This will depend on the type of service the user is opting for.

We note that for the bundled services, such as email and website hosting, there are a number of organisations providing such services for free – Hotmail is a clear example for email, and for website hosting examples include Geocities, Tripod or Homestead. These services are by no means ideal for all users but will generally be acceptable substitutes for the free services offered by an ISP, making the offer of such services from an ISP largely irrelevant.

Parameter 19: Additional cost of website hosting

Definition
Annual cost, over and above the cost of connectivity, of hosting (a) 10Mb, (b) 100Mb and (c) 1Gb of webspace, with secure/non-secure differentiation.

Discussion
This parameter measures – over and above the cost of connectivity covered in the previous parameter – the cost of hosting various sizes of website, for both non-secure and secure sites. Secure sites tend to be generally more expensive, but can be essen-
tial if the user is planning to adopt an e-commerce strategy or some other business plan which requires people to submit confidential information over the web.

Like Internet access, web page hosting is likely to be bundled with other Internet services making it difficult to pinpoint the exact cost of individual services. Martin Maguire, from Connect Ireland, suggested that people should be made more aware of the fact that they don’t necessarily need to use the same provider for access and hosting.39

It is because services are frequently bundled that our parameter measures the cost of website hosting over and above the cost of Internet access – for users who are already paying an ISP for their Internet access, and that ISP offers free website hosting as a joint product with the Internet access, the additional cost of the website hosting is zero.

Of course, website hosting is a more complex service than can be captured in one single parameter. For example, some ISPs charge for traffic rather than actual disk space used, or there may be various charging levels for megabytes both stored and delivered.40 In addition, the website host may offer an SLA (Service Level Agreement) containing guarantees of Quality of Service, such as ‘uptime guarantees’. Website hosting may also offer mirrored sites.41 These are replicas of the original site hosted on a different server. The advantages of this are that it reduces access time for the users by putting a copy close to their geographical location, it provides a backup of information, and enables load-sharing.42

To fully reflect the richness of the different options would be the subject of a separate study in and of itself, and probably of little interest to the vast majority of users. Our parameter, therefore, gives an idea of the basic cost of website hosting – users with specialist needs will doubtless want to explore the area in more detail before reaching any decision or assessing Quality of Service.

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**Parameter 20: Annual supplemental cost for domain management**

**Definition**

Annual supplemental cost, in addition to both Internet connectivity and website hosting, to register and manage a domain name such as ‘something.com’, ‘something.org’, ‘etwas.de’, and so on. By managing the domain name, we mean providing web and mail forwarding – i.e. ensuring that if you register ‘domain.com’ with your ISP, people browsing ‘www.domain.com’ will be redirected to the company’s website (hosted by the ISP) and mail sent to ‘anyone@domain.com’ will get forwarded to the appropriate mailbox (again, hosted by the ISP).

**Discussion**

Domain names are seen as a measure of company prestige and also of the credibility of their web presence.

The cost of a domain name is actually two-fold – one element of the cost is actually registering the name with a domain name registry, and some ISPs are able to get a discounted fee for their customers by making bulk registrations. The second cost is the actual management of the domain name. For the purpose of this exercise, we are assuming that the user will want the ISP to physically host the user’s website and provide one or several mailboxes for the user and will handle web and mail forwarding. The alternative is for the user to host the
website and mailboxes themselves on one of their own PCs with a permanent Internet connection. We will ignore this option, as it implies that the user is sufficiently familiar with the minutiae of Internet service provision as to not need these parameters to judge their QoS.

This parameter, therefore, will measure the annual cost of registering and managing, as defined above, the highest level domain name specific to the country of the ISP so, for example, ‘algo.es’, ‘qualcosa.it’ or ‘something.co.uk’. We were told that these tend generally to be cheaper than registering a ‘.com’ or ‘.org’ address, so we have chosen to specify a country specific domain name in order to ensure that the costs are comparable.

Parameter 21: Cost of technical support

Definition
The additional cost – over and above the cost of Internet access – of one hour’s telephone technical support, including the cost of the telephone call.

Discussion
Technical support can be very important for newcomers to the Internet, or those with limited technical skills. Equally, it can be important for users who are very IT-literate, and are trying to implement complex Internet-based services.

