Section 6

Internet access services

Overview

6.1 Much of the preceding analysis in this report has focused on the availability and performance of the access networks that network operators use to provide connections to customers, either via direct fibre or copper physical lines to the home, for fixed networks, or through radio coverage from masts, for mobile networks. In this section we explore the issues relating to the other parts of the internet connection chain linking consumers to online services.

6.2 Access networks now deliver an increasingly wide range of services, not just the traditional voice telephony and cable TV that many legacy networks were initially designed to deliver. In particular, consumers are increasingly using these networks to access a vast range of services available on the internet. These services now constitute the majority of traffic delivered over access networks. As a result, consumers are becoming increasingly concerned about the quality of their internet connection, in addition to the performance of the more traditional services such as voice telephony.

6.3 Internet service providers (ISPs) often do not have full control over the full end-to-end internet connection chain to consumers, and hence over the quality of internet services delivered to consumers. In this section we explore a number of topics related to how ISPs are supporting the delivery of internet services over their networks, including how they manage the flow of data over their networks and how they interconnect with other ISPs, content delivery networks and the wider internet. We also consider the effect of the performance of the ISP networks on the consumer and SME experience, and how ISPs manage the assignment of internet addresses to consumers’ equipment.

6.4 The highlights are:

6.4.1 ISPs are simplifying their consumer broadband packages and improving the information they provide to consumers about the use of traffic management on their networks. Meanwhile, a broader international debate continues to explore whether regulatory authorities need greater powers to protect consumers if damaging traffic management practices emerge.

6.4.2 An increasing amount of internet data is being delivered to consumers by major video content providers. The use of content delivery networks (CDNs) continues to increase: internet content is increasingly being served from caching servers embedded in the ISPs access networks and provided by the content providers.

6.4.3 The effects of different parts of the internet delivery chain on consumers’ and SMEs’ experience of using online services are materially different for different connection speeds.

43 Akamai, Google, Amazon, Netflix and the BBC.
6.4.4 Larger-scale ISPs are likely to progressively introduce support for the latest IPv6 internet addressing system over the next 12 to 18 months.

Managing data use within ISP networks

6.5 The growth of the internet has created both an opportunity and a major challenge for network operators: consumers’ reliance on and use of their services continues to grow, but they are faced by a significant challenge in how they cope with the consequent huge growth in data traffic.

6.6 As consumers use more 'bandwidth hungry' internet services such as video, existing access networks are likely to experience congestion problems. Networks must have the capacity to accommodate overall data volumes as well as peak instantaneous demand. One way for ISPs to manage congestion is to increase the capacity of their networks. However, despite the ongoing deployment of superfast-capable networks across the country, congestion problems are still likely to persist in the ISPs’ networks as demand continues to rise.

6.7 In addition to increasing network capacity, ISPs can adopt a range of approaches to manage how data travels across their networks; for example, ISPs can cap the amount of data that consumers can access or reduce speeds at peak times. These approaches are discussed in Figure 29.

Figure 29: Operators have a range of tools for managing data use

<table>
<thead>
<tr>
<th>Fixed broadband usage caps</th>
<th>ISPs may limit users to a certain amount of data per month, or at peak times. Exceeding the cap can result in additional charges or a reduction in speeds.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ISPs now offer ‘unlimited’ packages with no data caps(^{44}) and over 80% of consumers are now taking such services.</td>
</tr>
<tr>
<td></td>
<td>Peak period usage restrictions are still used by cable-based ISPs, such as Virgin Media, to manage the inherent limitation in upload capacity in the DOCSIS systems they use.</td>
</tr>
</tbody>
</table>

| Mobile usage caps          | Most mobile operators impose data caps on their packages, and those who previously offered unlimited data packages, notably Three and GiffGaff, have changed their terms of use\(^{45}\). These changes probably reflect the impact of increased media streaming on overall network capacity. |

| Traffic management (TM)    | ISPs may adopt TM techniques to alleviate network congestion at busy times. In practice, this is achieved by prioritising some types of traffic over others, or entirely blocking certain types of traffic, e.g. peer-to-peer (P2P) file sharing, or VoIP telephony on mobile |

\(^{44}\) BT, Virgin, TalkTalk, Sky, EE, KCOM and PlusNet all offer one or more unlimited fixed broadband packages among their broadband product choices.