Some providers are now offering different support line call charges depending upon which package the user chooses. While some free ISPs may charge comparatively high rates for technical support – such charges can provide ‘free’ ISPs with an important revenue stream – providers with high monthly subscription rates may provide the service free of charge.

We have included the cost of the telephone call in the parameter, as some ISPs will derive revenue from sharing the cost of the call with the telco. In the case of a telephone number with a premium charge, these costs can be quite substantial for a one hour call.

As a caveat to this parameter, not all hours of technical support are equal. However, there is no easy way to objectively measure the quality of the technical support on offer, and this may even vary widely for an individual ISP depending on the quality of the staff manning the help line. We would emphasise that this parameter will merely measure the cost of an hour of technical support, and does not provide any guidance as to the quality of the support on offer.
9. Others

Initially we proposed to produce a list of parameters relating to ‘other factors’. These included areas such as:

- reliability of billing;
- ease of payment;
- content control;
- spam control; and
- security.

From discussions with ISP staff, however, it became clear that although these are important areas to consider when measuring quality of service, they are largely subjective. At present it would be very difficult to meaningfully measure the service offered by ISPs on these grounds.

For example, while security is clearly a very important issue,\(^4\) it is not possible to produce a single parameter that objectively measures, in numerical terms, the level of security offered. Similarly, although ISPs can choose from a variety of billing software, no consensus was found as to how they could be judged on the basis of reliability of billing, in order to state that, for example, ISP A has twice as reliable billing as ISP B.

While such issues are largely subjective, and are therefore not being included in the list of parameters – which are explicitly objective at least in their definition if not always in their interpretation and measurable in numerical terms – they are nonetheless important factors in determining ISP quality of service. They should therefore be borne in mind when considering an holistic picture of quality of service.
10. The parameters in use

This chapter of the report has two parts. In the first, we will re-visit our sample users mentioned originally in Chapter 2, and show how important they might consider each parameter to be. The purpose of this is to demonstrate that not all parameters are important to every user, and some care will be needed in their interpretation depending on the audience.

The second part will look at how the parameters can be measured, and how they can be used to provide the basis for various comparisons other than the choice between different ISPs implicit in the first part of this chapter.

10.1. Sample users and the importance of the parameters

The table below shows some estimates of the relative importance of the QoS parameters to four different ‘typical’ users:

- A family, using their Internet connection from home for entertainment and purchases. This type of user would typically have a dial-up connection over traditional telephone lines to an ISP.
- An employee working from home, using his internet connection primarily to gain access to his company’s intranet and to stay up to date with developments in his enterprise sector.
- A start-up company, using the Internet as a marketing and sales tool.
- A well-established SME managing relations with suppliers and clients over the Internet. This type of user is assumed for the purposes of this discussion to have a permanent Internet connection.

Unsurprisingly, the table demonstrates that many of the measures are important to all types of users. This applies to the simple and readily apparent measures of QoS such as the number of tries and the time it takes to get a connection. It also applies to those parameters that together reflect the performance of the ISP’s internal network (P7, P8, P9 and P10) and the performance of the ISP’s upstream network (P14, P16 and P17).

Among the other parameters, the table shows that the different users have different priorities and require more or less stringent standards in their QoS. For the family, ability to connect is obviously important but not crucial in the way it is for the other users who need to conduct business over the Internet (comparing the scores for P1 through P5). They are not as constrained as other users in terms of the times during the day/week that they use the Internet. The family is less demanding than other types of users in terms of speed and quality of connection except when they engage in online gaming when P8 will be important.

For the home-worker, speed and reliability are important as his/her ability to do the job depends on the Internet connection. However, the quality of the connection is less important, unless they engage in video-conferencing (P8). The ability to connect to certain websites, notably that of the company for which they work, is crucial (P14).

For both the start-up and the established SME, the health and success of the business can depend on the quality of their Internet connection. Slow or disrupted access can mean the loss of favourable deals. This greater reliance on the Internet will usually mean that they are willing to pay more for a better connection. For the start-up, the website is a key to building the customer base, so parameters affecting its performance will be central (P16 and P17).

The greatest differences in importance are to be found in the section relating to cost.