\(^{45}\) Three announced last year that it would introduce caps, limiting the amount of data that customers can access via tethering, which refers to connecting a device, such as a mobile phone, to another device (e.g. tablet or laptop) in order to use the first device’s internet connection. GiffGaff also dropped the unlimited aspect of a number of its plans - [http://www.ispreview.co.uk/index.php/2014/09/giffgaff-uk-scraps-cheaper-unlimited-mobile-broadband-data-plans.html](http://www.ispreview.co.uk/index.php/2014/09/giffgaff-uk-scraps-cheaper-unlimited-mobile-broadband-data-plans.html)
6.8 Better controlling the flow of traffic across an ISP’s network by using traffic management (TM) can benefit consumers by improving the performance of their broadband connections at peak times. However, there are concerns that ISPs could use TM in a discriminatory manner. For example, an ISP could prioritise the delivery of its own services over others’, so that they are more attractive to consumers, or better quality.

6.9 In 2011 we published a statement in which we set out the concerns we would have if ISPs were to apply TM in a manner that degraded access to the internet. Since then, we have used the Infrastructure Report series to monitor and report on what ISPs are actually doing, to determine whether we should have any such concerns. Two important concerns are:

- **transparency**, i.e. whether consumers know that TM is being performed on their broadband connections; and

- **net neutrality**, i.e. whether the use of TM has an adverse and unfair effect on the delivery of some traffic or applications, compared to others.

6.10 We discuss both of these in more detail below.

**Transparency**

6.11 There is increased regulatory pressure on mobile and fixed operators to be transparent about the ways in which they manage consumers’ data use. We believe that competition provides an important discipline for ISPs’ network management practices. In order for competition to operate effectively, consumers need to have clear and transparent information about whether TM will affect the services they purchase, and it should be easy for them to switch provider.

6.12 ISPs in the UK are therefore subject to a regulatory obligation to be transparent with consumers about their TM practices. There is an industry-wide code of practice explaining how they should comply with this obligation (the Traffic Management Code).

47 General Condition 9.2e.
Transparency Code of Practice\(^{48}\) which requires that each ISP publish a table summarising its TM policy for each package on offer. These tables have been available on signatories’ websites since July 2011.

6.13 In late 2013, Ofcom conducted research on consumer awareness and use of the TM information provided by ISPs. It found that, while the information provided by ISPs was largely accurate and understandable, consumer awareness of TM generally was low. Following this, during 2014 we worked with ISPs to help them improve the impact of the information they provide, with a focus on improving consumer awareness and usability. The ISPs now provide introductory information explaining their policies and the impact of these policies on their services, and have updated their websites to include glossaries of technical terms.

6.14 We have reviewed the information provided by ISPs. Our conclusion is that, broadly, transparency about TM practices has improved, and in general TM policies are less restrictive than previously. For fixed networks, TM policies are rarely invoked.

Net neutrality

6.15 ‘Net neutrality’ refers to a policy debate about the way ISPs manage the data carried on their networks, from content providers such as the BBC, YouTube and other websites to end-users. The issue has gained prominence as the internet has become an essential platform for the delivery of all kinds of content, services and applications.

6.16 Some argue that the use of some TM practices by ISPs could be discriminatory, in particular by undermining the ease with which innovative services can launch and become successful. Their concerns can be described in terms of constraining competition, innovation or freedom of expression.

6.17 Some TM practices are generally accepted as legitimate, e.g. to manage network congestion or to block access to unlawful content. On the other hand, TM intended to secure commercial advantage for the ISP is generally not accepted. This may happen if the ISP blocks a service provider’s content in favour of its own. As Figure 30 shows, between these two extremes are ‘grey areas’ that might elicit different responses in different countries.

6.18 A recent addition to the net neutrality debate is ISP commercial practices that involve differentiated charges for data associated with specific services, i.e. consumers are charged different amounts for different classes of traffic. The most commonly cited commercial practice of this kind is known as ‘zero-rating’, e.g. an MNO offers a package with a 5GB download limit for general data, but zero-rated or unlimited access to Spotify. Zero-rating is a new hot topic in both the US and the EU.

6.19 Some aspects of the net neutrality debate address the delivery of services to consumers more broadly. For example, some of the largest content providers now operate their own delivery networks, which must interconnect with ISPs in order to deliver content to consumers. They can do this either by paying a transit network, which itself connects to the ISP (Figure 31a), or by interconnecting directly (Figure 31b). Direct interconnection is cheaper (for the content provider) for the delivery of large volumes of data.