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For the family, the cost of using the Internet will be compared to the cost of other recreational activities. The start-up has to balance the cost of Internet access with the company's other essential set-up costs by assessing its contribution to marketing and sales. For the tele-worker and the well-established business, there is no satisfactory alternative to the Internet so cost is less important.

<table>
<thead>
<tr>
<th></th>
<th>Family</th>
<th>T-Worker</th>
<th>Start-up</th>
<th>Est. SME</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1: Number of attempts required to achieve connection</td>
<td>****</td>
<td>*****</td>
<td>*****</td>
<td>N/A</td>
</tr>
<tr>
<td>P2: Time to connect</td>
<td>****</td>
<td>*****</td>
<td>*****</td>
<td>N/A</td>
</tr>
<tr>
<td>P3: Time to connect during the busiest hour of the week</td>
<td>**</td>
<td>*****</td>
<td>*****</td>
<td>N/A</td>
</tr>
<tr>
<td>P4: Frequency of connection termination</td>
<td>****</td>
<td>*****</td>
<td>*****</td>
<td>*****</td>
</tr>
<tr>
<td>P5: Frequency and duration of ISP ‘outages’</td>
<td>**</td>
<td>*****</td>
<td>*****</td>
<td>*****</td>
</tr>
<tr>
<td>P6: Theoretical maximum speed of connection</td>
<td>*</td>
<td>*</td>
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<td>*</td>
</tr>
<tr>
<td>P7: Connection speed achieved</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>*****</td>
</tr>
<tr>
<td>P8: Latency, jitter and packet loss statistics communicating with the ISP</td>
<td>***</td>
<td>**</td>
<td>**</td>
<td>***</td>
</tr>
<tr>
<td>P9: Speed of download from ISP’s server(s)</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>****</td>
</tr>
<tr>
<td>P10: Speed of download from ISP’s mail-server</td>
<td>**</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>P11: Ratio of ISPs’ bandwidth to product of number of customers able to achieve simultaneous connection and the maximum bandwidth of those connections</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>****</td>
</tr>
<tr>
<td>P12: Proportion of packets travelling through the ISP’s routers which are lost</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>****</td>
</tr>
<tr>
<td>P13: Proportion of designated sites connected to: (a) the ISP’s own backbone/backbone provider(s); (b) to the ISP through private peering arrangements; and (c) through public NAPs/IXPs</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>P14: Proportion of time which designated sites are unreachable</td>
<td>***</td>
<td>*****</td>
<td>****</td>
<td>****</td>
</tr>
<tr>
<td>P15: Latency, jitter and packet loss statistics for designated sites</td>
<td>**</td>
<td>*</td>
<td>*</td>
<td>**</td>
</tr>
<tr>
<td>P16: Number of NAPs connected to and the bandwidth of the connections</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>****</td>
</tr>
<tr>
<td>P17: What are the bandwidth utilization figures for the ISPs NAP connections and how congested are the NAPs at which the ISP peers?</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>****</td>
</tr>
<tr>
<td>P18: Cost of Internet access</td>
<td>****</td>
<td>*</td>
<td>****</td>
<td>***</td>
</tr>
<tr>
<td>P19: Cost of website hosting</td>
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<td>*</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>P20: Annual supplemental cost for domain management</td>
<td>*</td>
<td>*</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>P21: Cost of tech support</td>
<td>***</td>
<td>*</td>
<td>****</td>
<td>*</td>
</tr>
</tbody>
</table>
10.2. Measuring the parameters, and using them for comparisons

10.2.1 Comparing ISPs
The previous section illustrated, for sample users, some likely importance weightings for the various parameters. In the most obvious use for these parameters – comparing various ISPs – the mechanics of using the parameters is relatively straightforward. An independent and trusted source, such as a consumer association or magazine, could score the various ISPs on a scale of zero to ten, with zero for the worst-performing and ten for the best-performing, against each of the parameters. A user could then derive the importance of each of the parameters for themselves on a scale of zero to five, as illustrated in the previous section. By multiplying the performance of each ISP against each parameter by the importance attached to that parameter and summing the results, a user could attribute to each ISP a total score to enable them to rank various ISPs according to their needs.

Some parameters may also be considered too technical for some users – such as the latency, jitter and reliability statistics. In these cases, average and variation in download speeds should prove broadly acceptable proxies, and the more technical parameters could be assigned weightings of zero.

In the case of parameters where there are multiple values – such as Parameters seven through nine where both the average and variation are measured, or Parameter 15 which measures jitter, latency and packet loss – the process will need further refinement. It is conceivable that the user will attach importance to each sub-parameter, or that the user may decide that one particular sub-parameter is the one that is most important, for example jitter is important but latency is not.

The actual measurement of the parameters – which would need, as mentioned, to be undertaken by an independent, trusted and transparent organisation – would require a variety of techniques depending on the parameter. Some are reasonably straightforward, such as the cost of Internet access, and would require simple desk research together with some basic verification. Others, for example the number of NAPs the ISP was connected to, would require polling the ISP and more rigorous verification – in the case of the number of NAPs this would involve verification with the NAPs to which connections were claimed. There would also be a requirement for some primary research – for example Parameter 7, the connection speed actually achieved – would require repeated dialling into the ISP in order to gain sufficient data points to accurately measure the parameter. While this could be readily automated and the measurement could take place largely unattended, it nonetheless does require an investment which is probably beyond the resources of an individual wanting to compare different ISPs.

Care must also be taken to ensure that the measurements are carried out in a consistent and fair fashion – for example using a number of different telcos in order to connect to an ISP if one is testing dial-up PSTN services in order to give an accurate reflection of all users’ experiences. Also, a number of technical issues, such as the ISP’s use of proxies or caches impacting on latency figures, must also be considered. A full discussion of all of these points is without the scope of this study.

The parameters could also be used, though, for comparisons other than between ISPs for a particular user, though in a reasonably similar way. We will consider two such examples below, which are intended to be illustrative rather than exhaustive.

10.2.2 Comparing different connection technologies
Another scenario in which these parameters may prove useful is in comparing connection technologies. If a user is, for example, considering changing from a dial-up connection to, say, ADSL then the cost will change, as well as the QoS received. In order to try and analyse the cost/quality trade-
off in a systemic way, the user could go through the same process of attaching various weights to the parameters and scoring the two different technologies according to these parameters.

For example, the ability to connect parameters, 1 to 5, may be considered important to the user, the speed parameters, 6 to 17, less important and the cost parameters, 18 to 21, very important.

Each parameter could then be scored for the average – or even specific – dial-up setup and an average or a specific ADSL setup, and the same process of multiplication and summing to derive total scores for both technologies in order to clarify the decision-making process.

This procedure may seem overly elaborate, particularly for an individual consumer facing a decision where the cost difference is not considerable. However, it is not inconceivable that an SME would undertake such a process, particularly if it is comparing a permanent ISDN connection to a dial-up PSTN connection, where the costs involved could be substantial, or if a serious web presence was an integral part of their business plan.

10.2.3 Comparing Internet QoS across countries

The parameters derived in this report could be used to measure the QoS received by users in different countries.

The top 5 ISPs in each member state, for example, could be scored using the parameters and the results averaged for each country. These scores could then be weighted according to the derived weights of some sample users to show that, for example, small business users are better served in country A than in country B.

The above examples are merely supposed to show that the above parameters can be used in a variety of ways in order to compare Internet QoS, and not just used to assist users in assessing the price/quality trade-off faced when choosing an ISP.
PART III - CONCLUSIONS
11. Conclusion

In this report we have tried to suggest and place in context some parameters that will enable meaningful, objective and transparent assessment of the quality of service which Internet users receive. Our interviews revealed a view that the ISP industry was consolidating as ISPs which were unable to invest in the infrastructure needed to improve QoS, such as bandwidth, peering arrangements and connection hardware (e.g. modems) were delivering poor QoS and going bust. The hope was expressed that QoS would become more important to users, and that the resultant pressure on ISPs would mean that Internet access would come to be taken for granted, like “water out of a tap.”

These parameters can be used to compare the services offered by different ISPs – and in particular to inform a price/quality trade-off decision for a consumer – but may also help to inform decisions about technology upgrades, for example, or permit cross-country comparisons of Internet QoS.