**Source: Ofcom**

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**Figure 30: The spectrum of traffic management practices**

<table>
<thead>
<tr>
<th>Less disputed</th>
<th>Highly disputed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic management under congestion</td>
<td>Priority always given to most time-sensitive services e.g. voice, video streaming, games</td>
</tr>
<tr>
<td>Best efforts internet, network management only</td>
<td>Priority given to an individual CAP’s services for payment (ISP as Gatekeeper)</td>
</tr>
<tr>
<td>Blocking unlawful content</td>
<td>Zero-rating</td>
</tr>
<tr>
<td>Parental Controls (especially default on)</td>
<td>Blocking rival’s content or applications e.g. rival TV service or VOIP</td>
</tr>
</tbody>
</table>

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**Figure 31: Changing approaches to interconnection**

- a) Distribution in 2013
6.20 Particularly in the US, these ‘direct’ interconnection agreements between ISPs and content delivery networks have led to allegations that ISPs are attempting to become *gatekeepers*, extracting a charge from content providers such as YouTube to allow them to access the ISPs’ subscribers.

6.21 The allegations are particularly prominent in those countries (like the US) where there is limited competition among ISPs, and hence the negotiating position of content providers is seen to be weaker. Conversely, in Europe (where there is a large degree of ISP competition, but where there is concern about the dominance of US content providers like YouTube and Netflix), these deals have led to allegations that large content providers are able to buy preferential access to ISPs’ subscribers (to the detriment of smaller ones).

6.22 In fact, these arrangements are arguably no different from traditional network operator interconnection negotiations and arrangements that have always existed. We have no reason to believe that UK ISPs are abusing their position to extract payment from content providers, nor that large ones have been allowed to buy better quality content delivery to the detriment of their smaller competitors.

The EU Regulation and its impact

6.23 The EU Telecoms Single Market Regulation\(^49\), approved in the European Parliament in late October 2015, is likely to have a significant impact on how net neutrality is regulated when it comes into force at the end of April 2016. There are four relevant Articles in the Regulation:

6.23.1 **Article 3** imposes net neutrality/traffic management obligations on ISPs.

6.23.2 **Article 4** imposes a range of specific transparency conditions on ISPs in relation to the speed and quality of the services they offer, and to their handling of complaints and unsatisfactory performance.

6.23.3 **Article 5** requires NRAs to monitor and enforce Articles 3 and 4, and to report annually on their findings. It reinforces NRAs’ power to impose quality of service obligations on ISPs.

6.23.4 **Article 6** requires member states to introduce a sanctions regime to support enforcement of Articles 3-5.

6.24 The TSM requires BEREC to “issue guidelines for the implementation of the obligations of national regulatory authorities”. This process is under way, and should help provide clarity and guidance as to the requirements of the Regulation. BEREC\(^{50}\) intends to publish the guidelines in August 2016, a few months after the Regulation comes into force.

6.25 We would encourage industry to work collectively, where possible, to develop their approach to new obligations under the Regulation. For example, it may be helpful to develop a common approach to the new transparency obligations set out in Article 4. It is helpful in this context that the Broadband Stakeholders Group is currently reviewing industry codes of practice dealing with net neutrality and traffic management\(^{51}\). This work (along with past industry collaboration in developing the common Traffic Management Key Facts Indicators template), may be able to form the basis for development of new industry codes intended to reflect the provisions of the new Regulation.

**Interconnection with other networks**

6.26 In previous years we have reviewed and reported on the nature of the connection arrangements used by ISPs to deliver internet content. Last year we noted an increasing use of content delivery networks (CDNs) and direct connections between the access providers and the providers of content and services, and a reducing use of transit and public peering arrangements to deliver internet content\(^{52}\).

6.27 This evolution is typified by the changes in interconnection used by the Netflix service illustrated in Figure 31. In particular, we note that its CDN arrangements, and those of other major internet content providers, are now being further extended into the access provider’s own network using ‘caching servers’\(^{53}\). This approach further reduces transit or backhaul connectivity costs, and can improve the customer experience by reducing the likelihood of data congestion in these parts of the network.

6.28 Peering takes place at a location agreed by both parties. In many cases this will be at internet exchange points (IXPs); locations built to facilitate peering. In the UK a large number of public peering points – ‘internet exchanges’ - are located in London. The

\(^{50}\) The Body of European Regulators of Electronic Communications consists of the telecoms regulators of the EU member states.