The parameters are designed to be of interest to individuals and to SMEs – large businesses are likely to have or be able to afford dedicated Internet expertise in order to inform their choice of Internet Service Provider. The parameters are also designed to be sufficiently flexible to be used across a mixture of connection technologies, from dial-up modem access to new xDSL technologies. We have also tried to make them sufficiently inclusive to capture the recent increased richness in pricing structures, including differentiated pricing for peak and off-peak usage and bundled internet services included with the cost of internet access – though we were unable to develop parameters which were meaningful but also sufficiently generic to capture the value of other services which are also sometimes bundled with Internet access, such as voice telephone call discounts.

We found that not all elements of QoS were readily measurable in a numerical and objective fashion. Some examples include security, reliability and ease of billing and the filtering out of objectionable material. These can only really be measured subjectively, and may also not ever be part of a price/quality trade-off – for example, a parent may consider technology to filter out objectionable material in order to stop their child seeing pornography on the Internet to be an absolute necessity, rather than a desirable feature but one that might be overlooked if it costs too much.

The purpose of this work was to come up with some suggested parameters to allow the measurement of Internet QoS. As such, this report has not come up with any measurements as such of QoS – this would clearly be impossible without data. As the data collection tasks required to sensibly use these parameters are sizeable, there are clear economies of scale to be reaped by the promotion of a single, trusted and independent body to collect and disseminate these statistics.

Finally, we have briefly discussed a methodology for allowing users to rank the importance of these parameters to themselves and hence to derive total scores for various ISPs in order to better inform their decision-making. We have also discussed some illustrative sample users, together with some suggested weightings for each of the parameters, and also some possible applications of the parameters beyond comparing ISPs for particular users.
The main content of this report is the list of parameters themselves and our discussion of them – these are not easy to summarise and we therefore shall not attempt to do so.
APPENDICES
Appendix 1. Interview Methodology

Discussions amongst the project team led to the development of an initial list of parameters for measuring ISP quality of service. It included four main sections:

- ability to connect;
- speed of connection (upstream and downstream);
- cost; and
- other factors.

The list consisted of measures expected to be relevant to the end user, measurable and objective. They were designed to be relevant irrespective of the type of user, and the varying needs of those users. As such, they were designed to be applicable to both domestic and business users. In addition, they were designed to be relevant irrespective of the method of Internet connection used e.g. whether it be broadband or narrowband, via a PC, a digital TV, a WAP enabled cell phone, or indeed any of the growing number of alternative methods continually appearing.

Contacts were then made by email or telephone with ISPs, telcos and NAPs in order that the list could eventually be modified or improved on the basis of their feedback. To encourage participation each potential interviewee was asked to comment on only one of the four sections. Following confirmation that they were interested in partaking in the study, they were sent a list of parameters. In the subsequent telephone interviews three main questions were addressed. These were if each of the parameters would be easy to measure, relevant to the quality of the user’s Internet experience, and if there were any other measures (within the specific area under consideration) which ought to be included. Where appropriate, interviewees were specifically asked to comment on a particular section of the list according to their own expertise. In addition to the questions regarding ISPs upstream connectivity, staff from NAPs were asked broader questions such as what they considered to be the main cause of delays on the Internet.

The list of parameters was then improved on the basis of the feedback.
Appendix 2. People interviewed

**NAPs**
Denis Curran, INEX Operator
Walter van Dijk, AMSIX Operator, Head of Accounts Management and marketing at Surfnet.
Keith Mitchell, Executive Chairman, LINX.

**ISPs**
Andrew Bonar, Founder of Cheapnet and Surf London.
Fredrik Engval, Managing Director, Professional Internet.
Johan Helsingius, Chief Technology Officer, Senior Vice President, KPNQ West Belgium.
Siegfried Langenbach, President of Eurolnternet.
Martin Maguire, Project Director, Connect Ireland.
Miguel Perez, President of the Spanish Internet Users Association.
Daniel Pope, IP Manager, Telia UK.
Steve Rawlinson, Systems Manager, clara.net.
Ian Robertson, Manager, Fastnet International.
Lee Wade, Director of Internet Strategy, CIX Internet.