\(^{52}\) For an explanation of these terms, please see section 9, p161 onwards at [http://stakeholders.ofcom.org.uk/market-data-research/market-data/infrastructure/infrastructure-2014/](http://stakeholders.ofcom.org.uk/market-data-research/market-data/infrastructure/infrastructure-2014/)

\(^{53}\) Caching servers are CDN servers which can be placed within the ISP’s network or on a third-party network, storing the most popular content. This removes the need for the ISP to connect to the original source of the content every time a customer requests it.
London Internet Exchange (LINX) and the London Network Access Point (LONAP) are two of the largest not-for-profit organisations providing these interconnect locations. Other exchange points are located elsewhere: Leeds, Manchester, Edinburgh, and soon, Cardiff. A number of ISPs, often those with an international network footprint, also peer at other leading IXPs, such as AMS-IX in Amsterdam.

6.29 The use of CDNs by both fixed and mobile operators has increased over the past year; Figure 34 shows that fixed operators use CDNs to deliver a larger proportion of their traffic than do mobile operators.

![Figure 32: Share of peering and transit interconnections for typical fixed and mobile operators](image)

**Source:** Ofcom analysis of operator data

6.30 The proportion of traffic provided by the top content providers which have individual interconnection arrangements has also increased. For some fixed networks, the proportion of traffic delivered via the BBC, Google, Netflix, Akamai and Limelight can make up 60% or more of all interconnecting traffic. On mobile networks, the proportion is lower. This shows that the source of internet data is increasingly consolidating into a small number of providers.

6.31 However, increasingly, the direct connectivity provided via CDNs is not the route that much of the content served actually takes to the end-user. Earlier we noted the increasing role of content providers’ caching servers in ‘local’ delivery. Anecdotally, one fixed ISP has estimated that around 65% of the content downloaded by its customers is now served in this way.

6.32 Location of interconnection is consequently changing as, typically, each national ISP may have up to about ten sets of such content providers’ servers distributed across

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54 The Welsh Government has been working with LINX, Cardiff County Council and other partners to bring an internet exchange to Cardiff. [http://wales.gov.uk/newsroom/businessandeconomy/2014/8838915/?lang=en](http://wales.gov.uk/newsroom/businessandeconomy/2014/8838915/?lang=en)
its network. Since the actual volume of traffic served to each individual server may be comparatively small, and since it may partly be carried over the ISP’s own network, this makes analysis of the proportions of traffic exchanged at various locations increasingly difficult.

6.33 Peering connections, including public and private peering, have the largest proportion of their interconnect traffic exchanged in London. This is unsurprising, given that many operators are based in London. After London, around 20% of peering traffic is exchanged at other large co-location facilities in Europe, mainly in Frankfurt and Amsterdam.

6.34 Our data suggest that only a small proportion of traffic is carried across the other regional interconnections in the UK. This is probably due to the smaller number of networks currently present at these locations; these internet exchange points are relatively new.

Factors other than connection speed can affect the consumer experience of using internet services

6.35 As discussed in Section 4, consumers with faster broadband connection speeds are more likely to rate their experience of using of internet services as ‘good’. However, connection speeds relate to only one part of a larger chain of interconnected networks and systems that consumers use to access internet services. In this section we consider the effect of this wider connection chain on the consumer experience, which we have separated into four main parts (see Figure 33):

6.35.1 The home network: this includes connections from the home router to consumer devices, using, for example, Wi-Fi, Ethernet and powerline. The effect of the performance of this part of the connection was discussed in Section 4.

6.35.2 The ISP’s access network: this includes the ‘last mile’ connections between the ISP’s network and the user’s premises (the availability and speed of these connections is set out in Section 4). For some ISPs, this part of the ISP’s network may also include connections between smaller local exchanges and larger metropolitan locations.

6.35.3 The ISP’s network: this relates to interconnections within the ISP’s network between the ‘last mile’ connection and the wider internet;

6.35.4 The internet: this relates to the national and international connections to services hosted on the wider internet.
6.36 The performance of these different parts of the connection chain, and how they are perceived by consumers, is more widely dependent on:

6.36.1 **The internet application being used**: this is because different internet services have different levels of sensitivity to connection performance.

6.36.2 **The expectations of the consumer**: consumers may have differing broadband performance expectations. For example, those relying on their domestic broadband connection to run a small business, or those who have paid a higher price for a higher speed connection, may have greater expectations than those making infrequent use of a broadband connection using a lower price subscription.

6.37 Ofcom has commissioned research into a new, innovative internet measurement approach, to help identify how the four parts of the internet connection chain, as described above, are likely to affect the consumer experience of using differing online services. Predictions made by this new approach about how consumers are likely to rate the quality of their broadband connections appear to correlate closely with actual consumer ratings.

**The performance of other parts of the connection chain**

6.38 As described in Section 4, the new measurement approach has found that the higher the connection speed that consumers have, the more likely they are to rate their broadband experience as at least 'good'.

6.39 The new measurement approach has also identified (see Figure 35) that factors beyond the speed of the access network can have a meaningful effect on broadband connections likely to be rated by consumers as 'less than good'.

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The consumer experience of using broadband services is generally lower in rural than in urban areas

Using the new measurement approach, we find that a higher percentage of consumers in rural areas (45%) than in urban areas (28%) are likely to rate their broadband performance as 'less than good'. As already discussed in Section 4, this is in large part due to the availability of slower speed connections in rural areas. However, as shown in Figure 36, other parts of the connection chain can affect performance in rural areas. The impact of these other factors affect proportionally more households in rural than in urban areas, as a greater proportion of households experience lower performance in rural areas.

Source: Actual Experience for Ofcom
The applications used by some small businesses are sensitive to broadband performance

6.41 Small- and medium-sized enterprises (SMEs) use a broad range of online services. Many of these are the same as those used by domestic consumers, such as email and web browsing. However, using the new measurement approach we have been able to identify that other types of services that they often use, including video-conferencing and cloud-based customer management and billing services, are more sensitive to end-to-end internet performance using residential broadband connections.

6.42 In particular, Figure 37 illustrates how connections between the ISP’s network and the wider internet play a more significant role for many of the services likely to be used by SMEs..
Internet addressing

Introduction

6.43 The internet relies on a numeric address scheme to route data across the globe. For data to be delivered, each device connected to the internet must have access to a publicly-routable internet protocol (IP) address. The current, widely deployed, version of IP is version 4 (IPv4) which provides around 4 billion unique addresses and is administered by the US-based Internet Assigned Numbers Authority (IANA). IP address allocations in the UK are serviced by the RIR for Europe and the Middle East, Réseaux IP Européens Network Coordination Centre (RIPE NCC).

6.44 In 2011, IANA declared that the central pool of IPv4 addresses was “exhausted”. Each of the RIRs is, in varying degrees, running out of its final block of IPv4 addresses. We asked providers to estimate the likely date of IPv4 exhaustion for their networks. They gave varying estimates of when they would run out of IPv4 addresses. Their estimates were between one and five years, based on the current rate of use.

6.45 The Internet Engineering Task Force (IETF) has long been aware of the potential exhaustion of IPv4 addresses. In 1998 it standardised a successor to IPv4: internet protocol version 6 (IPv6). However, the implementation of IPv6 is likely to present some significant challenges: it requires investment in the network by online service providers.

Source: Actual Experience for Ofcom
providers, and in updating or replacing consumers’ equipment to handle the new-format IP addresses.

6.46 Mobile operators are generally looking to introduce IPv6 addressing, as many of the latest generation of 4G handsets are already compatible. However, further software upgrades or configuration changes within the network and in consumer devices may be required before mobile operators can begin to use IPv6 addresses. In the meantime, a technology known as CGNAT56 is used to share a single IP address among multiple users.

6.47 Fixed operators are also considering, or trialling, CGNAT and/or an approach in which both IPv4 and IPv6 run in parallel. None of the major providers we contacted are currently offering IPv6 addresses for their residential/ non-business users, although IPv6 services are available from some smaller fixed broadband providers, such as Andrews and Arnold. However, most major ISPs have told Ofcom that they intend to roll-out IPv6 addressing in the next 12 months, with BT recently announcing that it will make it available to all its customers by the end of 201657.

6.48 As mentioned, a potential barrier to the introduction of IPv6 addresses is the availability of compatible equipment in the home. Most of the main fixed-line providers that we contacted reported that the majority of the routers provided to customers were already IPv6-compatible. In aggregate, approximately 80% of consumer routers provided by these operators are IPv6-ready. For these routers, only a firmware upgrade was necessary. However, customers owning older routers will require new IPv6-compatible hardware.