**Telcos**
Nigel Pitcher, Group Marketing Director, Fibernet Group plc.
Wayne Vinton, Director of Marketing Strategy, IP Division, Global Telesystems (Europe) Ltd.
NOTES

1 “Why we can’t compare ISP performance – yet”, Business Communications Review, Sandra Borthick, vol. 28 no. 9, Sept 98

2 Top 25 ISPs, Data Communications survey, June 1999.

3 Bandwidth refers to the theoretical maximum speed of a network connection, typically measured in thousands or millions of bits per second. The higher the number of bits per second, the quicker data can be transferred over the line and, typically, the higher the cost of the connection.


5 Web Performance Tuning, Patrick Killela. (www.patrick.net/wpt/) For another discussion of this point, see http://www.frag.com/help/quake/wtq3a.html, which discusses some of the issues relating to modem-induced latency from the perspective of the user wanting to play games over the Internet – something which requires high QoS.

6 Financial Times, Telecoms survey, October 1999

7 The first hop is the link between the individual’s computer and their ISP. This leg of the journey is the most transparent to the end user, and can be over the phone network for a typical dial-up customer, over cable, via satellite, and so on. Whatever medium is used to connect to the ISP, this is always the first stage of the journey.

8 Peering denotes an arrangement whereby two ISPs agree to swap data for free. Typically, these will occur between ISPs of roughly equal size. Where there is a substantial size discrepancy, and hence a data-flow asymmetry, there may be charges for data flow, called transit charges.

9 See http://www.linx.net/membinfo/peer.html

10 In practice, the data may travel via the States for short periods of time if, for example, NAPs in Europe are busy. However, for the journeys cited, the journey patterns were consistent at different times over a number of days, suggesting that this was the ‘permanent’ route.

11 The distance (round-trip) is 426 miles, so time taken is \[
\frac{426}{186,000} \approx 0.002s
\]

12 A dedicated Internet connection supporting data rates of 1.544Mbps. T1 lines are a popular leased line option for Internet Service Providers (ISPs) connecting to the Internet backbone. The Internet backbone itself generally consists of faster T3 (43 Mbps) connections.

13 \[
\frac{32 \times 11 \times 8}{1544000} = 0.002s. \text{ This is a rough estimate only.}
\]

14 See, for example, Data networks are lightly utilized, and will stay that way, available along with many other relevant papers at www.research.att.com/~amo.


16 Tornado-Insider.com interview with Andreas Schmidt, July 1999

17 Association des Fournisseurs d’Acces et de Services Internet, March 2000.

18 Belgian Internet Service Providers Association, January 2000.

19 See www.anxo.net for more details.


21 Nigel Pitcher, Fibernet.
Suggested by Lee Wade, Director of Internet Strategy at CIX Internet.

Suggested by Daniel Pope, IP Manager at Telia UK.

Cheaper modems in general are less able to tolerate line noise without losing the connection. Upgrading to a higher quality modem supporting the V.90 standard may reduce this problem.

Andrew Bonar of Surflondon and Ian Robertson of Fastnet.

Steve Rawlinson of ClaraNet

Nigel Pitcher, Fibernet.

Fredrik Engval from pi.se (corporate ISP with emphasis on hosting and leased line services)

Provided, of course, they are using the same ISP for their email services as they are for their connectivity services.

This can be identified by using Traceroute, or a similar utility.

Denis Curran from Inex.

Daniel Pope from TeliaUK.

These need not actually be websites – for example, it could be a business partner’s mail-server, or a printer used by a graphics house which is connected to the Internet. We will use the term websites, though, for convenience.

www.ripe.net

Steve Rawlinson from ClaraNet

Daniel Pope, IP Manager, Telia UK.

Steve Rawlinson, Systems Manager of ClaraNet International.

Miguel Perez, President of the Spanish Internet Users Association.

He also commented that ISPs are intent on tying people in by such measures as combining voice phone and Internet services.

Johan Helslingius, Senior Vice president of KPN Q West, Belgium.

Johan Helslingius.

"Mirror sites are useful when the original site generates too much traffic for a single server to support. Mirror sites also increase the speed with which files or Web sites can be accessed: users can download files more quickly from a server that is geographically closer to them." from http://webopedia.Internet.com/TERM/m/mirror_site.html

This was stressed by Wayne Vinton, Global Telesystems.

Wayne Vinton, Global Telesystems.

Nigel Pitcher, Fibernet.