Next steps and further work

6.49 The analysis conducted in this section remains a key part of Ofcom’s statutory duties to encourage investment and innovation and to improve the availability and use of high speed data transfer services throughout the United Kingdom. Helping industry to identify how and where network performance may be suffering degradation, we believe helps in this process. Similarly, highlighting the potential for in-home networks to affect overall performance can help consumers take steps to improve their experience.

6.50 We therefore plan to continue our work in this area. Given the many factors involved, work to further increase the number and distribution of participants remains a key priority. Moreover, we are conscious that the quality of experience relies not only on the end-to-end digital distribution chain, but also on the interaction between the data transmission layer (IP) and the sessions and applications that operate over it.

6.51 We anticipate our further work to divide into two areas. The first will be to agree a full set of consistent measurements and tests that can be conducted on a regular basis, either as part of, or in conjunction with, the existing broadband speeds work that we do. The second will be to conduct further research into how different network layers and elements affect quality of experience, over and above those that we already can measure. We expect to publish the results of both of these areas of activity in next year’s Connected Nations report.

56 Carrier Grade Network Address Translation.
An emerging, and as yet poorly-understood aspect of web services, which may adversely affect the consumer experience, is the increasing complexity of web pages and, in particular, the growing volume of advertising content that is an integral part of the web browsing experience. Many popular websites and services use advertising served to their users as an important part of their business model. In some cases the revenue arising from these advertisements represents the main, or only income to support their operations.

The adverts embedded in many consumer websites or other services are increasingly sophisticated in content and may be specifically targeted at the recipient through the use of tracking cookies and other techniques to identify perceived topics of interest. Video adverts are increasingly common, with many being ‘auto-play’ or taking over the full area of the user’s screen while playing. Many users see this behaviour as annoying and take steps to prevent adverts being served, by using blocking software such as AdBlock58.

The impact on the overall broadband experience may be even more significant. In many cases, the article content on a webpage may be far outweighed by the advertising and the software involved in serving it. In one case, the total download size of a single page was more than 9.5 MB, taking over 30 seconds to be completed over a good broadband link, and required 263 separate HTTP sessions involving more than 30 different web service companies. The actual article content represented less than 1% of the total data volume. These problems have also been identified in international media coverage59.

The underlying issue has implications for the user experience, where the perception is that the service is ‘slow’. For mobile users in particular, it has a potential financial impact as data caps may be exceeded earlier than anticipated. This has led to a number of major internet content and service providers supporting an approach developed by Google to strip out excess content in the network to alleviate these concerns60.

In addition, the complex, multi-session nature of these emerging new norms for website design may be exposing the limitations of one of the fundamental building blocks of the internet, the transport protocol TCP. A number of technically-informed commentators have touched on these issues over the last few years; one of the most credible is Jim Gettys, a leading internet engineer who has been involved in many technical initiatives and projects that have made a major contribution to the success of the internet and world wide web.

A few years ago, Gettys and others identified a problem he referred to as “buffer bloat” – a phenomenon where apparently high-capacity network connections performed poorly because of excessively high buffer capacity in the routing software of the network elements. This measure, ostensibly done to improve performance, had the counter-intuitive effect of actually degrading it in some circumstances.

Gettys ascribed this problem to weaknesses in the way that TCP deals with flows of packets competing for processing resources in these network elements – essentially

58 http://www.theguardian.com/commentisfree/2015/aug/23/beginning-of-the-end-for-web-ads
59 http://www.nytimes.com/2015/10/01/technology/personaltech/ad-blockers-mobile-iphone-browsers.html?_r=0
it operates on a simple ‘FIFO’ basis without any ability to prioritise flows that are more urgent or more likely to suffer from delay or latency.

6.59 In more recent work, Gettys has taken this diagnosis further to specifically address the problems caused by latency in the face of ever-increasing website complexity. In this he has identified that, in some instances, the cumulative impact of the round trip times of the packet requests and flows involved in complex web pages is the real determinant of page load time, not the bandwidth available. This may help explain consumers’ subjective perception that internet performance remains poor as, above a relatively low broadband speed threshold, little improvement is seen in page load time. Clearly, other factors are likely to have an influence on the user experience, as the Actual Experience work shows, but this does emphasise that a simple ‘faster is better’ perspective may be misleading.

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61 https://gettys.wordpress.com/2013/07/10/low-latency-requires-smart-queuing-traditional-aqm-is-not-enough/

62 Gettys’ answer to this problem is to promote the development and implementation of improved flow queuing algorithms in routing nodes, that allow for some degree of differentiation in how packet flows are treated, based on the applications that create them.